

ABSTRACTS

OF SCIENTIFIC PAPERS

of Assist. Prof. Eng. Toncho Hristov Papanchev, PhD

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A total of 30 peer-reviewed scientific papers are presented for participation in the application.

The scientific publications are divided into three groups, in accordance with indicators B.4, Г.7 and Г.8 of the document “5. Detailed reference for compliance with the minimum national requirements“.

Indicators B.4 and Г.7 include 18 scientific publications that are referenced and indexed in the SCOPUS scientific information database.

Indicator Г.8 includes 12 scientific publications in unreferred journals with scientifically peer-reviewed or edited collective volumes.

[Indicator B.4] Scientific work for associated professor - publications indexed in internationally recognized databases

[B.4.1.] Georgiev A., N. Nikolov, T. Papanchev, *Maintenance process efficiency when conduct reliability-centered maintenance of complex electronic systems*, XIX-th International Symposium on Electrical Apparatus and Technologies SIELA 2016, DOI: 10.1109/SIELA.2016.7543002; Proceedings of digests ISBN: 978-619-160-648-1, pp. 123-126, Bulgaria, 2016.

Maintenance process efficiency when conduct reliability-centered maintenance of complex electronic systems

A. Georgiev, N. Nikolov, T. Papanchev

The paper analyzes some possibilities for optimizing the maintenance of complex electronic systems in order to improve their reliability. The study took into account the problems associated with detection and elimination of sudden failures. The specifics concerning the replacement of the failed elements with working ones are reflected, as well as the provision of an economically acceptable number of spare elements, at a guaranteed level of operational reliability.

A generalized model of the process of reliability-oriented maintenance of complex electronic systems is presented, taking into account the periodic occurrence of both sudden and parametric failures. Based on this model, an analysis of the maintenance processes of complex electronic systems with functional redundancy is made. The Wilcoxon-Man-Whitney theorem from queuing theory was used to optimize the minimum required number of spare elements of each type. Mathematical dependencies have been formulated and nomograms have been compiled, with the help of which the necessary number of spare parts can be determined to achieve a certain value of the probability of failure-free operation, at a given capacity of the maintenance team.

The developed approach proposes possibilities for: (1) optimization of the reliability-oriented maintenance of a complex electronic system regarding the required number of spare parts and maintenance teams, in order to ensure the desired reliability indices; (2) prevention of interruption of the operation of complex electronic systems due to shortage of spare parts or maintenance teams.

[B.4.2.] Georgiev A., T. Papanchev, N. Nikolov, *Reliability assessment of power semiconductor devices*, XIX-th International Symposium on Electrical Apparatus and Technologies SIELA 2016, DOI: 10.1109/SIELA.2016.7543003, Proceedings of digests ISBN: 978-619-160-648-1, pp. 127-130, Bulgaria, 2016.

Reliability assessment of power semiconductor devices

A. Georgiev, T. Papanchev, N. Nikolov

This paper addresses some issues related to the occurrence of sudden failures in power semiconductor devices. Using the the reliability prediction methods, an analysis of the requirements for achieving reliable operation of the semiconductor elements is made. Special attention is paid to the evaluation of quantitative indices for flawless operation of power semiconductor devices Isolated Gate Bipolar Transistors (IGBT). The possibilities for application of accelerated tests with constant electrical and temperature loads are analyzed.

Several tests of different duration, operating modes and temperature were applied sequentially on a set of twelve IGBT transistors. The analysis of the data obtained from the tests takes into account not only the number of components that fail or remain in working condition after the next test, but also takes into account the change in electrical characteristics of the devices, assessing changes in transconductance ΔG_F and the steepness ΔS before and after each test.

The analysis of the obtained data shows the excellent stability of the tested semiconductor devices with respect to the performed reliability tests. No failure of any of the tested elements was found. Moreover, no noticeable changes in their electrical characteristics were detected. The high reliability of the tested semiconductor devices was confirmed, but the gathered information does not allow designing reliable models of the degradation processes, as well as estimations of the activation energy and the mean time to failure MTTF. However, the experiments performed provides information on further research by the team, with applying tests with simultaneous application of temperature and electrical stresses. The experience gained will help to draw up a test plan for the next phase of research, namely, the design of electronic devices with high reliability and safe-failures states.

