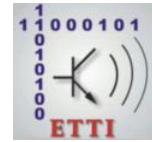**POLITEHNICA UNIVERSITY
OF BUCHAREST**

**Doctoral School of Electronics, Telecommunications
and Information Technology**

Decision No. 823 from 21-03-2022

Ph.D. THESIS
SUMMARY

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COMPUTATIONAL INTELLIGENCE APPLIED TO ELECTRONIC SYSTEMS USED IN NUCLEAR ENGINEERING

THESIS COMMITTEE

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Acknowledgment

Content

Chapter 1

Introduction

Intelligence can be expressed as the ability to perceive certain relationships between objects and phenomena. This can be sensory (in animals) due to conditioned reflexes, or intellectual (in humans) in which language and concepts intervene.

The techniques belonging to computational intelligence are: fuzzy logic, artificial neural networks and evolutionary computation.

Computational intelligence in nuclear engineering has undergone substantial changes in recent years. The main activities were focused on the development of monitoring conditions and diagnostic techniques for nuclear power plants, but recent activities focus on the implementation and development of methods for the next generation of plants and reactors.

1.1 Presentation of the doctoral thesis field

One of the main purposes of computational intelligence is to understand the principles that make intelligent behavior possible in natural or artificial systems. In the case of engineering, the main purpose is to specify methods for designing intelligent and useful objects. The role of Computational Intelligence (CI) in the nuclear industry is in constant transition due to operations, operational objectives, future needs and requirements in a nuclear power plant. Many of the techniques developed in the last 30 years have reached maturity and new techniques are being applied. One is the non-destructive eddy current (EC) analysis of a fuel element.

1.2 The purpose of the doctoral thesis

Within the Institute for Nuclear Research (INR), the Post-irradiation examination laboratory (PIEL) department, both non-destructive and destructive examinations are performed on irradiated combustible elements and structural materials. Universal examination machines are used for non-destructive examinations. Fuel elements or structural materials that are moved by the universal examination machine come from nuclear power plants. The purpose of doctoral research is to determine the movement of a fuel element through computational intelligence. In this

regard, research has been conducted on the operation of the universal examination machine. A system similar to the one present in PIEL was also developed and exposed.

1.3   Content of the doctoral thesis

The doctoral thesis is structured in six chapters including the chapter of conclusions, the original contributions of the author, the results of the research carried out during the doctoral studies, as well as proposals for future guidelines for further research.

In the first chapter, the introductory one, the field, purpose and content of the thesis are presented.

In the second chapter, the current state of computational intelligence and non-destructive testing techniques in the nuclear field is presented. The subfields of computational intelligence are briefly described: fuzzy logic and artificial neural networks. Also presented are gamma spectrometry tomography, spectroscopy, visual inspection and examination using eddy currents. These are test techniques used in post-irradiation examination laboratories to highlight possible defects from irradiation in nuclear power plants.

In the third chapter, research on the current state of predictive regulation, the basic concept and model of predictive regulation is presented. Chapter three concludes with highlighting the contributions of control research and sensor monitoring based on traditional and advanced estimation methods.

In the fourth chapter, we present the stepper motor, the drive component of universal nuclear testing machines. In order to highlight the usefulness of computational intelligence in the nuclear environment, a case study was presented on the need to establish the errors arising from the use of the stepper motor and the response obtained by positioning it. In this regard, another case study was developed on the operation of stepper motors with permanent magnets, namely the bipolar SM control, which followed their behavior at different operating frequencies. Following the analyzes made, a system was developed for the control of the universal machine for examining the samples from the nuclear environment. The entire drive system was presented, following which the development system based on the fuzzy controller for the SM control was designed. The chapter concludes with the impact of system design on sensorless drive performance.

In the fifth chapter, control and adjustment systems for the operation of the universal irradiated combustible material examination machine are developed. The design and simulation of control and regulation systems were performed, their experimental models were presented, following which statistical analyzes of the data sets obtained were performed. A sensitivity analysis of the motor positioning error was performed, after which the control algorithm was implemented using artificial neural networks. At the end of the chapter, the conclusions of the research were presented.

The sixth chapter presented the results of the paper, the original contributions of the author, a list of papers and perspectives for further development of the thesis with proposals for future directions for further research.

The last section of the paper presents the annexes and bibliographic references used.

Chapter 2

Current state of research on computational intelligence and non-destructive testing techniques

The field of computational intelligence is in a state of permanent development, its evolutionary nature can be seen in the implementation of various genetic algorithms in time series, which leads to solving problems in areas such as biology, economics, analysis and data prediction (forecasting and data analytics) [1]

2.1 Computational intelligence subdomains

Computational intelligence provides the techniques needed to process information in intelligent systems.
The main directions of work are represented by:
•   fuzzy logic - used when the data of the problem (and the relationships between them) cannot be described accurately, there is a degree of uncertainty ("fuzzyness"), the basic idea is given by replacing the exact values with fuzzy values, described by the functions of affiliation;
•   neural networks - used mainly to solve association problems, based on extracting, through learning, an example-based model. The source of inspiration, an explanation and the functioning of the brain;
•   evolutionary calculus - used to solve problems based on finding solutions in a large space of potential solutions, the source of inspiration being the principles of Darwinian evolutionism.

2.2 Non-destructive testing techniques

Non-destructive testing (NDt) is one of the most widely used testing techniques for investigating the structure of nuclear materials. There are a limited number of different physical phenomena that can be detected by non-destructive techniques in material samples mainly thermoplastic deformations following the irradiation process,

however, they can be applied differently depending on the geometry and location of the phenomena. Non-destructive testing methods are classified as follows: acoustic (using sound), using penetrating radiation, using electromagnetic and optical radiation. Figure 2.7 shows a classification of NDt methods [2].
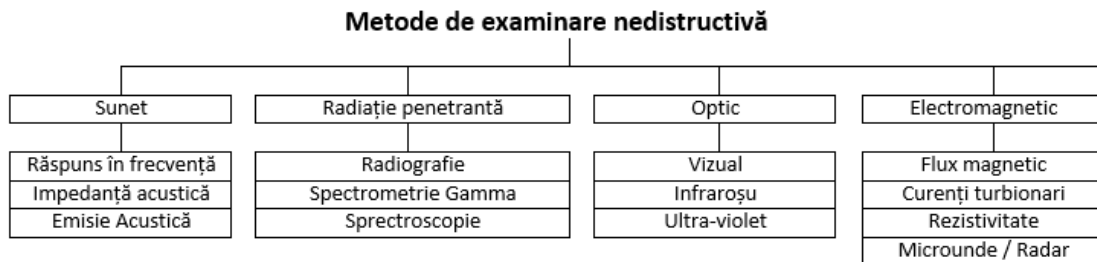
Figure 2.7 *Classification of NDt methods*

