SUMMARY OF HABILITATION THESIS

SYSTEMS RELIABILITY INVESTIGATIONS ENHANCING RISK MANAGEMENT DECISIONS MAKING IN DYNAMIC ENVIRONMENTS

ENG. GABRIELA TONŢ, Ph.D.
University of Oradea

2016

SUMMARY

The integrator factor of my scientific, professional and academic activities is the use of quantitative assessment of the reliability and risk for electrical equipment integrated in various dynamic environments.

To predict system behavior and failure patterns, the reliability analysis have to take into account the causal relationships between increasingly sensitive and interrelated systems, their influence points with other systems and the specificity of environmental factors. To adequate to the applied methodologies, in these analysis the electrical equipment are considered as a subsystems structure composed of elements, or, in certain situations, a countable set of measurable attributes.

The quantitative assessments of systems reliability provide indices values corresponding to real level of reliability of system structure, whereas in literature are available average values which are, sometimes, incomplete, vague and conflicting. Assessing instantaneous reliability and optimal reliability values, obtained by approximating the experimental characteristics of failure and repair rates, enable their use in modeling the time evolution of systems with or without renewal. Studying the non-stationarity processes in representing time evolution of systems running in non-nominal and / or transient regimes is essential to increase accuracy of operational probability estimation.

Quantifying the uncertainties supports economical decision regarding the optimal level of reliability acceptable for producer and user, in a more realistic, broad and extendable to similar systems manner. As the analysis deepens, an insight about the probability of failures and inherent system weakness give the possibilities to assess economic consequences of risk levels for different configurations and identify optimal structure of dependable electrical equipment.

The theoretical and practical researches in my doctoral studies starts in 2000 at "Politehnica" University of Bucharest under the advisory of regretted Professor Vasile M. Catuneanu.

In 2002 I continued the doctoral studies at Technical University of Cluj-Napoca, where I have the honour to work under the coordination of Professor Radu Ioan Munteanu. The starting point on investigations concerning the reliability electrical equipment with extends to other complex systems was the doctoral studies and continued in my postdoctoral activity.

The habilitation thesis *Systems Reliability Investigations Enhancing Risk Management Decisions Making in Dynamic Environments* summarizes my professional and academic achievements beginning with April 2005, when my PhD thesis was defended, until 2015. It is based on original findings gathered, as coordinator or member in national and international research grants, author of books, national and international patents.

First section of the habilitation thesis is consecrated to the synthesis of scientific contributions, grouped in three parts, according to main research direction.

Chapter II addresses the issue of predictive and operational reliability for systems and equipment in dynamic environments, synthesizing my post doctoral contributions in this research direction. The adopted work hypotheses, regarding the analytical and applicative aspects of are more general than in dedicated the scientific literature, which enlarge analysis framework.

The first approach of this topic is dedicated to non-stationarity in reliability analysis of electric equipment running in non-nominal and transitory regimes. Transient regimes of

electrical equipment can propagate and create tensions which involve exceeding the nominal (required) performances. This study focused on the predictability control of electrical equipment operating in nominal regime by evaluating the impact of the transition states have on reliability indices of complex systems.

The proposed model introduces a method of non-stationarity identification for the multi-state components by means of hierarchical reliability analysis of complex dynamical systems. The model apprehends the evolution of a system by two states, characterized by 100% respectively 0% availability, including the system intermediate states involving partially success states is validated analytically, experimentally and by LabView simulation.

The second part presents, after an overview of hierarchical reliability analysis presents a hierarchical model of reliability indices evaluation for power switching device with standby system showing the dependencies of each variable on others by means of Directed Acyclic Graph (DAG). The developed model, validated by simulation and measurements illustrate that proposed framework can be implemented into a software tool to forecast realistic target reliabilities for similar systems.

The second part is devoted to techniques for electrical system hierarchical reliability analysis in dynamic environments. The research introduces a hierarchical analysis method of target reliability by means of Directed acyclic Graph method (DAG) and proposes a model of reliability assessment for a power switching device with stand-by system. The model developed, validated by simulation and measurements will be implemented in a software tool for predicting reliability realistic target values for similar systems.

The final part of **chapter II** focuses on reliability control and performance improvement approach. The methodology evaluates the failure behavior of the system in different operating conditions based on Failure Rates for Dynamical System framework. The proposed model is able to analyse multivariate data and allows the isolation of the effects of failures from time/stress aging. Another matter of this part is to identify critical components of photovoltaic networks in by means of a reliability performance assessment.

Chapter III is referring to contribution in reliability of robotic systems and multi-sensor networks integrated in robotic environments. Investigating the factors which determine autonomous mobile robots systems to perceive their environments, react to unforeseen circumstances, and plan dynamically in order to achieve their mission is one of latest scientific concern.

To find collision-free trajectories, in static or dynamic environments containing some obstacles, between a start and a goal configuration, the navigation of a mobile robot comprises localization, motion control and planning, and collision avoidance. Its task is also the [Online] real-time re-planning of trajectories in the case of obstacles blocking the pre-planned path or another unexpected event occurring. Inherent in any navigation scheme is the desire to reach a destination without getting lost or crashing into anything a higher-level process, a task planner, specifies the destination and any constraints on the course, such as time. Most mobile robot algorithms abort, when they encounter situations that make the navigation difficult.

The complexity in control and supervision originates from the fact that the lower level of execution control involves both set-point and task oriented controls. Modeling system dynamics and concurrency control in a more efficient way involves the development of synchronization-structures with some features need to be added in order to specialize the knowledge representation. To maintain those features, when the information flow within the system takes the form of process, control sequences and task, hierarchical fuzzy Petri nets approach is associated Markov analysis.

