Intelligent control system with application in nuclear equipment

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***Abstract*— The Predictive Control Model (PCM) has been widely applied in various industrial plants, which have relatively slow processes. PCM applications for fast processes are usually limited by the ability of fast-optimizing algorithms or digital processors. Stepper motors (SM) are used in nuclear engineering due to the presence of a wide range of control frequency, positioning accuracy. They have been used successfully in moving fuel elements for non-destructive measurements such as gamma scanning, dimensional, eddy currents. In this paper is presented a system of command and control of the universal exam machine with the presentation of the operation of a stepper motor with permanent magnet in full step, respectively the results obtained from its analysis and some tests regarding the dynamics and the accuracy of the motor. A SM control and control system has been created to help move the fuel element to an established axis. With this system, a non-destructive examination of the gamma scanning, dimensional, eddy currents.**

Keywords*— *step motor; predictive control, nuclear, stepper motor

I. INTRODUCTION

In recent years, PCM has been used in most cases in industrial processes. The most common constraints are found at inputs of industrial processes in the form of actuator saturation. Inputs of optimal computational control over constraints consume many computing resources. Fortunately, most industrial processes are relatively slow in response because there is no worry about a slow response. This can be a disadvantage because it limits PCM applications to fast processes. The approach of predictive current control is improved by compensating delays in the actuator in changing the frequency for the inverter voltage source despite the large amount of calculations. Combining this controller with the PWM pulse module and the current module is also used in the case of a seedless sensor speed and the induction motor rotor flow control [1,2]. In recent years, there has been a trend towards machine control such as SM-PM. The technique most used in position and speed control of induced motors is the field-oriented field control method (MFOC). The MFOC technique ensures that induction motor torque control commands are disengaged so that the induction motor can be linearly controlled as a separate dc motor [3,4].

Generic predictive control (GPC) is based on predictive control algorithms, being implemented in multiple single-input single output (SISO) and multiple-input multiple output (MIMO) processes across industry. The principle of predictive control in operation is to calculate the initial control signal and then apply it to the given system in order to follow a well-known reference in which the system model is required. This is an advantage over other algorithms, which track the errors in the type of system usage and do not take into account the errors that will occur in the future. They allow integration of system constraints into controller design minimizing costs and ensuring optimal system performance [5,6].

In any case, the value of the predictive control algorithms is greater than the value of a conventional control. Therefore, predictive controllers were initially implemented in slow processes. Recent technological advances have made it possible to implement predictive computational algorithms in fast processes using the speed and performance of microprocessors, the particularities of digital signal processing have been found in power electronics.[7] One of the main research directions in the field of power electronics is the predictive computational control of electric motor drives. Several types of research work have been carried out based on the use of GCP as the main controller, which is chosen for engine precision and speed.[8] To control the rotor flow, stator currents, rotor torque and engine speed, the researchers included GPC controllers as cascade-connected. [9].

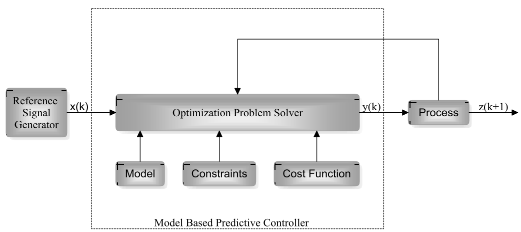


Fig. 1. Block diagram of predictive control

The simplest predictive control systems have low costs and can be linked to well-defined controllers. The predictive control model has a wide use, offers significant performance benefits, but requires a lot of sampling calculations to solve associated optimization problems. In the second section are presented the basic concepts regarding the predictive control applied in the industrial processes and a model thereof. This predictive control is associated with a command and control system for the operation of the Universal Examination Machine in the nuclear environment described in Section Three. Parameters monitored in predictive control may vary in the normal thresholds of fuzzy system inputs, but they may tend to get out of the normal range, and a noticeable ascending or descending trend is observed.

II. BASIC CONCEPTS ON PREDICTIVE CONTROL

Various methods of predictive control used for driver control and power electronics have been proposed in the literature. Most Predictive Control Model (PCM) strategies are formulated while discreetly setting a fixed sample interval. System inputs are restricted to changing their values only at discreet sampling times

$$x(k+1) = f\big(x(k)\big), u(k)), \;\; k \in N \qquad (1)$$

where $x\ k) \in R^n$ indicate state value at time k and $u(k) \in R^m$ represents the system input.[10,11]

A. The control efficiency

A distinctive feature of MPC over other control algorithms is that at each time point k and for a certain state x(k), a cost function is minimized on a finite length of N length. The next choice comprises many alternatives documented:

$$V\big(x(k), u'\ k)\big) \triangleq F\big(x'\ k+N)\big) + \sum_{l=k}^{k+N-1} L(x'\ l), u'\ l)) \qquad (6)$$

where L and F are the weighting functions that are used to penalize the behavior of the given system [5].
The state of predicted states, x '(l) are formed using the system model (1):

$$x'\ l+1) = f\big(x'\ l), u'\ l)\big), l \in \{k, k+1, \ldots, k+N-1\} \qquad 7)$$

where

$$u'\ l) \in U, \quad l \in \{k, k+1, \ldots, k+N-1\}$$

refers to provisional entries (which will degrade) [10].