2.2.1 Gamma spectrometry tomography

Gamma spectrometry tomography (GSt) is one of the most advanced non-destructive techniques. This is a method of accurately measuring the amounts of radioisotopes as well as the activity of fission products in a fuel element. The first GSt system was developed in the Los Alamos National Laboratory in the 1990s. A similar device was called the A & PCT which was manufactured in the Livemore National Laboratory. Although commercial GSt systems are available, this technique needs to be improved.
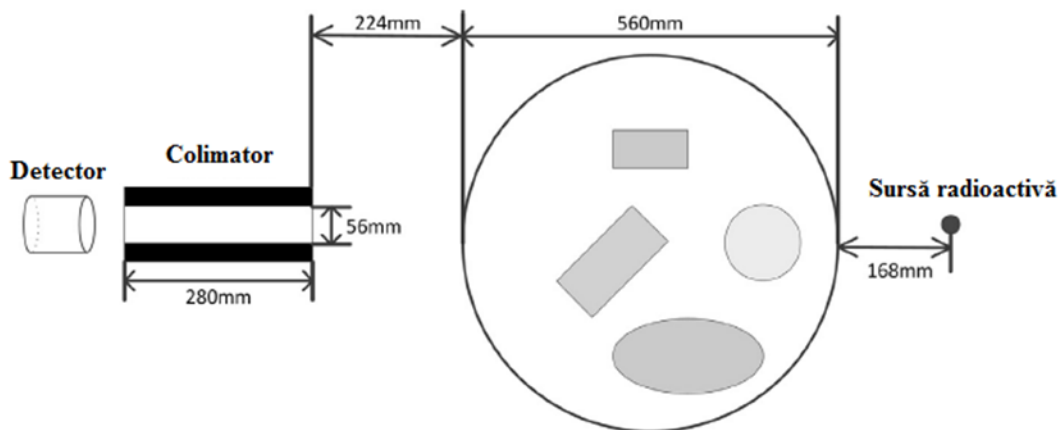
Figure 2.9 *Simulation model*

2.2.2 Spectroscopy

Spectroscopy is used as an alternative approach to penetrating radiation, it provides information about the elemental or mineralogical composition of the material. The spectroscopic elements in the material are exposed to a certain type of radiation

which causes them to absorb incident radiation at certain frequencies or to emit a certain type of radiation.

2.2.3 Visual inspection

Various optical tools such as periscope, endoscope, magnifying glass, lamps, etc. are used for visual inspection. Visual inspection provides a series of indicators related to the appearance of the surface of the material as well as the estimation of internal defects (fuel elements, metal containers, tubes, etc.). Figure 2.10 shows a sequence from the visual inspection of an irradiated fuel element in the nuclear reactor type VVER-400 [3].
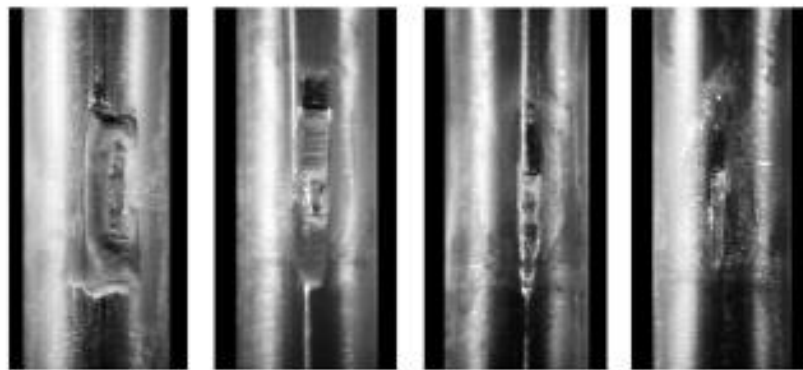
Figure 2.10 Visual inspection for an irradiated fuel element in VVER-400
Adapted according to [7] - Figure 7

2.2.4 Examination using eddy currents

The eddy current (EC) fault detection method is one of the main methods of non-destructive monitoring of irradiated fuel elements.

The EC method is the inspection of combustible elements based on an analysis of the interaction of an external electromagnetic field with the eddy current field, where a sinusoid or pulsed magnetic field generated by a coil induces eddy currents in a steel or zirconium fuel element.
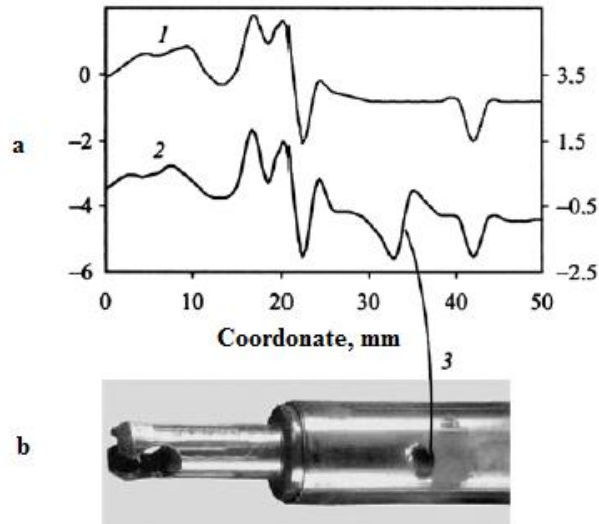
Figure 2.11 a. Diagram of eddy currents b. Fuel element irradiated in VVER-1000

2.3 Conclusions

The role of computational intelligence in nuclear engineering has been illustrated through the discussion of several current approaches to both the surveillance and diagnosis of nuclear equipment and nuclear testing. Research in each of these areas is ongoing. The theme used in the paper will be extended by creating a system based on computational intelligence, on a system used in the nuclear field.

Chapter 3

Control techniques for electric motors

3.1 Predictive control techniques

Generalized predictive control (GPC) is based on predictive regulation algorithms, which have been successfully implemented in the regulation of many single-input single-output (SISO) and multiple-input multiple-output (MIMO) processes in the industry.

3.1.1 The concept of model-based prediction control

To implement this model-based predictive control (MBPC) strategy, the basic structure shown in Figure 3.1 is used. A model is used to predict process output values based on the proposed optimal future adjustment actions. These actions are calculated by the optimization device taking into account the constraints and the objective function (where the tracking error is monitored) [4].
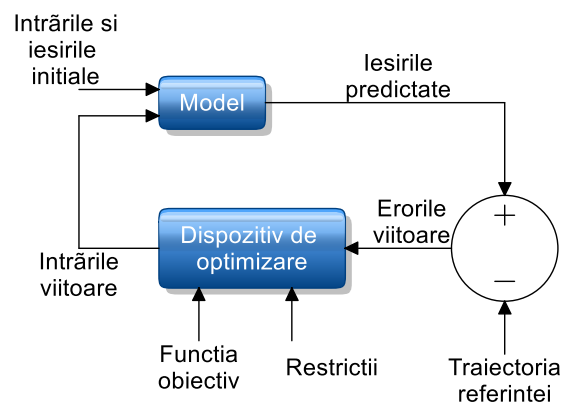
Figure 3.1 *Optimal control adjustment strategy for predictive control*

3.2 Sensorless control techniques for electric motors

Complex control systems in the industry are maintained by specialized engineers, these systems use control methods and models with multiple variable parameters. When a regulator is designed, regulation problems usually create differences between mathematical systems and models. This is largely due to the dynamic parameters of the system [5]. In addition, the control strategy for practical research of industrial applications, advanced sensorless systems for induction motors (IM) and permanent magnet synchronous motor (PMSM) is introduced.

