Motion Control with Fuzzy Logic in an High Speed PLC System

Ovidiu Neamtu
Department of Electronics, University of Oradea
410087 Oradea, University Street 1
ROMANIA
E-mail: oneamtu@uoradea.ro

***Abstract* – The paper presents a new strategy of making software modules with fuzzy control. It is the best solution for implementing complex applications. Dynamic control today takes place in discrete time and discrete values. Concurrently, it is desirable that the discrete values are as close as possible to the continuous values. This needs A/D and D/A converters with high resolutions (up to 16-bit) and support of floating point operations in controllers. This approach forced slow migration from MCU (Microcontroller unit), to DSP (Digital Signal Processor), to CPLD (Complex Programmable Logic Device) and FPGA (Field Programmable Gate Array).**

***Keywords:* Fuzzy, Logic, PLC, Programmable, Controller.**

I. INTRODUCTION

Programmable Logic Controllers (PLC) is the basic units of industrial automation. They form the control level in distributed systems. They are connected either directly to sensors and actuators via special cards or to subordinate distributed IOs. PLCs are equipped with 16-bit or 32-bit MCUs.

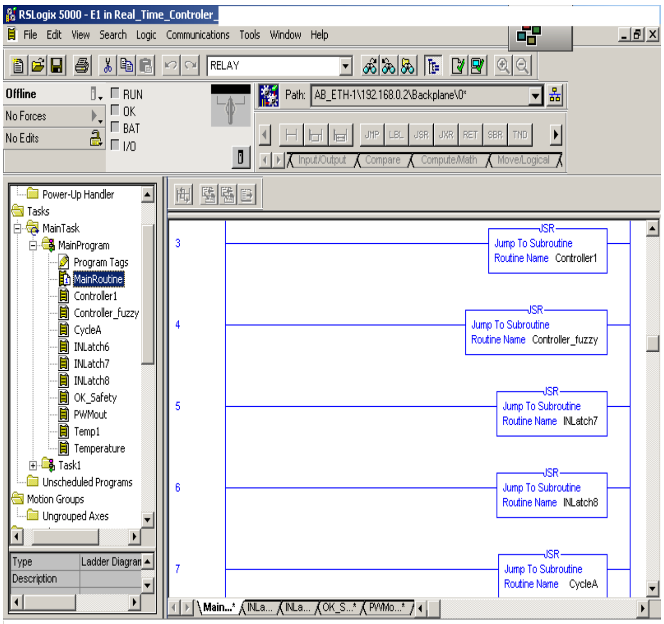

Fig.1. Fuzzy logic subroutine in RSLogix 5000 software for PLC.

The recent trend is to interconnect PCs and PLCs. One approach is to turn PLC hardware into software and run it on a PC. These Soft PLCs reduce cost of hardware but do not replace the original devices ultimately. Slot-PLCs are cards plugged in PCs. They have their own hardware and simple operating system which enables them to run independently of Operating System of the PC. Higher level control and visualization are immediately accessible. The PLC in industrial automation combines simplicity, reliability and availability.

The FuzzyDesigner option for RSLogix 5000 is an editor for create a costume fuzzy logic algorithms to use in the Logix5000 family of controllers. The fuzzy logic algorithms created with FuzzyDesigner is integrates with Logix controllers by compiling the fuzzy logic algorithm into an Add-On Instruction.

Fuzzy logic can be useful for complex process and traditional control methods such as PID control cannot provide adequate response. Oftentimes, such processes are still controllable by using the expert knowledge of operators who have learned how the process responds to various input conditions.

Fuzzy logic can be used as a way to encapsulate this knowledge in a usable control algorithm. An Add-On Instruction created by FuzzyDesigner can be used in any Logix5000 controller.

II. LOGIC MODULES OF PLC

In the industry PLCs (Programmable Logical Controllers) are most common as an automation base. The PLCs are connected to the IO signals via local IO cards or via a network to distributed IO-devices. In factory automation PLCs are located at the control level and communicate with the distributed IOs and field devices via a real-time communication network. The control of the process is done by the application program running inside the PLC.