My contributions in this field are integrated in a team work. The research team proposed method can solve the problem of fine localization as well as global localization by tacking landmarks or by utilizing various patterns of magnetic landmark arrangement.

The navigation mobile walking robot systems for movement in non-stationary and non-structured environments was studied using a Bayesian approach of Simultaneous Localization and Mapping (SLAM) for avoiding obstacles and dynamical stability control for motion on rough terrain. By processing inertial information of force, torque, tilting and wireless sensor networks (WSN) an intelligent high level algorithm is implementing using the virtual projection method. The control system architecture for the dynamic robot walking is presented in correlation with a stochastic model of assessing system probability of unidirectional or bidirectional transition states, applying the non-homogeneous/non-stationary Markov chains.

The research in localization and tracking methods using Wireless Sensor Networks (WSN have been developed based on Radio Signal Strength Intensity (RSSI) and ultrasound time of flight (TOF). Many efforts have been devoted to the development of cooperative perception strategies exploiting the complementarities among distributed static cameras at ground locations and cameras on board mobile robots in compliance with the actuator position control.

The knowledge and findings of these researches was originals and patented at national level with patents OSIM A/00052/21.01.2010, *Method and Device for Walking Robot Dynamic Control,* OSIM A1024/07.12.2009, *Method and Device of Propulsion without Own Energy Source for Mobile Systems* and internationally with Patent EPO 104 64006.5/27.09.2010, *Method and Device for Walking Robot Dynamic Control*,

- The innovative character of the patents was recognized by 13 international awards and prices in:
- The Belgian International Trade Fair for Technological Innovation, EUREKA, Gold Medal with mention in Bruxelles for the Invention *Method and Device for Driving Mobil Inertial Robot* Brussels, 2009;
- Medal and Diploma of International Warsaw Inventions Show IWIS 2009, Association of Polish Inventors and Rationalizers, for the Invention *Method and Device Walking Robot Dinamic Control* Warsaw, 2009;
- Diplôme du Salon international des Inventions Genève, pour *Procédé et cōntrole dynamique de la marche de robots* Genève 2010;
- Diplôme du Salon international des Inventions Genève, pour Methode et dispositif de fonctionnement et de côntrole de robots, Genève 2010;
- Special Prize for in Recognition of Meritorious Achievements for the Innovative Invention *Method and Device for Driving Mobil Inertial Robot,* Isfahan University of Technology, Robotic Center, Republic of Iran, 2010;
- The Belgian International Trade Fair for Technological Innovation, EUREKA, Gold Medal with mention in Bruxelles for the Innovation *Method and Device Of Propulsion Without Any Source Of Self-Energy Mobile Systems,* 2010;
- Gold Medal and Diploma of International Warsaw Inventions Show IWIS 2010, Association of Polish Inventors and Rationalizers, for the Invention *Method and Device of Dynamic Control of a Walking Robot* Invention Warsaw, 2010.

– Gold Medal with Mention and Diploma of International Warsaw Inventions Show IWIS 2010, Association of Polish Inventors and Rationalizers for the Invention *Method and Device for Driving Mobil Inertial Robot* Warsaw, 2010.

– Medal and international Prize of The X-th Moscow International Salon Of Innovations and Investments, September 2010, Moscow, Russia, for the patent: *Method and Device for Walking Robot Dynamic Control,* 2010.

– Diplôme du Salon international des Inventions Genève, pour l'invention: *Methode et dispositif de fonctionnement et de côntrole de robots mobiles d'inertie*, 2011.

– Outstanding Invention Award, Hong Kong Polytechnic University, Diploma for the Innovation *Method and device of propulsion without any source of self-energy for mobile systems*, 2011.

– Gold Medal of the 9th International Exhibition of Inventions ARCA 2011, Zagreb, CROAŢIA, 13-15 October 2011, for the patent: *Method and device of propulsion without any source of self-energy for mobile systems*

– Gold Medal for Inventions at 5-th IWIS Exhibition, 3-5 November 2011, Warsaw, Poland for the patent: *Method and device of propulsion without any source of self-energy for mobile systems*, 2011.

Chapter IV shares a vision in risk management regarding the stages of risk-based analysis, identification and decomposition of risk.

Modeling the behavior of dependable systems under realistic time-dependent operational conditions, in order to allow an incremental development, requires assessment of architecture and core capabilities of a given system in the human – machine interactions and socio–technical cohesion condition analysis.

The understanding and implementation, in context of use of dependable system, considering human factors and the quantification of the reliability of human performance in the regulatory process, are the key problem in the safety analysis and risk quantification.
Modeling the robust systems, insensitive to variation, yet flexible, highly available, and safe, using Bayesian associated analysis technique expanded to support Probabilistic Risk Assessments (PRA) is the goal of this research. The proposed methodology examines low- and high- probability consequence scenarios which can emerge as a result of multiple events occurrence. Developed in terms of operational performance, the effectiveness of the proposed method for quantifying risk in a complex electrical system is validated, analytically and experimentally. The proposed integrated platform for probabilistic risk assessment is a step forward to dynamic reliability which proposes powerful methods for a more realistic modeling of interactions between components and process variables with respect with time evolution.

Second section of the thesis presents my perspectives on research and teaching activities. In short and medium term I intend to continue my research on the reliability of integrated multi-sensors systems in diverse environments towards dynamic reliability, but also to approach issues like the reliability growth and performance improvement of complex dynamical systems. Improving masters' courses and gaining knowledge in programming will be my future concerns also.

Third section of the thesis includes afferent references list.