However, the speed sensor determines the complexity of the hardware [6]. Figure 3.2 shows a block diagram of estimating techniques without sensor for IM. Two types of technology have been developed in recent decades: the use of the mathematical model in estimating spatial vector equations and the injection of an estimation signal [30].
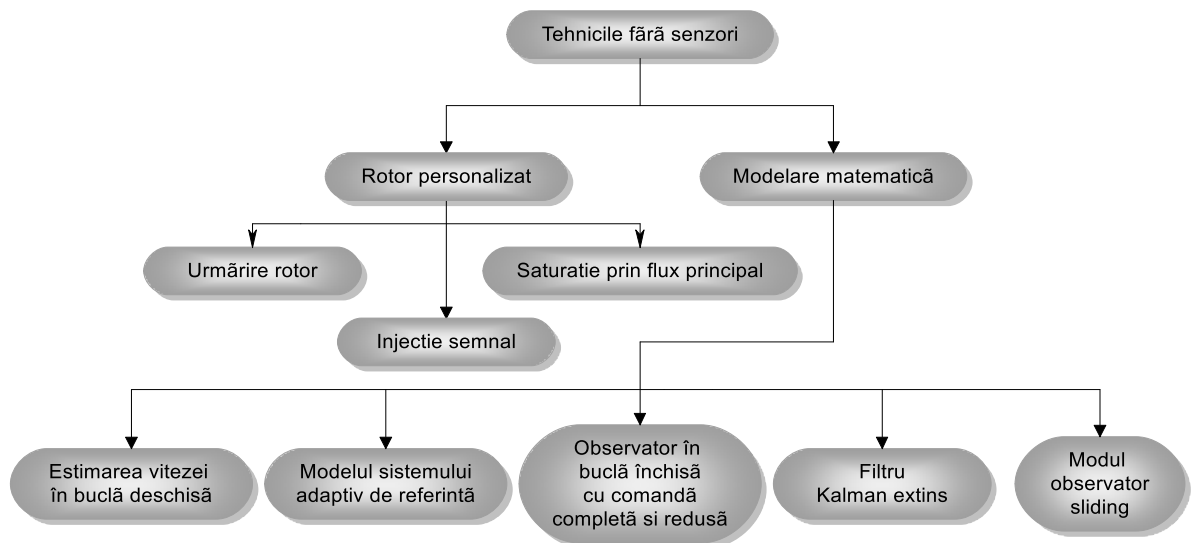
Figure 3.2 *Sensorless estimation techniques for induction motor*

3.2.1 Field-oriented control

Unlike scalar control, the control scheme is based on the dynamic IM model, in which voltage and current are expressed by spatial vector equations. The direct current in the rotor is proportional to the synchronous rotation speed.

Unlike scalar control, the development of the field-oriented control scheme is based on a dynamic model of IM in which voltages, currents and flows are expressed in vector forms.

3.2.2 Direct torque control (DTC)

Thanks to optimized torque response and simplified adjustment algorithms, the DTC control method can be considered better than FOC. The DTC for MI is shown in Figure 3.5 [7]. The DTC consists of torque and flow regulators, a search table, and a voltage inverter. Torque control and flow control are determined by selecting the appropriate voltage vector to maintain the torque error and flow in the hysteresis band. In the DTC, the accuracy of stator flow estimation is important to ensure both the correct selection of voltage and flow control vectors and the decoupling of torque [8].

3.2.3 Sensorless control method for a permanent magnet synchronous motor (PMSM)

The sensorless PMSM control method typically uses a high frequency signal injection (HFIM) technique in the rotor to estimate rotor position. Rotor position can be observed by signal processing techniques and injection of HF voltage into the motor coil.

Sensorless control strategies. Speed measurement is essential for both the control algorithm and the IM adjustment. A tachometer or optical encoder can be used to measure engine speed. However, mechanical speed sensors have several disadvantages: high size and cost, low reliability and durability.

Recent trends in sensorless IM slide control mode. The control techniques are determined by a new structure of the rotor flow observer which aims at the operation without speed sensor of an MI both at low speed and at high speed, where rapid gear changes can occur. In [9], the principles of SMO, DTC and field-oriented control modulation ensure high performance in steady and transient conditions. The accuracy, robustness and operation of the sensorless IM are also presented.

3.3 Conclusions

The use of induction motors (IM) in various types of electric drives has led to a significant reduction in energy consumption. In order to control the IM speed, information about the rotor speed is required, which can be obtained by installing speed sensors or using observers. Note that FOC and DTC are IM control techniques that reduce power consumption and provide a simple implementation and fast dynamic response, so they are promising for research to improve their performance.

Chapter 4

Analysis of stepper motor control techniques based on algorithms specific to computational intelligence

4.1 Stepper motor

The stepper motor (SM) is an electromagnetic converter that transforms a series of digital pulses into a proportional rotational motion of its axis. It is supplied with current pulses resulting from the application of "step" type voltages or combinations between several "steps". One of the dedicated features of SM is that the total angular displacement, which consists of a well-determined number of steps representing the number of control pulses applied to the motor phases. By this characteristic, SM can also be defined as a numerical integrating element, characterized by an integration constant equal to the inverse of the control frequency. The final position of the rotor is given by the last control pulse applied, and this position is maintained until a new control pulse appears.

4.2 Decision support systems in nuclear engineering - case study

This section describes the operation of a fuzzy controller-based system. Develops an algorithm, which transforms the linguistic regulation, based on the specialized knowledge into an automatic control strategy [10].

4.2.1 Non-destructive online examination decision support system - case study

The non-destructive examination system (NDES) within the Pitesti Nuclear Research Institute is designed for the examination of both nuclear fuel and materials tested in various reactors or nuclear power plants. FLC offers an algorithm that transforms language regulation into an automatic control strategy based on specialized knowledge.
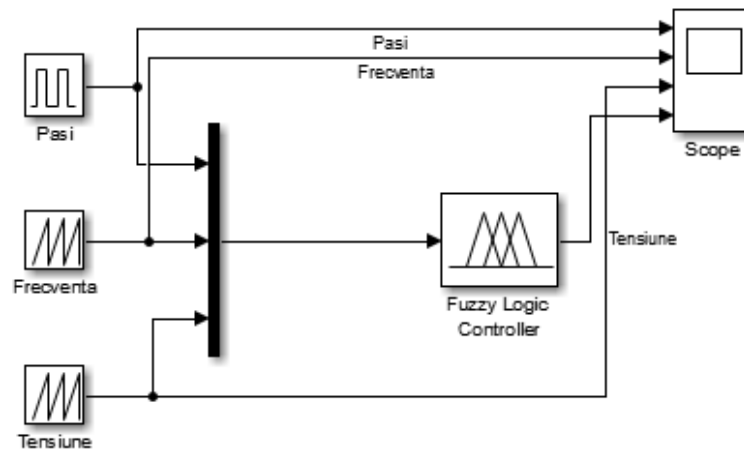
Figure 4.7 *Model for implementing the fuzzy controller with SM in Matlab / Simulink*