[B.4.3.] Nikolov N., T. Papanchev, A. Georgiev, *Reliability Assessment of Electronic Units Included in Complex Electronic Systems*, 40th International Spring Seminar on Electronics Technology (ISSE), Proceedings, pp. 1-6, ISSN 2161-2536, DOI: 10.1109/ISSE.2017.8000926. Bulgaria, 2017.

Reliability Assessment of Electronic Units Included in Complex Electronic Systems

N. Nikolov, T. Papanchev, A. Georgiev

The report is dedicated to the study of the reliability of electronic units, which are part of complex electronic systems.

Two approaches for estimating quantitative reliability indices of such systems have been proposed and compared. The first one is based on borrowing data for units' reliability resulting from tests performed by the manufacturer or by users, as well as of calculations regarding units' reliability estimation, required by other applications. The second one, recently applicable, requires direct reliability studies and tests on functionally similar units built by wide-spread commercial modules such like Arduino and Raspberry, regarding which there is accessible technical information there, required for their reliability estimation.

Both approaches are used to assess the reliability of several electronic devices - Network Adapter (NA), Modem (M) and Remote Terminal Unit (RTU). The estimates of the failure rate and the reliability function of the devices obtained by both approaches are compared and analyzed.

Based on the obtained results the following conclusion can be made: (1) In cases when there is a lack of technical information on the units design and their set of functions, then it is acceptable to be used initial reliability information borrowed by other reliability studies, performed in regard to similar units if these have a uniform design, typical and clearly defined purpose and functions. Reliability indices values calculation based on borrowed reliability data for complex units, which might be characterized by variety in their design and set of functionalities would cause unacceptable inaccuracy in the reliability estimation. (2) The study points out the opportunity an electronic unit to be composed by well-known wide-spread modules achieving this way an unit design very similar in term of its functionality to a certain unit under reliability assessment and assessing the reliability of the former one there can be obtained there estimation values regarding reliability indices of the latter one, close enough to these, which could be calculated on the base of its technical documentation and specifications. The main advantage is that such a physical model can be subjected to appropriate reliability tests to assess the reliability indicators with sufficiently high accuracy.

[B.4.4.] Garipova J., A. Georgiev, **T. Papanchev**, N. Nikolov, D. Zlatev, *Operational Reliability Assessment of Systems Containing Electronic Elements*, DOI: 10.1007/978-3-319-68324-9_37, 2nd International Conference on Intelligent Information Technologies for Industry IITI 2017, Advances in Intelligent Systems and Computing, vol. 680, pp. 340-348, ISBN: 978-331968323-2, Bulgaria, 2017.

Operational reliability assessment of systems containing electronic elements

J. Garipova, A. Georgiev, T. Papanchev, N. Nikolov, D. Zlatev

The report presents and analyzes problems related to the operational reliability of measuring instruments used in medicine and containing electronic elements. The analysis is based on the probability modeling through a Markov process. The identification of the system states is performed from the point of view of the overall operability of the system. The probabilities for transition from one state of the Markov process to another state are analyzed.

The subject of a study in this paper is the analysis of the operational reliability of electronic devices with serial reliability block diagram, referring to information collected by real service data from maintenance and repair of specific kind electronic items.

The performed analysis is illustrated by an example describing the sequence of assessing the operational reliability of a semi-automatic blood pressure monitor. To assess the reliability of the specific type of products, real statistics on failures that occurred during the operation of the equipment were used. A diagram of the transitions is created with four states - operational state, failure occurred in the electronic unit of the device, failure occurred in the automatic exhaust valve APRV, and failure in the muffler of the monitor. The probabilities of stay of the studied equipment in each of the possible states are described with the help of a system of differential equations derived from the Kolmogorov equations for a continuous Markov process.

Based on the obtained results, the following conclusions can be made: (1) Significant difference was found in the reliability of the individual components of the tested equipment, with the highest value of the probability of being in a state of failure of APRV. (2) On the basis of the collected data an analysis of the reasons for occurrence of the registered failures has been made. (3) Specific measures have been proposed, the implementation of which would lead to an increase in the operational reliability of the examined medical equipment.