B. The optimization

At the next sampling step, at discrete time k + 1, the state of the system x (k + 1) is measured (or estimated), the horizon is moved one step, and another optimization is updated. These yields $u^{opt}(k+1)$ and the first element provides $u(k+1) = u^{opt}\ k+1)$.
As shown in FIG. 1 for an N = 3 horizon length, the horizon taken into account in miniaturizing V slides redirected as increases k. [11].

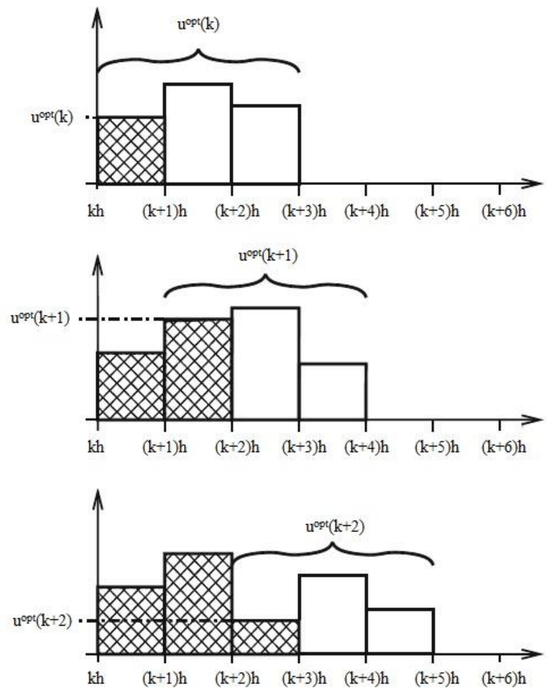


Fig. 2. Horizon principle shifted with N = 3

III. COMMAND AND CONTROL SYSTEM FOR THE OPERATION OF THE UNIVERSAL EXAMINATION MACHINE IN THE NUCLEAR ENVIRONMENT

Within the Nuclear Research Institute (ICN) in Pitesti there is a system that operates the universal exam machine for different non-destructive examination methods. This system is equipped with step-by-step motors for moving the universal exam machine. A system similar to that of the one-axis actuator ICN Pitesti was created according to the figure below.

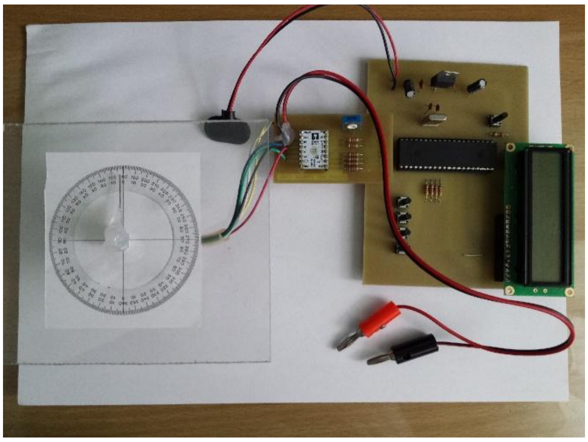


Fig. 3. Command and control system with SM

Through this system, we have tried to test the functioning of a SM for different driving conditions:

- Frequency variable steps;
- Variable number of steps;
- Sense of rotation;
- Power supply SM.

The data obtained from the engine test led to the definition of a set of rules for achieving a fuzzy SM drive.

It was proposed to move on a single axis. For the simulation, the electrical scheme in the figure below was partially implemented. The on / off button is used for selection, the PASI button to set the number of steps and the TIMP button to set the step frequency. The LED display showed when the order was made. The alphanumeric LCD (2-line, 16-character) displays the information on operating parameters.

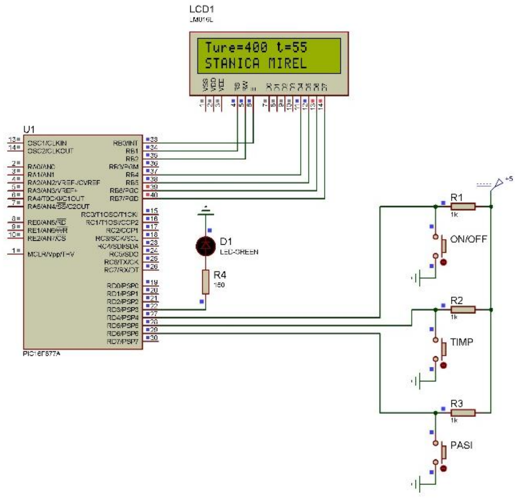
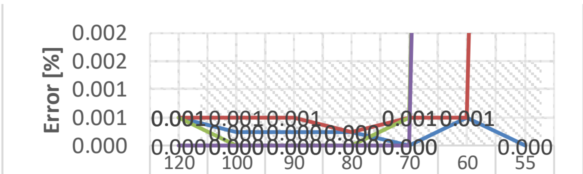


Fig. 4. Full step SM signals

Simulation of the system was created by designing and simulating the above figure. With the help of this simulation, we have obtained tests and results regarding the dynamics and the accuracy of the engine, which is a very important thing in the design of the shaft given its precision in conducting non-destructive control measurements from the nuclear environment.