The interval was used in the simulation to determine the initial error [0 0.8].
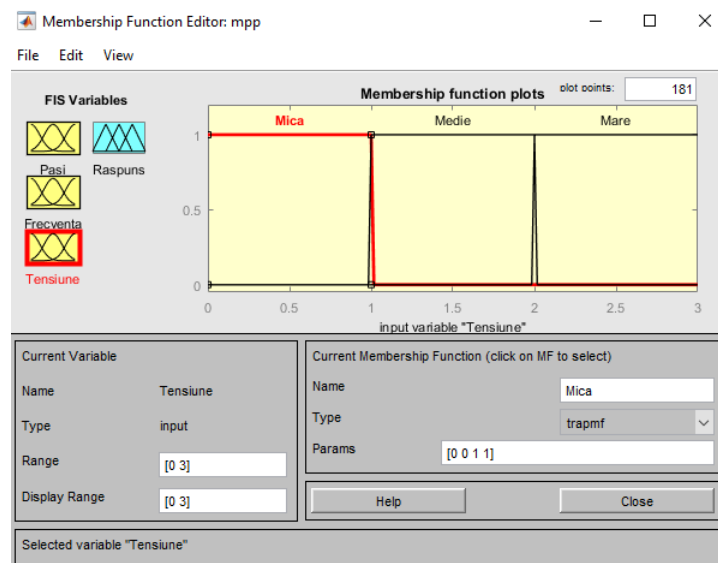
Figure 4.9 *The membership function used in the fuzzy set to determine the initial error*

The surface graph of the FLC is shown in the figure 4.16.
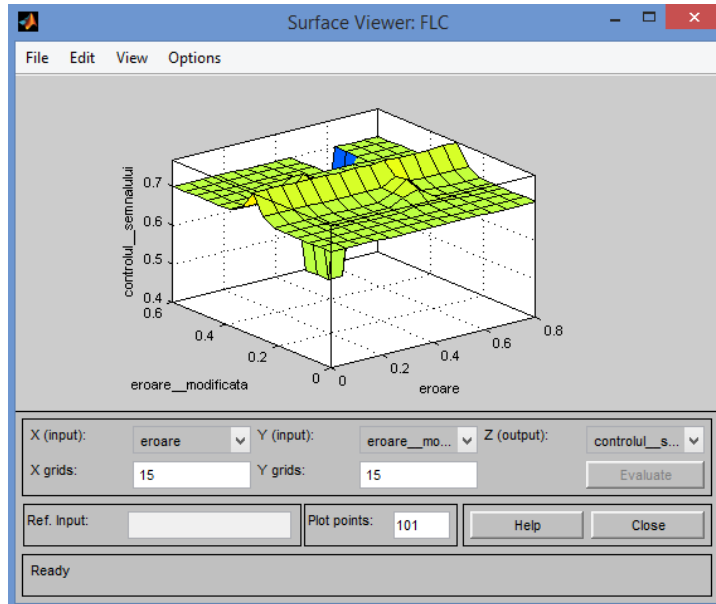
Figure 4.12 *FLC surface graph*

4.2.2 Control of unipolar stepper motors

It should be noted from the outset that although it is the easiest and cheapest way to adjust a stepper motor, you get about 30% less torque than a bipolar motor, this type of driver is called L / driver R or constant voltage driver.
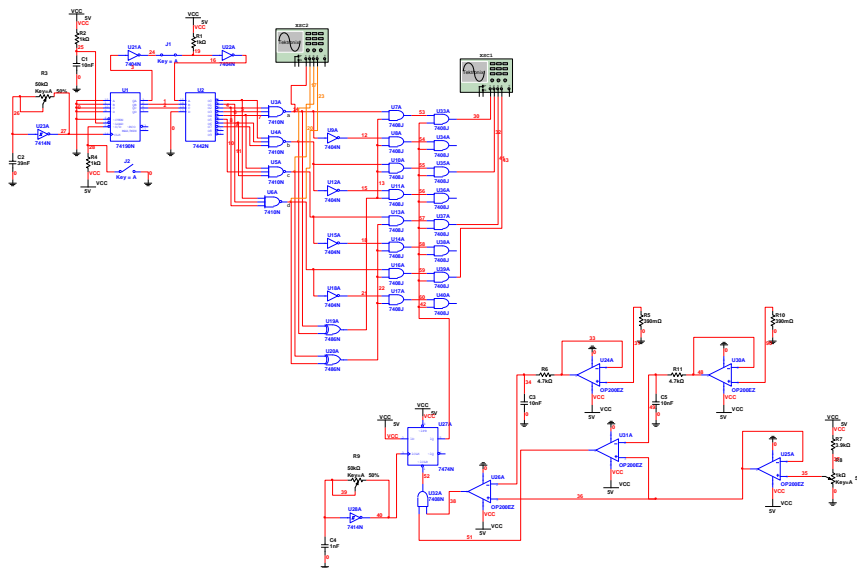
Figure 4.17 *Wiring diagram of a driver for unipolar SM*

Practically for "full pitch" a 360^0 rotation of the motor shaft is performed in 200 adjustment sequences, obtaining an axis rotation, for an adjustment pulse of 2.5 s. The "half step" command divides a 360^0 rotation of the motor shaft in 400 control sequences, with a shaft rotation, for an adjustment pulse of 0.9 s.
Figure 4.22 shows the SM signals for "full step".

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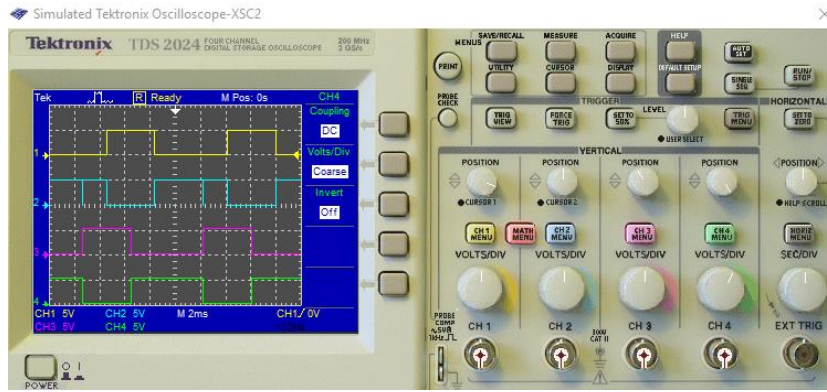
Figure 4.19 *SM signals for "full step"*

4.3 Development system for the control of the universal nuclear testing machine

The post-irradiation examination laboratory of the Institute for Nuclear Research was designed and developed to examine by non-destructive methods both nuclear fuel and materials tested in nuclear reactors and subjected to the irradiation process. The main examination equipment, installed in the examination cell (the place where the examination process is carried out), consists of universal examination machines similar to those which are analyzed for visual, dimensional and gamma scanning inspections.

1. Șurub pentru mișcare verticală „Z";	8. Dispozitivul de măsurare a diametrului;
2. Motor pas cu pas pentru mișcare de rotație „R";	9. Dispozitiv de încărcare;
3. Limitator origine „R";	10. pritor mecanic;
4. Tijă prindere port-element;	11. Limitator origine „Z";
5. Cap prindere port-element;	12. Camă acționare limitator;
6. Suportul elementului combustibil - port-element;	13. Limitator sfârșit de măsură „Z";
7. Element combustibil;	14. Limitator cursă prindere port-element.

