

MINISTRY OF EDUCATION AND SCIENTIFIC RESEARCH



TECHNICAL UNIVERSITY
OF CLUJ-NAPOCA

**ENGINEERING APPLICATIONS IN THE FIELD OF SIGNALS
PROCESSING MEASUREMENT, OF RELIABILITY ANALYSIS AND OF
PROCESS CONTROL AND MONITORING**

HABILITATION THESIS

- summary -

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***Preamble* – Motivation of the Application for the Habilitation Certificate in Electrical Engineering**

In the everyday reality defined by permanent changes, the essence of the existence is given by the ability to adapt to the changing context. However, nothing changes more rapidly than technology and it is for this reason that people working in technology need to have the fastest capacity to change. When wishing to explain, lead, teach other people too, the fast ability of adaptation has to be shadowed by the teaching aptitude, too. In such a context, all the candidate's statements relate in a flowing and harmonious way with the profession of teacher in technical and engineering sciences.

The academic environment teaches us that the best results of ideas can arise only by working in teams. The students' ideas for graduation or dissertation thesis, the ideas concerning research contracts with the private business environment and those for national and international projects, or with national or international partners challenge one to work in teams with various people. The transposition of ideas in a project plan, the writing and fulfilment of such a project teach one the interaction with others is not only a social component, but also an important component of the technological progress. Then, ranking ideas and activities within a team project should be assumed by a project coordinator, who shall meet the role of interface among the group members, and in the relationships with the external environment as well. The project coordinator, also called today project manager, must have the ability to assume the responsibility for developing and fulfilling the project, both as an individual and in the name of the entire team. The attitude and the commitment of every member of the team highlight the awareness of individual tasks and the team, collective responsibilities. The happiness related to the success is then infinitely more pleasantly shared in a team...

In such a context, the projects that are more complex, from the viewpoint of forming values through research, can be found in the Doctoral School activities, where the "Ph.D. supervisor – Ph.D. student" binomial can generate the performance that contributes to developing the knowledge in a particular field. Such an aspect motivates both the partners, and, in time, can contribute to international scientific communication increase and, implicitly, to a higher university prestige.

The habilitation certificate will have a strong and positive impact upon the candidate's academic teaching activity, research, management and tutoring activities, starting from the research shared in team by the candidate and supervisor. At the same time, acquiring the habilitation certificate will enlarge the research capacity and the visibility of the Department of Electrical Engineering and Measurements, and last but not least, will strengthen the capacity of the department to compete for new projects, contracts or other forms of financing the university.

Professional Directions and Competences. Fields of competence complementary to Electrical Engineering

The candidate graduated from the Faculty of Electrical Engineering of the Technical University of Cluj-Napoca, in the programme of study named *General Electrical Engineering*, getting the degree of *engineer in electrical field*, in 1999, as the head of his generation (the graduation thesis was made at the Institut fuer Werkzeugmaschinen der Universitaet Stuttgart, Germany – in a Socrates-Erasmus project); concomitantly, the candidate has also graduated *Sociology*, in the programme of study *Sociopsychopedagogy/Sociology*, at the Babes-Bolyai University from Cluj-Napoca, in 1998. The graduate continued studies in these two fields, at Master of Science level in *Metrology and Instrumentation* (2000) and Master of Arts level in *Sociopsychopedagogy/Social Communication* (1999).

A significant moment in the professional career of the candidate lies in getting the degree of ***Doctor in Electrical Engineering*** (Minister Order no. 4871/ August 7, 2006), with *Magna cum Laude*, for the thesis entitled "*Contributions to developing synchronous detection techniques and applications*". In the following year (2007), the candidate was promoted as a Associate Professor coming as a confirmation of teaching and research experience and expertise, providing the opportunity to manage research teams and be involved in the coordination and activity of research projects, of projects of institutional development and human resources formation.

An important point in the development and involvement in research projects is related to the activities in the field of inventics, started while still a Ph.D. student.