Several control loops which run on the control station are soft real time processes. Most of the not cyclic data are processed in soft real time procedures. Fuzzy controller issues control signals based on linguistic inputs overheated accompanied by measure of validity of the variable. These controllers possess many drawbacks. However, they can be easily tuned without knowing control theory. Contrary to that, deep knowledge of the process is necessary. Sugeno controller combines the straightforward features of the PID and fuzzy. It changes parameters of the PID controller based on the change of the outer conditions which proved to be very efficient. Not many other sophisticated methods are implemented as they do not fit the requirements on convergence and robustness.

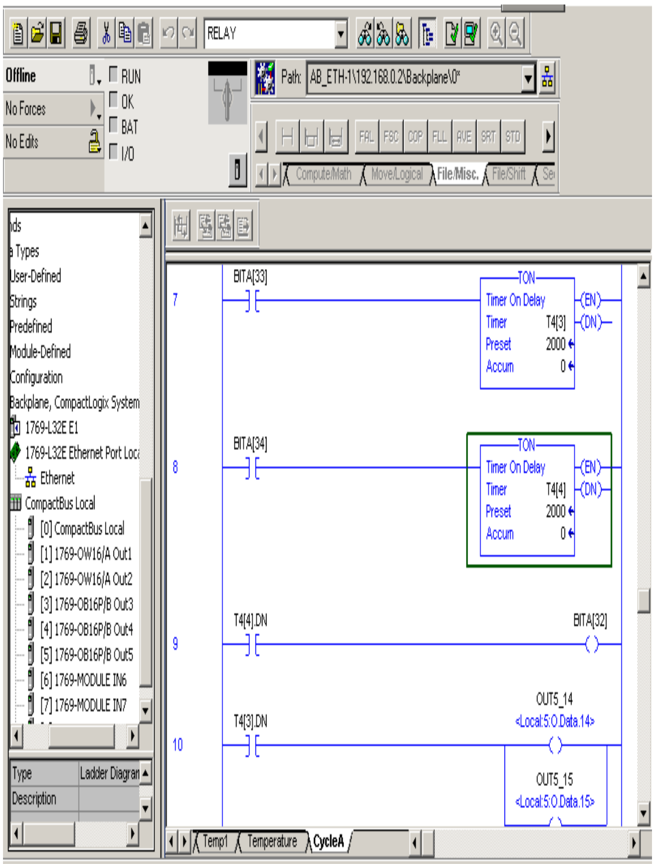

Fig.2. Logic modules in real-time function for electronics devices.

The scheme block is presented in Fig.3. With Fuzzy Toolbox Matlab was developed a fuzzy controller.

The inverse matrix in these case is:

$$\left[M_{qd0}(\theta)\right]^{-1} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ \cos\left(\theta + \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) & 1 \end{bmatrix}$$

This last transformation is used for the realization of functional blocks for the scheme Fig.3. in Simulink-Matlab software.

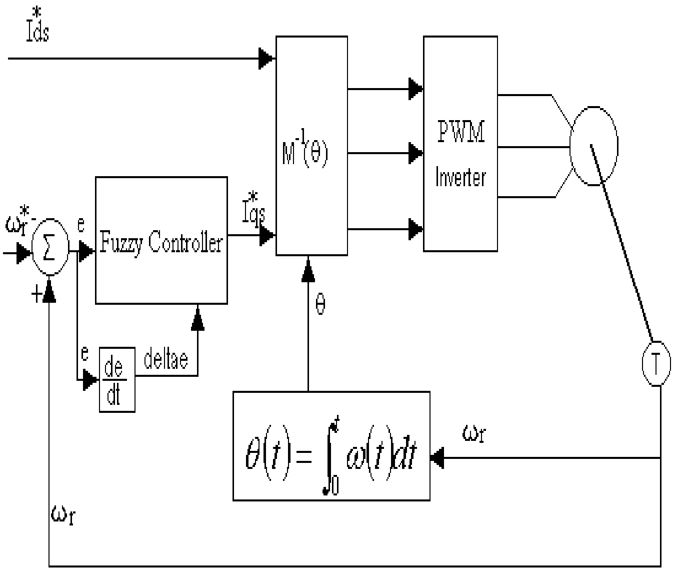

Fig. 3. Schematic Indirect Field Oriented Control.