Figure 4.29 *Universal examination machine*

These universal examination machines have the possibility of moving on three limited axes "X", "Y", "Z" with the help of stepper motors such as NEMA 34.
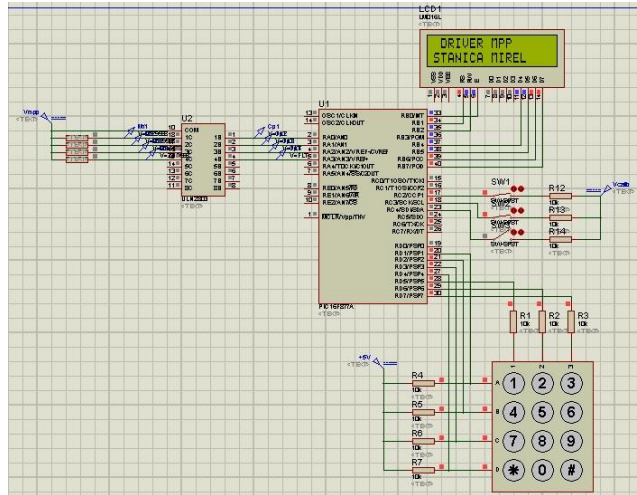
Figure 4.31 *Wiring diagram of the universal examination machine*

Fuzzy controller for SM command. A fuzzy logic controller is designed based on the knowledge provided by a human expert, without the need to know a mathematical model of the process. The microcontroller used in the design of the development board can also have the function of fuzzy controller for the SM control shown in figure 4.40.
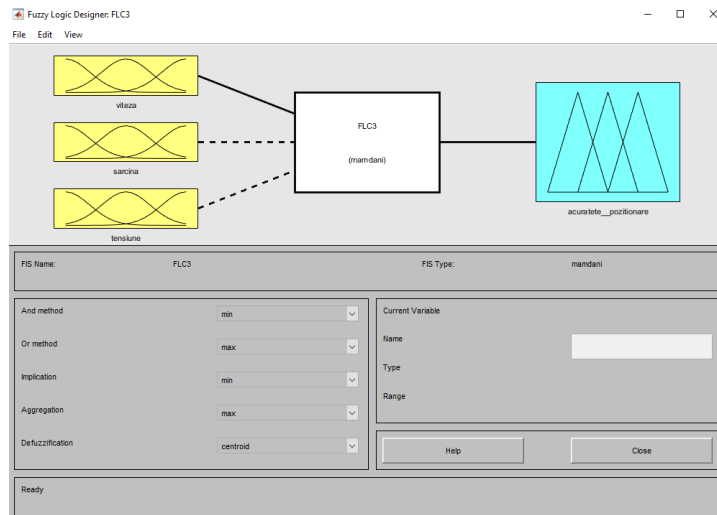
Figure 4.37 *FLC*

4.10 Conclusions

This chapter provides an overview of sensorless control solutions for permanent magnet motor drives, including the impact of system design on sensorless drive performance. In addition, this chapter also looked at the sensorless operation of the permanent magnet and how the motor design needs to be optimized for best results.

Chapter 5

Command and control systems for the operation of the universal irradiated combustible materials examination machine

Command and control systems use in the feedback loops information provided by the instrumentation devices, in areas with high radioactivity, the instrumentation devices (sensors and transducers) are affected over time by the destructive effects of radiation and fail relatively quickly. This chapter presents the steps for the proposed technical solution for operating the stepper motor for areas with high gamma activity..

5.1 Design and simulation of command and control systems

According to the block diagram shown in Figure 5.3, a wiring diagram of the system containing a PIC 16F877 microcontroller for driver control has been made..
One-axis scrolling in ISIS Proteus 7.6 software was used to simulate the system.
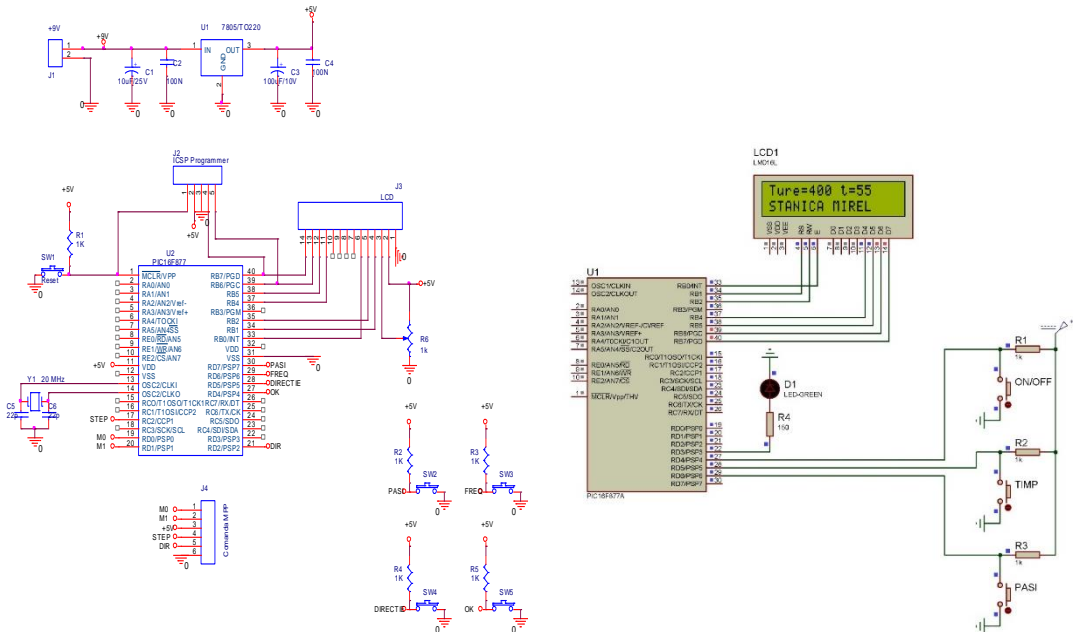
Figure 5.1 Wiring diagram of the system; *Figure 5.2* Simulation of the electrical diagram of the system

The first technical solution implemented is based on a PIC16F87 microcontroller and was used to test the command and control functions of the SM.
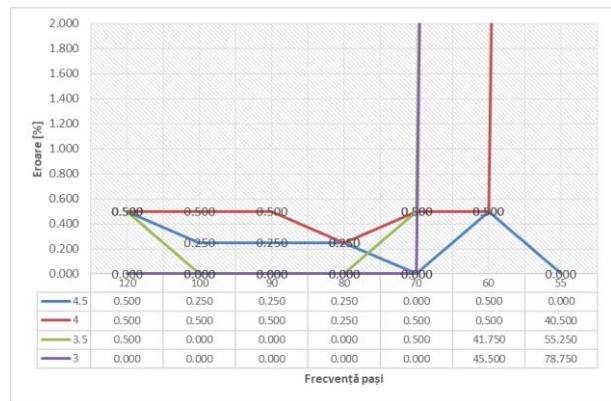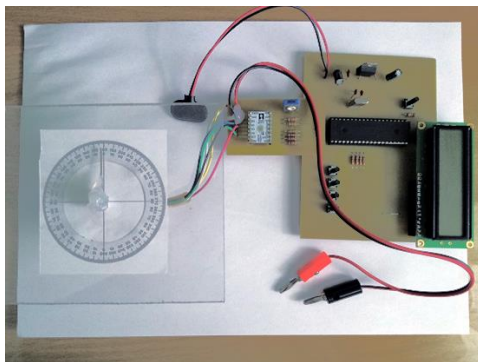
Figure 5.5 Command and control system with SM; *Figure 5.6* SM 400 steps, left direction at different supply voltages