[B.4.5.] Papanchev T., A. Georgiev and N. Nikolov, Dynamical Reliability Estimation and Critical State Early Detection by Application of FIDES Guide 2009, DOI: 10.1109/ET.2017.8124375, XXVI International Scientific Conference Electronics - ET2017, ISBN 978-1-5386-1752-6, pp.314-317, Bulgaria, 2017.

Dynamical Reliability Estimation and Critical State Early Detection by Application of FIDES Guide 2009

T. Papanchev, A. Georgiev and N. Nikolov

This paper presents the continuation of the work of the research team in assessing the reliability of electronic systems. An innovative approach for dynamic assessment of the operational reliability of such systems is proposed, the application of which would allow through ongoing assessment of certain indicators of reliability and analysis of their changes to produce early signals for critical conditions from the point of view of reliability.

For the realization of this approach it is necessary: (1) to be described in details all different operation modes of the studied system, their duration and sequence - the so-called "life profile"; (2) periodically to collect data for a certain set of parameters, which describe the state of the system in each operation mode. Such parameters are temperature, humidity, vibration and others. Reliability is assessed by applying the reliability prediction methodology FIDES Guide 2009. The research is based on the periodic calculation of statistical point estimates of the failure rates of the elements of the electronic systems, and reporting deviations of parameters' values from previously accepted reference values.

To verify the proposed approach, an analysis of the reliability of an electronic unit and a basic electronic component is made. It was found that the reliability indices of an electronic unit or of a single component, in this case the failure rates, register significant changes when changing the parameters of the operating modes.

Based on the obtained results, an early warning tool for approaching/occurrence of critical states is proposed, by compiling criteria for permissible changes in the failure rate both in absolute values and in terms of the rate of change, in relation to predetermined critical elements, as well as for all electronic equipment. A formula for calculating an integral state index has been proposed to serve as an early signal for the onset of a critical state.

[B.4.6.] Georgiev A., N. Nikolov, T. Papanchev and J. Garipova, *Providing Medical Apparatus with a High Reliability at the Design Stage*, DOI: 10.1109/SIELA.2018.8447176, XXth International Symposium on Electrical Apparatus and Technologies SIELA 2018, ISBN 978-1-5386-3419-6, pp. 1-4, Bulgaria, 2018.

Providing Medical Apparatus with a High Reliability at the Design Stage

A. Georgiev, N. Nikolov, T. Papanchev and J. Garipova

This paper proposes an approach for optimizing the structural scheme of electronic devices for which high reliability requirements are set. The presented optimization methodology is suitable for application in the design stage of portable medical electronic equipment, when there are additional requirements for their construction, such as volume and weight.

The proposed approach is based on the compilation of variants for redundancy of some of the units of an electronic equipment, which variants achieve the set reliability requirements, and the selection of the most optimal of them. Those blocks that cannot be reserved due to technical or economic reasons are determined in advance. For the other units, a sequential calculation of the minimum sufficient redundancy rate is performed, which allows the achievement of the required values of the reliability function. All eligible variants for structural redundancy are assessed according to pre-defined requirements such as price, volume, weight, etc. An equation for the decision function D of the optimization process is derived. All units are evaluated with respect to the given optimization criteria, and their normalized relative estimations $norm_{xy}$, with which they participate in the decision function, are calculated. The weighting coefficients ω of the optimization criteria are set in advance.

$$D(R_{S_j}(t), c, V, w | j = 1 \div s) = \min_{j=1 \div s} \left(norm_{R_{S_j}}^{-1} \cdot \omega_R + \sum_{k=\{c, V, w\}} \frac{\sum_{i=1}^m (\alpha_{ij} + 1) \cdot norm_{k_i}}{\max_{j=1 \div s} \left\{ \sum_{i=1}^m (\alpha_{ij} + 1) \cdot norm_{k_i} \right\}} \cdot \omega_k \right),$$

[B.4.7.] Zlatev D., A. Georgiev, T. Papanchev, J. Garipova and T. Stefanova, *Reliability Modeling of MOSFETs in Resonant Full Bridge Inverter*, DOI: 10.1109/ET.2018.8549590, XXVII International Scientific Conference Electronics - ET2018, ISBN: 978-1-5386-6692-0, pp. 1-4, Bulgaria, 2018.