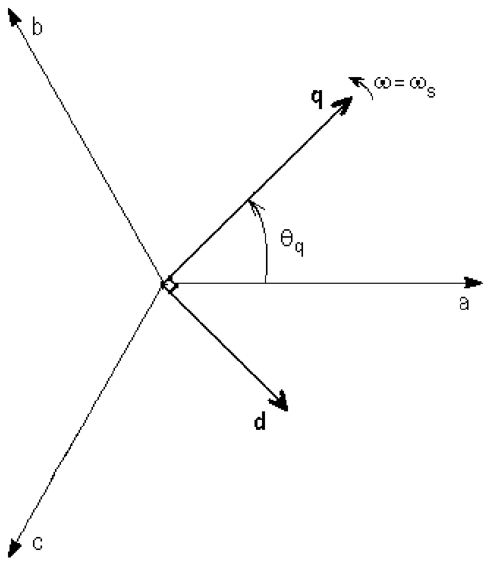

Fig. 4. Systems of the reference “0qd” and “0abc”, for Park transformer

The difference between the real unghiular speed and the reference one generates the component error:

$$e = \omega_r - \omega_r^*$$

The derivative value is obtained after the calculus value of error in a routine of the circuit controller:

$$deltae = \frac{d(e)}{dt}$$

III. FUZZY LOGIC IMPLEMENTATION

The tow components are the input in the Fuzzy Controller and are subroutine of the PLC software developed.

The output value of the Fuzzy Controller is the reference stator current component of the 0q axis: $i_{q_s}^*$

A subroutine $\left[M_{qd0}(\theta)\right]^{-1}$ with three inputs: $i_{q_s}^*, i_{d_s}^*$ and $i_{0_s}^* = 0$ achieves the transformation for three-phase currents i_{a_s}, i_{b_s} i_{c_s}. With PWM (Pulse With Modulation) technique, the PLC inverter has the best switches times for power electronics devices in a three-phase bridge topology.

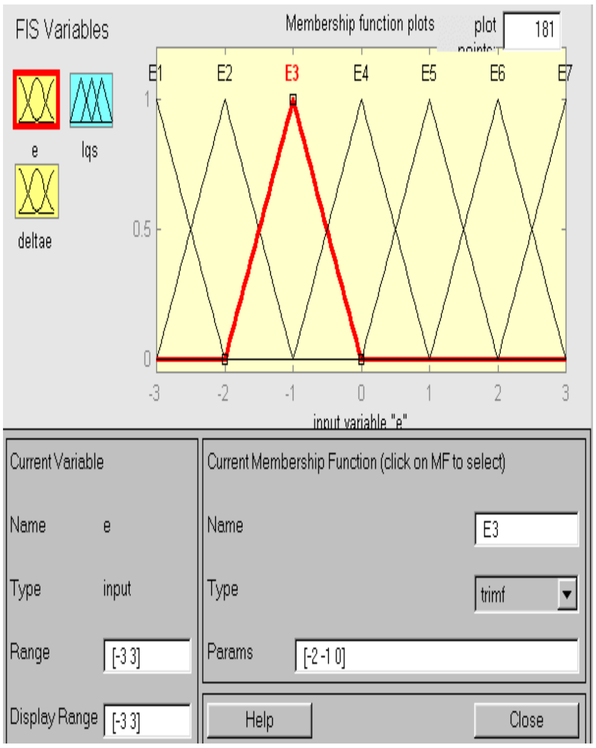

Fig. 5. Input error “e” membership of the fuzzy controller.