Because this system could not perform and the acquisition of parameters in real time, it was decided to update the system with a more powerful one that uses an Arduino Uno microcontroller. Thus, on the same development platform, a step-by-step engine control, control and adjustment system could be realized. An SM was tested for different frequencies, for different steps, and for different voltages in order to observe the efficiency of the SM positioning. The system has been set to operate at 400, 800 and 1200 steps, with 400 steps representing a complete rotation, SM specific to the documentation uses 0.90 / step. 3600 (full rotation) / 0.90 (step) = 400 steps (full rotation).
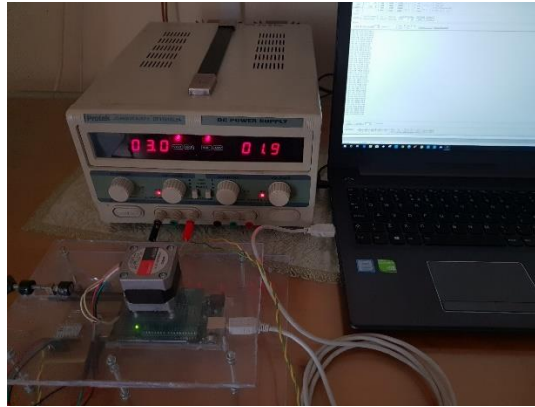
Figure 5.9 Command and control system with SM

Given the purpose of developing this system by positioning the SM as accurately as possible, it was established that the engine should be operated 10 times at different speeds (300 ÷ 600 rpm) and voltages from 3V to 4V.

Voltage	Direction	Repetition	Microstep	No. Rotati	Speed	RawAngle	Error
3	1	10	4	1	300	301.85	0.09
3	1	10	4	1	301	114.53	172.69
3	1	10	4	1	302	287.43	172.9
3	1	10	4	1	303	104.16	176.73
3	1	10	4	1	304	276.45	172.28
3	1	10	4	1	305	100.65	184.2
3	1	10	4	1	306	283.74	183.1
3	1	10	4	1	307	100.73	176.99
3	1	10	4	1	308	283.83	183.1
3	1	10	4	1	309	107.68	183.85
3	1	10	4	1	310	287.43	179.76

Figure 5.11 Data purchased at 3V

5.2   Statistical analysis of data sets

All data related to the engine parameters were stored in data sets grouped according to the three dynamic modes: FC, CJ and CM. Each data set contains several subsets (10-11 subsets), and each subset contains measurements (3010 measurements). Representing the error as a function of the speed of the stepper motor (figure 5.13) is important because, based on the analysis of the representation, we can extract information about its behavior and we can find nonlinearity intervals.
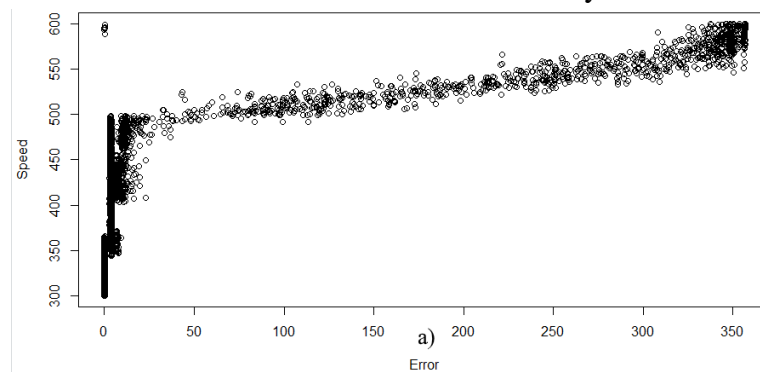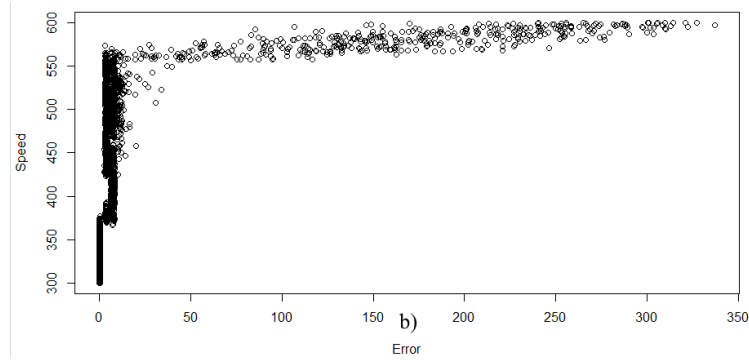
Figure 5.13 *Graphical representation of the error as a function of speed: a) The supply voltage of the SM with 3V; b) The supply voltage of the SM with 4V*

5.3 Implementation of the control algorithm using artificial neural networks (ANN)

The position of the rotor for electric motors, especially for the type of synchronous motor, is an important piece of information in speed or motion control applications. The position information of the rotary systems can be measured by means of the incremental / absolute encoder, the resolver or the hall type sensors.

More recently, artificial neural networks (ANNs) have attracted attention as identification techniques. ANNs were used in regulation applications, system identification, and uncertainty observations. Based on the data sets processed in the previous section, the following neural network was developed and maintained.

Numărul hidden layers	10
Numărul output layer	3
Funcția de antrenare	Levenberg Marquardt (trainlm)
Funcția de performanță	Mean squared error (mse)
Numărul de iterații ai antrenării	1000 epochs
Timpul de antrenare	17 min
Numărul de epoci	1000
Parametru de antrenare show	25
Parametru de antrenare mu	0.001
Parametru de antrenare goal	0
Funcția de activare	Sigmoid

Figure 5.19 *Flowchart for ANN; Table. 7 RNA drive parameters with FC specific data*

When running the MATLAB program, three training sessions specific to the three situations are performed: Case 1 where the data comes from MS without mechanical load (FC), Case 2 the data comes from SM with mechanical load 60% (CJ) and case 3 , the data come from MS with mechanical load 85% (CM).

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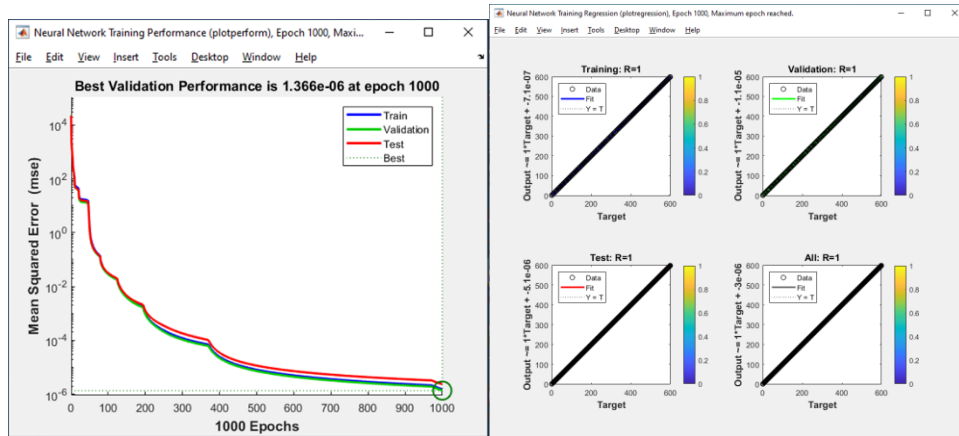
Figure 5.21 *Graphical representation of learning performance with specific FC data (OX axis - number of iterations (Epochs), OY axis - Mean Square Error (mse);* ***Figure 5.24*** *Regression graphs of the neural network with specific data FC: a) positioned "left-top" of the training graph; b) positioned "top right" the validation chart; c) positioned "left-bottom" of the test chart; d) positioned "right-bottom" all the regression lines (overlapping the three graphs)*