The main research and teaching lines of the candidate concern the following:

- ✓ Electrical and Electronic Measurements, Measurement Signals Processing
- ✓ Reliability and Testing
- ✓ Automation, Process Monitoring and Control

The candidate put the basis of the preoccupations for research while a Ph.D. student and they were completed while working in research contracts (30 contracts), especially the four contracts won by competition where he acted as a project manager or responsible. The results and the experience acquired in the interval of post-doctoral activities (June 2006 – up to the present) were rendered into four patents, other 10 patent applications submitted to Romanian State Office for Inventions and Trademarks (OSIM), 7 books and 94 scientific papers published in international / national journals or presented in prestigious international conferences. The student-management activity also needs to be mentioned in their designing and writing the graduation or dissertation theses or the active involvement in the research topics of several doctoral students in Electrical Measurements, an activity whose outcomes are visible in the consequent publications. The expertise and experience gained is also

capitalised in the work of reviewer/editor of prestigious journals or widely recognised international conferences.

The candidate's research competences developed along his entire academic career can be grouped in two large categories, specific of modern evaluation processes:

Professional competences

- Electrical Engineering, specialised in Electrical and Electronic Measurements, Reliability, Data Acquisition and Signal Processing;
- Industrial Applications, especially for automation and control, with particular application to domotics and process monitoring;
- Advanced knowledge in engineering multi- and intra-disciplinary research methods and techniques;
- Use of research specific software packages, and mainly of software for complex reliability analysis;
- Advanced notions of inventics, focused on engineering issues and solutions explanation from the viewpoint of patent observation and rigour.

Cross competences

- Management of projects and related human resources – certificate of project manager, project manager/responsible in two institutional POS-DRU projects,
- Counsellor in career orientation - R29 certificate,
- TIC (Information and Communication Technology) competences.

Technical and Scientific Report upon the Activity and Research Results in the Interval after Receiving the Ph.D. Degree (September 2006 – May 2015)

This activity is described using the information in the patents or patent applications, as well as in the research reports published by the candidate. The emphasis is put on achievements where the candidate was seriously committed in (as first author, main co-author, field of research of interest) pointing out creativity and innovation as features of successful research and premises of pertinent coordination and supervision of would-be Ph.D. students.

1. Electrical and Electronic Measurements, Measurement Signals Processing

The domain in the heading is the Ph.D. domain of the candidate and besides the thesis, the author has published 34 articles and patents in this line. Several achievements in this field, also related to the Ph.D. thesis, are:

- **Intuitive method and electronic apparatus for determining phase shifting in frequency analyzers [B6].** The invention relates to an intuitive method and an apparatus meant to measure the phase shifting between a sinusoidal input signal and the output signal in case of frequency analysis of the electronic, mechanical and automating processes. The electronic apparatus claimed by the invention consists of a unit generating synchronized complex signals: triangular, rectangular and sinusoidal signals and of a module processing the signals whereby some signals are created to be applied to a horizontal scanning and to an input amplifier comprised in an oscilloscope, on whose display a distinctive marker allows to determine the phase shifting between the input and output signals from the element to which the frequency analysis is applied in the conditions in which the marker position is changed together with the change of the test frequency and indicates not only the absolute value of the phase shifting but also the type thereof: delay or advance.

- **Analogous electronic transducer for measuring power in direct current circuits, has circuit for generating filling factor which is astable flip-flop circuit based on amplifier [B7], [A123].** The invention relates to an analogue electronic transducer used for measuring power in direct current circuits. According to the invention, the transducer consists of a circuit for generating the filling factor which is an astable flip-flop circuit based on an amplifier with positive reaction through two resistors but also with negative reaction through two diodes, two equivalent controlled resistors and a capacitor, the equivalent resistors corresponding to some bipolar transistors from two oppositely-connected optocouplers, the output voltage of the differential amplifier controlling, in synchronism, two electronic switches connected with two low-pass filters which have the role of smoothing the rectangular waves generated by the switches and an amplifier which controls the current of the diodes. This patent application refers to an analogous electronic transducer used to measure power in circuits with continuous electrical current. The transducer can be used in automated adjustment systems of various dynamic magnitudes (couple, speed) or technological magnitudes (temperature, pressure, etc.) or in the case of adjusting the load strength power released during heating, melting, evaporation or of the power developed by photovoltaic cells, fuel cells, etc.

- **Direct, simplified algorithm for the calculus of the frequency response in sinusoidal signals [B12].** This patent application refers to a direct and simplified algorithm for the calculation of the frequency response in sinusoidal signals. The solution proposed is direct, much simpler, more inexpensive, easy to implement, not requiring multipliers and based on electronic relays. The novelty of the technical solution lies in the signal integration along well-defined time intervals, with the aim of obtaining components $\text{Re}(\omega)$ and $\text{Im}(\omega)$, while removing the correlation and, implicitly, the multipliers, that were inherent in conventional variants of such cases.