The solution for fuzzy controller realization can be given through the use TOOLBOXULUI FUZZY. The graphic interface for the defined memberships fuzzy functions for two inputs: error “e” and speed error “delta e” is presented in Fig.5. and in Fig.6.

In one example is presented membership E3. The definition domain for these membership is [-2 0]. It is the trianghiular form of the membership. There are seven memberships in domain [-3 3]. It is considered sufficient this number taking into consideration the use of memory to accessible sizes and for PLC run in real-time. The speed of error variation “deltae” has seven memberships in the same domain [-3 3]. In Fig. Is presented “delta E4” membership with the domain definition [-1 1]. It is the trianghiular form of the membership. Can be another form of function.

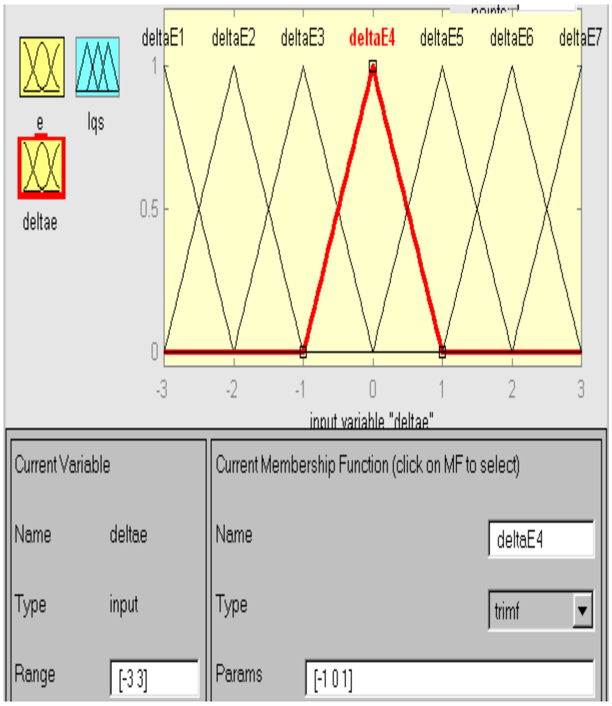

Fig. 6. Input speed of error ”deltae” membership of the fuzzy controller.

The one-two entrances shall be used in the inferences fuzzy process. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The Rule Viewer displays a roadmap of the whole fuzzy inference process.

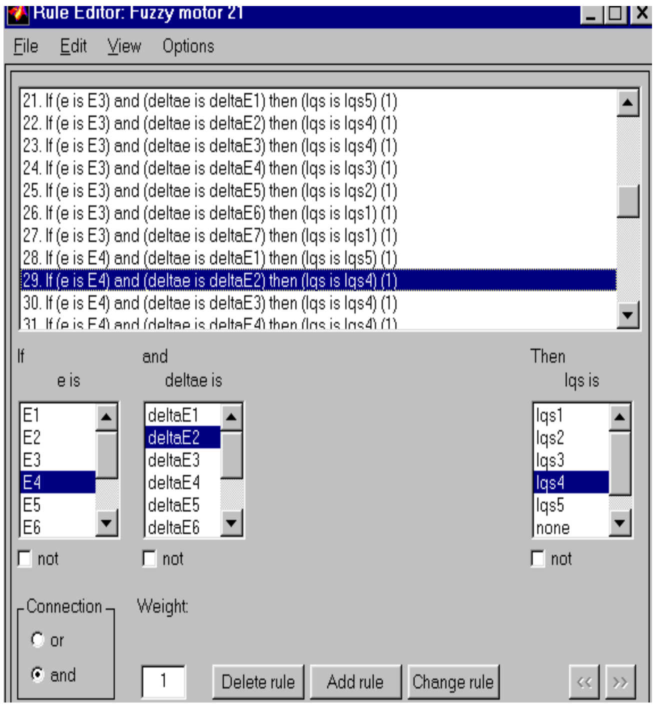

Fig. 7. The Rule Viewer displays a roadmap of the “E4” and “delta E2” for output current Iqs4.