Case # 2 - Training the neural network with CJ specific data. In this case, the evolution of the total square error of the network for 1000 epochs was determined. Network training stopped at 355 iterations in 1,000 epochs.
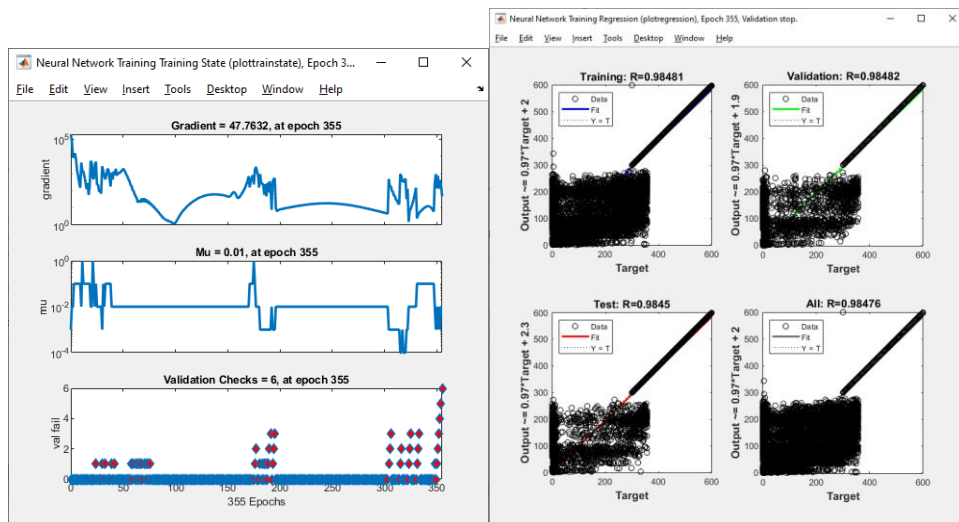
Figure 5.27 *Graphical representation of the drive state of the neural network with specific CJ data;* ***Figure 5.29*** *Regression graphs of the neural network with CJ specific data: a) positioned "left-top" of the training graph; b) positioned "top right" the validation chart; c) positioned "left-bottom" of the test chart; d) positioned "right-bottom" all the regression lines (overlapping the three graphs).*

5.4   Conclusions

Statistical analysis of parameters that describe the dynamic loading behavior for the stepper motor and determine areas with high accuracy is based on statistical tools embedded in complex software programs (MATLAB ©) or dedicated programming languages such as statistical programming R. In this regard, designed and implemented accurate tracking of ANN-based behavior of an SM. The performance of the controller is tested for the tracking property using different MS parameters in the simulation and experiments. The neural network has been successfully trained with input values, voltage, direction, speed, number of rotations, number of repetitions to give the values corresponding to the angular position. Therefore, the rotor position values have been accurately estimated and the system speed control is obtained in an efficient and simple way using an artificial neural network, which can be used in many industrial applications.

Chapter 6

Conclusions

This chapter presents the results obtained, the original contributions, the list of original works and the possibilities for further development.

6.1   Results obtained

Chapter number one introduced the field of computational intelligence. The usefulness of this thesis in the field of nuclear research was presented by the results obtained in doctoral research. Both its purpose and its content were highlighted.

Chapter number two presented in detail the current state of research on computational intelligence and non-destructive testing techniques in the nuclear environment.

In chapter number three, research was done on the adjustment techniques for electric motors, namely predictive adjustment techniques and sensorless adjustment techniques. Sensor-free adjustment techniques for electric motors were analyzed. The most commonly used technique for adjusting the position and speed of induced motors is the field-oriented control method.

Chapter four presented the operation, operation, stepper motor control, a case study on nuclear engineering decision support systems, stepper motor operation with permanent magnets, analysis of stepper motors set in open and closed loop, and finally the SM rotor position detection techniques were analyzed.

Chapter number five provides a complex analysis of command and control systems for operating the universal machine for examining irradiated combustible materials from the nuclear environment. Statistical analysis of the parameters describing the dynamic loading behavior for SM was performed. The main methods of statistical analysis and the sensitivity of the data sets for the SM parameters were presented. The results of the statistical analysis showed that there is a direct link between the positioning error and the speed parameters, respectively the supply voltage of the SM. Following these analyzes, a system was designed and implemented for the precise tracking of the ANN-based behavior of an SM.

6.2 Original contributions

Following the theoretical and applied research approach resulted the following contributions which are presented in chapters 2,3,4 and 5

1. A study was conducted on current trends in computational intelligence applied in nuclear engineering, focusing on non-destructive testing techniques in the nuclear environment. The paper can be found in the bibliographic reference [11] and in the list of original papers in point 8).

2. A study was performed on electric motor position detection techniques, which examined SMPM and the classification of sensorless control methods, sensorless methods that use basic knowledge of the excitation signal and various PMBLDC motor position detection methods. The paper can be found in the bibliographic reference [12] and in the list of original papers in point 1).

3. A comparative analysis of the control techniques of AC motors without sensors was performed, in which the control methods without sensors for induction motors, vector control, direct torque control and the control method without sensors for a sensor were studied synchronous motor with permanent magnet. The paper can be found in the bibliographic reference [13] and in the list of original papers in point 2).

4. The behavior of SM in open loop under different working conditions (at different frequencies and tasks) was analyzed in order to be a reference for the research that was carried out. The paper can be found in the bibliographic reference [14] and in the list of original papers in point 7).

5. A comparative analysis of the open loop SM command and the closed loop SM control was performed, highlighting the advantages and disadvantages, including the use of these systems in the nuclear environment. The paper can be found in the bibliographic reference [15] and in the list of original papers in point 6).

6. The level of error regarding the positioning of the universal examination machine used in the nuclear environment was analyzed, based on the polynomial regression. The proposed assessment was used to predict the error in estimating the position of the SM and an adjustment system was proposed based on the error estimation. The paper can be found in the bibliographic reference [16] and in the list of original papers in point 4).

7. A statistical and sensitivity analysis of the SM parameters was performed to identify the critical parameters on the positioning error. The development and testing of an SM command and control system resulted in a data set analyzing its positioning in repeated actuation sequences. Statistical analysis of data sets was performed, which were represented by polynomial approximation. A sensitivity analysis was performed to determine the extent to which the position

error varies with the SM parameters. The paper can be found in the bibliographic reference [17] and in the list of original papers in point 3).

8. Preliminary control tests based on fuzzy rules on a non-destructive examination system were performed. In this case study, the feasibility of fuzzy control in the nuclear field was demonstrated. This study is presented in the bibliographic reference [18] and in the list of original works at 9).