The control and control system tested a SM for different frequencies, for different steps and for different voltages in order to observe the SM positioning efficiency. The system was set up to work with 400, 800 and 1200 steps, 400 steps representing a complete rotation, SM specific to the documentation uses 0.9 ° / step.

$$\frac{360°(\text{complete rotation})}{0{,}9°\ \text{step})} = 400\ \text{steps (complete rotation)}$$



	120	100	90	80	70	60	55
4.5	0.001	0.000	0.000	0.000	0.000	0.001	0.000
4	0.001	0.001	0.001	0.000	0.001	0.001	0.041
3.5	0.001	0.000	0.000	0.000	0.001	0.042	0.055
3	0.000	0.000	0.000	0.000	0.000	0.046	0.079

Fig. 5. SM 400 steps, left-hand at different supply voltages

Following these purchases we could formulate the rules of a fuzzy regulator for computational logic control. The designed fuzzy controller is presented in the following section and has the input, STEP, FREQUENCY, SUPPLY VOLTAGE parameters, and the output parameter is a logic command signal.

A fuzzy regulator is projected on the basis of the knowledge provided by a human expert, without the need to know a mathematical model of the process, but the rules applied are based on well-defined knowledge, and there may be uncertainties in the choice of the form of function of belonging to their number and rules Deduction. The microcontroller used in the development board design can also have the fuzzy regulator function for the SM command and is shown in the figure below.

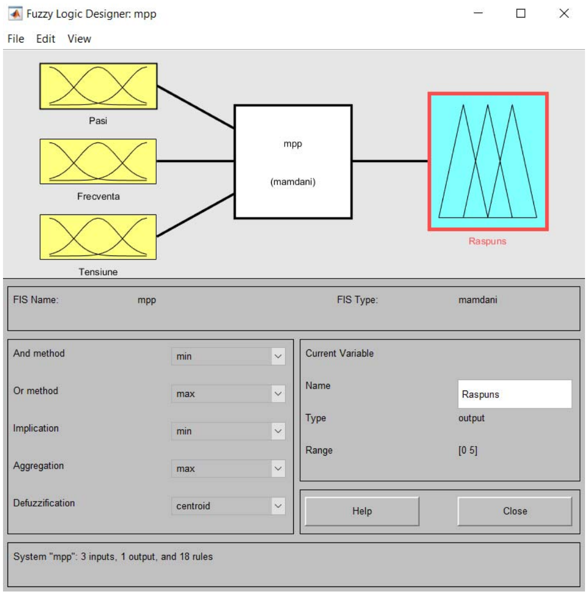


Fig. 6. Fuzzy regulator

Following the design of the fuzzy controller, it was tested with the above set rules with voltage, frequency, and step inputs.

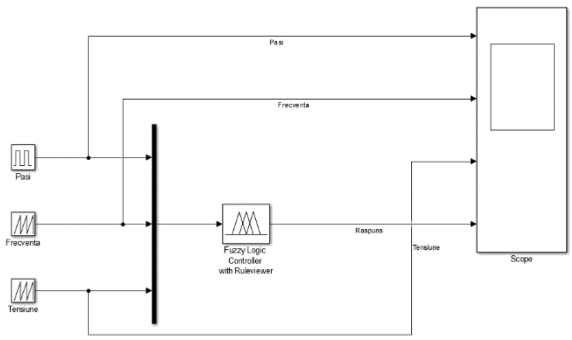


Fig. 7. Testing the fuzzy controller for the control and control system

Following the testing of the fuzzy controller, using different signals for step, frequency, supply voltage, the system response which is also the logical command signal of the system was displayed as shown below.

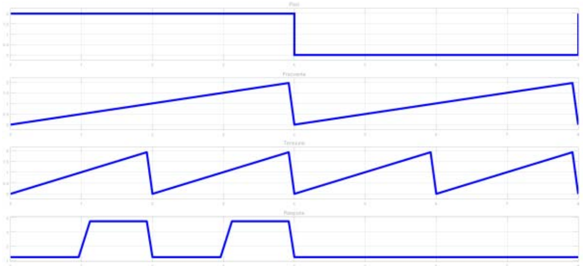


Fig. 8. The waveforms of the tested system

IV. CONCLUSION

In this paper we presented the predictive control based on the information received from the SM drive and control system. Parameters monitored in predictive control may vary in normal fuzzy system input thresholds, but they may tend to get out of the normal range. This predictive control has led to the development of a universal machine test and control system operated by SM with full-time permanent magnets, is the results obtained from its analysis and several tests on engine dynamics and precision.

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