- **Multiple synchronous detection method for measuring non-linear and static resistance [A46].** This paper presents the method of multiple synchronous detection for measuring non-linear and static resistance, coming as a continuation of

the preoccupations for synchronous detection of the candidate in the Ph.D. field. The method in question was developed on the basis of the research activities carried out in the framework of the Ph.D. research work.

- **Use of Hilbert Discrete Transform to realize a vector-voltmeter in discrete time [A129].** The work presents a discrete time application to realize a numerical vector-voltmeter. The vector-voltmeter is a direct application of a configuration of two synchronous detectors in quadrature. It is used to find both the information included in the amplitude, and the information contained in the phase.

Other works and papers included in the list of works of the candidate expressing concerns in the same field are [A36], [A37], [A39], [A40], [A42], [A44], [A51], [A67], [A96], [A103], [A128], [C6], [C7], [C9].

2. Reliability and Testing

In the direction of research called „Reliability and Testing”, there are included 19 articles published by the candidate. The following chapter will deal with the most significant achievements that illustrate the usefulness and applicability of reliability analysis in various fields of activity.

- **Study of the reliability of electrical engines with permanent magnets**

The article [A91] proposes to make an estimate of the probability of good operation of a MS-1 N-8811 electrical engine with permanent magnets. In order to find the reliability of an engine, the analytical method was used, taking into account the reliabilities of bearings, contacts and windings. The exponential and Weibull distribution models were applied. In the reliability calculus, for every engine component, coefficients were chosen considering the normal 5-year length of operation. The same engine type (MS-1 N-8811) was also used in paper [A104], as part of an extended study for the calculus algorithm of statistical and reliability indicators that are necessary for the design and analysis of small and medium sized electrical engines and the systems they are a part of. The working method was FMEA (Failure Mode and Effect Analysis), taking into consideration the common failures in the engine running. Hence, the influence of the engine constructive components upon its reliability was calculated as well as the prediction of the number of failures along the maximum duration of work, the analysis of the risk level and the critical values of the engine elements.

- **Study of the reliability of medical equipment**

The reliability of a medical product is extremely important today, as everyone requires products that work without failure as long as possible. Such a product is difficult to be made without investing in its reliability, from the very beginning of the design stage. Paper [A115] presents the reliability analysis of a personal holter (cardiac rhythm recorder along an extended interval of time) and the FMEA analysis made with the help of Relex software. This approach is applicable to any similar medical equipment, being of help for the manufacturer to design a quality product.

- **Study of the reliability of industrial devices and equipment, with application to industrial knitting machines**

Papers [A107], [A108], [A118] focus upon the reliability of an industrial knitter, for an operational interval of 4500 hours (approximately 6 months), after which maintenance works were provided. Owing to the large number of components in the machine, the reliability analysis focuses upon major value modules: the weaving module (Fabric Take-Down modular system), the Sliding System module, the Cam Box module. In their case, reliability, the failure rate and MTBF (Mean Time Between Failures) are analysed, as well as the components bearing the highest risk of failure or defect operation. The reliability calculus module developed here can be used in any kind of industrial knitting machine.

In this research direction, in the list of works can also be consulted papers [A58], [A73], [A102].

3. Automation, Process Monitoring and Control

In this field, the author has published 24 papers [A52], [A54], [A89], [A101], books, patents and patent applications and was involved in research contracts. Among them, one can enumerate:

- **Level capacitive cryogenic transducer with coplanar plates for liquid nitrogen** [B5]. The invention relates to a level capacitive cryogenic transducer for liquid nitrogen, meant to measure/adjust the nitrogen level in coolers, condensers, cryogenic installations. According to the invention the transducer consists of two coplanar metal plates with the role of fixed electrodes and a metal plate, insulated in relation to the other two plates, which may slide on some insulating pins due to a float adhered to the mobile plate, the transducer capacity thus constituted being modified simultaneously with increasing the nitrogen level, both due to liquid nitrogen penetrating between the plates and to the mobile metal plate approaching to the two fixed plates, some electric conductors connected to the fixed plates leading the signal to an electronic circuit for processing the signal.