6.3 List of original works

Published in ISI WOS indexed conferences

1) ECAI-2019 - PROCEEDINGS OF THE 11TH INTERNATIONAL CONFERENCE ON ELECTRONICS, COMPUTERS AND ARTIFICIAL INTELLIGENCE (ECAI-2019), A Review of Different Estimation Methods of DC Offset Voltage For Periodic-Discrete Signals. Arva Mihai-Catalin, Nicu Bizon, Dorin-Mirel **Stanica**, Eugen Diaconescu. DOI: 10.1109/ECAI46879.2019.9042099, **WOS:000569985400120**

2) ECAI 2018 - 10th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 28-30 June, 2018, Iasi, ROMANIA, Paper: "Determining the Risk Level Regarding to the Positioning of an Exam Machine Used in the Nuclear Environment, based of polynomial regression", Author: Mihai Oproescu, Dorin-Mirel **Stanica**, Vasile-Gabriel Iana, Ioan Lita, Mirela Gheorghe. DOI: 10.1109/ECAI.2018.8679054, **WOS:000467734100124**

3) ECAI 2018 - 10th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 28-30 June, 2018, Iasi, ROMANIA, Paper: Analysis on vibration and resonance characteristics of an low speed 3-phase stepper motor. Arva Mihai-Catalin, Dorin-Mirel **Stanica**, Eugen Diaconescu, Nicolae Anghel. DOI: 10.1109/ECAI.2018.8678993, **WOS:000467734100063**

4) SIITME 2017 - IEEE 23rd International Symposium for Design and Technology in Electronic Packaging (SIITME), 26-29 October, 2017, Constanta, ROMANIA, Paper: "Intelligent control system with application in nuclear equipment", Author: Dorin-Mirel **Stanica**, Ioan Lita, Mihai Oproescu. DOI: 10.1109/SIITME.2017.8259923**, WOS:000428032300074**

5) SIITME 2017 - IEEE 23rd International Symposium for Design and Technology in Electronic Packaging (SIITME), 26-29 October, 2017, Constanta, ROMANIA, Paper: "Comparative analysis of stepper motors in open loop and closed loop used in nuclear engineering" Authors: Dorin-Mirel

Stanica, Ioan Lita, Mihai Oproescu. DOI: 10.1109/SIITME.2017.8259924, **WOS:000428032300075**

6) ECAI 2016 - 8th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 30 June-2 July, 2016, Ploiesti, ROMANIA, Paper: "The analysis of different frequency for a stepper motor open loop operation" Authors: Dorin-Mirel **Stanica**, Ion Man, Mihai Oproescu. DOI: 10.1109/ECAI.2016.7861187, **WOS:000402541200123**

7) ECAI 2015 - 7th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 25-27 June, 2015, Bucharest, ROMANIA, Paper: "Trends in computational intelligence applied in nuclear engineering and non-destructive examination techniques of nuclear units" Authors: Dorin-Mirel **Stanica**, George Robert Sisman. DOI: 10.1109/ECAI.2015.7301174, **WOS:000370971100039**

Published in Scopus indexed conferences (IEEE Xplore); being indexed in ISI WOS

8) ECAI 2021 – 13th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 1-3 July, Pitesti, ROMANIA, Paper: "A brief review of sensorless motors position control", Authors: Dorin-Mirel **Stanica**, Nicu Bizon, Mihai-Catalin Arva. **DOI: 10.1109/ECAI52376.2021.9515050**

9) ECAI 2021 - 13th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 1-3 July, Pitesti, ROMANIA, Paper: "A brief review of sensorless AC motors control", Authors: Dorin-Mirel **Stanica**, Nicu Bizon, Mihai-Catalin Arva. **DOI: 10.1109/ECAI52376.2021.9515049**

10) ECAI 2021 – 13th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 1-3 July, Pitesti, ROMANIA, Paper: "Statistical and sensitivity analysis of stepper motor parameters used in high gamma radiation field", Authors: Mihai Catalin Arva, Dorin-Mirel **Stanica**, Nicu Bizon and Cosmin Ivan. **DOI: 10.1109/ECAI52376.2021.9515038**

Published in journals indexed in other international databases (Google Scholar)

11) IJTPE 2015 - International Journal on "Technical and Physical Problems of Engineering (IJTPE), Published by International Organization of IOTPE, 3 September, 2015, Issue 24, vol 7, no.3. Paper: "Preliminary tests based on fuzzy intelligence on a system of non-destructive examination" Authors: Dorin-Mirel **Stanica**. **ISSN** 2077-3528

Note. IJTPE has been indexed in Scopus since 2020.

Published in international conferences

12) ICTPE 2015 - 11th International Conference on "Technical and Physical Problems of Electrical Engineering" 10-12 September 2015, University of Pitesti & LUMINA - University of South-East Europe Bucharest, Romania. Paper: Preliminary tests of a system based on fuzzy intelligence on a system of non-destructive examination. Authors: Dorin-Mirel **Stanica**, Nicu Bizon.

Scientific reports

1. **Scientific report no. 5**: *On-line monitoring of nuclear power plants*, author **Stănică** Dorin-Mirel, Coordinator Prof. Dr. Eng. BIZON Nicu, Evaluation Commission: Prof. Dr. Eng. Liță Ioan, Şl. Dr. Eng. Iana Vasile-Gabriel, Şl. Dr. Eng. Răducu Marian

2. **Scientific report no. 4**: *Predictive control techniques and intelligent agents with applications in nuclear engineering*, author **Stănică** Dorin-Mirel, Coordinator Prof. Dr. Eng. BIZON Nicu, Evaluation Commission: Assoc. Prof. Dr. Eng. Diaconescu Eugen, CPI Dr. Eng. Talpalariu Mihail Corneliu, Assoc. Prof. Dr. Eng. Anghelescu Petre

3. **Scientific report no. 3**: *Comparative analysis of control and decision-making techniques based on computational intelligence applied in engineering field*, author **Stănică** Dorin-Mirel, Coordinator Prof. Dr. Eng. BIZON Nicu, Evaluation Commission: Prof. Dr. Eng. Şerban Gheorghe, CPI Dr. Eng. Talpalariu Mihail Corneliu, Şl. Dr. Eng. Iana Vasile-Gabriel

4. **Scientific report no. 2**: *Decision support systems in nuclear engineering*, author **Stănică** Dorin-Mirel, Coordinator Prof. Dr. Eng. BIZON Nicu, Evaluation Commission: Assoc. Prof. Dr. Eng. Eugen Diaconescu, CPI Dr. Eng. Corneliu Mihail Talpalariu, Şl. Dr. Eng. Mihai Oproescu

5. **Scientific report no. 1**: *Areas of research in Computational Intelligence applied in nuclear engineering*, author **Stănică** Dorin-Mirel, Coordinator Prof. Dr. Eng. BIZON Nicu, Evaluation Commission: Prof. Dr. Eng. Ioan Liță, Prof. Dr. Eng. Silviu Ioniță, Şl. Dr. Eng. Alin Mazăre

Research projects

6.4 Prospects for further development

Future research directions are related to the ideas that were presented in the thesis. Development of new hardware and software solutions for SM operation in order to perform non-destructive examinations in the post-irradiation examination laboratory.

The general trend is to operate with high precision and in a short time the universal examination machines within PIEL.

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[12] Dorin – Mirel Stănică, Nicu Bizon, Mihai – Catalin Arva, „A brief review of sensorless motors position control," 13th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 2021.

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