In Fig. 7 is presented the publisher for the basic established rules. It is 55 rules fixed. They are composed on theoretical criteria. The experimental observation can complete to fix what rules compensate the parameters.

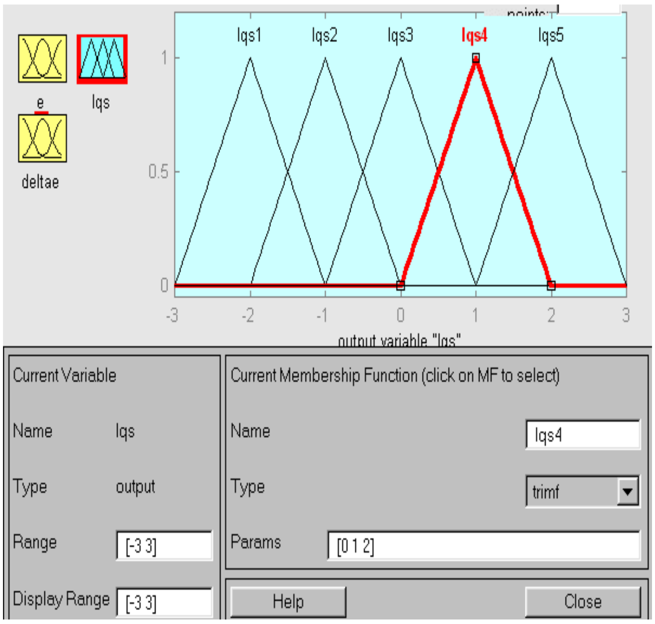

Fig. 8. Current membership function Iqs.

Defuzzify has seven memberships function for one current output Iqs. Defuzzification strategies is centroid (Fig.8.).

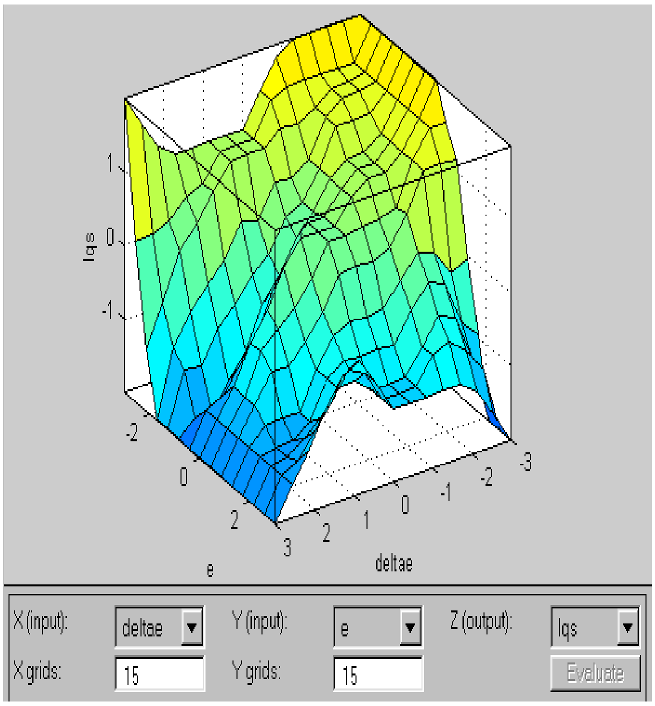

Fig. 9. Control surface for inputs “e” , “deltae” and current output “Iqs”.

In last figure it can be visualized the three-dimensional output of the current Iqs depending on two variable inputs the error “e” and the speed of error variation “deltae”.

IV. CONCLUSIONS

The simulation circuit controller was realized in Simulink-Matlab. The implementation of fuzzy module is achieved in the RSLogix 5000 software and becoming functional modules in a PLC use for general industrial electronics management and for induction machine control. It works in real-time for power electronics devices and for any industrial applications. The system has safety subroutines and a very good reliability.

A high level software has functional predefined bloks for fields of interest; industrial electronics is a possibility. Considerations regarding the practical implementation of the proposed solution and some experimental results are also given.

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