The research concerning intelligent mobile robot control was validated in presentations in international prestigious conferences and in patent applications which were awarded prizes in very important international invention fairs. Several of them are listed below:

- **Method and device for the extended force-position control of robotic and mechatronic systems** [B8]. The invention relates to a method and device for the extended hybrid force-position control of the movement of robotic and mechatronic systems. The claimed method consists of a first stage with offline functioning where there is defined a position and force error discourse universe, followed by other six stages, with real time functioning where there is determined the position and force extended distance after which there is determined the dependence function for both the position and force signals, there is obtained a selection matrix with correlation

coefficients for position and force, after which there is continued the hybrid force-position control for determining the position and force error signals, the error signals are processed, and in the last stage, the position and force signals are transmitted by means of some transducers mounted on a robotic and mechatronic system. The claimed device comprises some modules for calculating the position extended distance and the force extended distance, some modules for calculating the dependence functions for position and force, some modules for position and force extended transformation, some modules for calculating the position error and force error, an intelligent module for processing the error, a robotic and mechatronic system and a Cartesian coordinate calculation module.

- **Method for the dynamic control of a walking robot, involves computing of errors generated by position and force components on the freedom axes of a walking robot [B10].** The invention relates to a method and a device for the dynamic control of a walking robot, meant for the real-time control of the position of the robot's legs articulations and feet tips moving trajectory, the reaction forces and moving dynamics, with a view to improving stability in motion, with application in the transport of nuclear material, agricultural activities, military applications, for mine detection, and, in general, in applications carried on in difficultly accessible rough grounds. According to the invention, the method comprises the computing of errors generated by position and force components on the freedom axes of a walking robot, as well as the errors generated by the application of a strategy for the control of the stable dynamic walking of robot, some error signals being digitally controlled and multiplexed following two control strategies, and a strategy programmer setting the moment of action for each control strategy, depending on four stages of a whole step of the walking robot, and a program generating the robot's walking diagram by generating a reference signal and a desired position signal, so that, finally, by processing the error signals using the fusion of the signals resulting from the strategy programmer or the fuzzy control, there are obtained error signals for the control of actuators within the structure of the walking robot, on each axis of motion. The claimed device employed for carrying out the method comprises a complex of modules aiming at generating error signals on the axis of the robot, for each degree of freedom, for the control of actuators in the robot's structure, while taking into account the control strategies, with a view to improving the stability of the walking robot.

- **Method and device for actuating and controlling inertial mobile robots [B9].** The patent application concerns a method and a device for driving and controlling inertial mobile robots, mainly dedicated to biomedical checkups.

Other research related to this patent includes:

- **Method and real time control device of actuators [B11].** The present invention relates to a method and device for actuating and controlling inertial mobile robots meant especially for biomedical inspection applications. The claimed method consists in generating an oscillatory motion corresponding to an ideal pendulum by actuating and controlling some inertial bodies with rectilinear motion, wherein in the

desired direction of motion of the mobile robot there take place plastic collisions between the inertial bodies and some channel ends, the latter being integral with the robot body, leading to the inertial displacement of the robot, the plastic collisions being obtained by means of electrically controlled material with damping, such as magneto-rheological materials. The claimed actuation and control device comprises a number of n channels for displacing some inertial bodies, each channel comprising a stroke end A electromagnet, and a stroke end B electromagnet which generates an electromagnetic field controlled by a control system, wherebetween an inertial body moves, at the ends of stroke A and B there being provided a damping material whereon there is rigidly mounted a force transducer, a propulsion system and an actuation system for rotating the propulsion system depending on the signals received from the control system, the thus formed assembly being mounted in a body where there is rigidly fixed an acceleration transducer which transmits measuring signals on 3 axes of the acceleration to the control system, outside the body there being mounted a material with variable friction coefficient depending on the direction/sense of displacement.

- **Method and device for measuring rotation speed, in highly disturbing medium consists in digital determination of input signal by means of some counters with sequential functioning, with sequential discrimination of digital amplitude values [B1].** The invention relates to a method and device for measuring the rotation speed, in a highly disturbing medium of a hydrogenerator. According to the invention, the method consists in the digital determination of an input signal by means of some counters with sequential functioning, with sequential discrimination of the digital amplitude values or the variation speed in relation to a reference value imposed by the measured system and the application of some weighed mean wherein the weighing factors are determined off-line according to the transfer function of the measured system, excited with a Dirac impulse or a weighing function determined by the mathematical weight of the measured system so that the measurement accuracy is maximum in the desired performance field. According to the invention, the device for applying the method consists of a hysteresis shaper circuit, whose impulses are counted by k counter and an impulse generator which generates k impulses decoded by means of a decoder in k start-up signals for those counting k , a real time generator which determines each value of the rotation speed of a hydrogenerator by relating the signal generated by the hysteresis shaper to the real time generator, a number of k blocks for eliminating the digital values whose amplitude is higher than a reference value determined by the measured system and the transmission of this signal of k blocks of balanced intermediation, where the balancing coefficients are determined off-line depending on the transfer function of the measured system, excited with an impulse.

- **Wireless system for remote measuring of inclination of object in vertical plane of place [B4], [A57].** The invention relates to a wireless system for measuring the inclination of an object in respect of the vertical plane of the place, the system being carried out on a hardware platform which achieves the measurement of gravity acceleration on three orthogonal directions, using a 3D acceleration sensor, for the

conversion of said acceleration values into angles relative to the direction and sense of the gravity acceleration vector g there being used an A/D controller, based on a computing algorithm implemented with a microcontroller processing unit, the measured values being then communicated via an RF transceiver interface, to a mobile acquisition unit which displays/stores the measured values and communicates the same to some computing equipment, such as PC or PDA, the system being power supplied from an accumulator, by means of a management block having the function of charging control and monitoring of the charge state of the accumulator, the so obtained data being then transmitted to the microcontroller processing unit for being interpreted and then remotely communicated to the acquisition unit.

Part of this research direction, we also mention [A43], [A52], [A54], [A89], [A101], [A120], [A123], [A127], [C6], listed in the candidate's papers.

Mention should be made of the candidate's research activity carried out in related fields to the research directions presented until now:

- renewable energy; (7 papers)
- medical engineering and bioengineering (9 papers);
- inventics and industrial property;
- quality management in higher education and science politics (10 papers).

Conclusions

The research activity and the educational experience of the candidate along his career is represented by the following:

- ✓ 11 scientific books (of which, two as the first author),
- ✓ 129 articles,
- ✓ 4 patents and 10 applications for patents (of which, three as the first author),
- ✓ the Romanian Academy Prize "GHEORGHE CARTIANU" in Information Science and Technology,
- ✓ 3 ANCS prizes and the Diploma de Excellence of the Academy of Technical Sciences,
- ✓ 115 prizes, medals and distinctions at international and national salons of inventics,
- ✓ four research contracts obtained by competition, as director/responsible of the respective contracts,
- ✓ 2 institutional projects (POSDRU) obtained by competition, as project manager/responsible,
- ✓ 4 international research projects/contracts, as team member,
- ✓ 22 international research contracts obtained by competition, as team member,
- ✓ 6 institutional projects (POSDRU) obtained by competition, as team member,

- ✓ Technical University of Cluj-Napoca counsellor for education in intellectual and industrial property.

Career development directions requiring habilitation

The main direction for career development following the habilitation process consists in continuing the research activity already begun. The candidate will try to develop and extend the research performed until now and will pay a special attention to the transfer of the knowledge acquired to the students during teaching activities and also towards the academic research projects or projects in cooperation with the industry (the technology transfer will be focused upon the valorisation of the prototypes of patented inventions or inventions in the patenting process).

Through the habilitation thesis, the candidate intends to extend his expertise and research activity towards doctoral research reaching a higher level of coordination and control of this activity. The author considers he possesses the ability to make use of the experience gathered in research activities; he also thinks that the cooperation made with teams from other universities and from industry will increase the potential to attract new research contracts, at national and international level.

Here is a list of potential directions of research and applied development:

- ✓ the development of new algorithms in signal processing with applications to electrical measurements,
- ✓ measuring and monitoring of the parameters for renewable energy production plants,
- ✓ development of methods and algorithms for the measurement of various environment pollution levels,
- ✓ the study of the reliability of renewable energy production plants,
- ✓ reliability analysis of various industrial processes and systems,
- ✓ monitoring and control of domotic systems,
- ✓ people's assistance through the monitoring and processing of biomedical signals,
- ✓ statistics and measurement of research results and scientometric analyses.

A special attention will be given to the research original character and the patenting and dissemination of results reached.

Finally, we should emphasise that the entire activity of the candidate was performed in the Technical University of Cluj-Napoca. Through the present habilitation thesis, the candidate would like to express his gratitude for the institutional frame in which the career development took place. The candidate is convinced that the habilitation certificate will represent an opportunity to make this well-known institution of higher education more visible and more prestigious.