Reliability Modeling of MOSFETs in Resonant Full Bridge Inverter

D. Zlatev, A. Georgiev, T. Papanchev, J. Garipova, T. Stefanova

This paper concerns reliability modeling of the MOSFET transistors in a full bridge inverter with series resonance at the load circuit. Taking into account the resonant process and its parameters a model concerning transistors reliability in such an inverter is obtained.

The suggested reliability model is based on the methodology for reliability evaluation of electronic components described in MIL-HDBK-217F. In order to identify and describe some dependences of the reliability function of the converter on the parameters of the resonant circuit, simulations are performed in resonant processes with different inductance and capacity, respectively different characteristic impedance of the load circuit.

Expressions are derived for the power losses in the transistor and for the junction temperature, which include the load apparent power and the characteristic impedance of the resonant circuit.

A mathematical model concerning the reliability function of MOSFET transistors in a resonant bridge inverter is derived.

Based on the obtained results, the following conclusions can be made: (1) The reliability of the MOSFET transistors depends on the properties of the resonant circuit in the bridge inverter, in particular its characteristic impedance. (2) The reliability model clearly demonstrates the particular importance of this dependence in increased output power and increased R_{DSon} . (3) At increased output power, the reliability of the transistors can be improved by increasing the value of the characteristic impedance. (4) An approach using such a model provides an opportunity to assess the reliability of the power switches, and hence of the whole device regardless of its power and application.

[B.4.8.] Garipova J., A. Georgiev, T. Papanchev and D. Zlatev, *Life Data Analysis and Operational Reliability Point Estimation Related to Medical Electronic Devices*, DOI: 0.1109/ELMA.2019.8771582, 16th Conference on Electrical Machines, Drives and Power Systems, ELMA 2019, ISBN: 978-172811413-2, pp. 1-5, Bulgaria, 2019.

Life data analysis and operational reliability point estimation related to medical electronic devices

Garipova J., A. Georgiev, T. Papanchev, D. Zlatev

The present paper is focused on a life data analysis of the Weibull model parameters through a parametric E-Bayesian assessment related to a set of medical electronic devices. The analysis is work on using a priori data for analyzing the current incoming information. The case study is purposed for formalize both the priori and accumulated sampling data obtained from real service information in the form of reliability empirical data. As a result of the case study and the current analysis, the point estimates of the operational reliability indices valid for the medical devices under study are experimentally obtained.

The subject under study in this paper is the life data analysis of the one type of semi-automatic blood pressure monitors (SABPMs) through a parametric E-Bayesian estimation regarding statistical data obtained during the service's operation and obtaining new data set information in the form of empirical data by using the Weibull distribution. Thereby, an algorithm of stochastic mathematical models, which consider the maintenance data, are developed and optimized.

The value of the shape parameter β of the Weibull distribution is calculated by linear transformation and least squares estimation LSE on complete and multiple censored data. A Herd-Johnson estimation approach is used for assessing the statistical value of cumulative density function. To estimate the characteristic time θ of the Weibull distribution, a formula for the likelihood function is derived according to the method of maximum likelihood estimation MLE. On this basis, an expression is obtained for the a priori distribution of the characteristic time as an inverse Gamma distribution with hyperparameters a and b . The associated a posteriori distribution has the form of a normal distribution with hyperparameters μ' and σ' , the values of which are calculated by applying the method of moments based on the incoming new data on failures. By applying the Gaussian approximation to the moment of inverse Gamma distribution, the a posteriori updated hyperparameters a' and b' are calculated, that achieves updating the distribution law of characteristic time θ .

The Bayesian approach to reliability estimation presented in this paper is based on the use of operational data related to the Weibull distribution. It can accurately assess reliability in the absence of sufficient "fresh" data.

[B.4.9.] Papanchev T., A. Marinov, E. Bekov and J. Garipova, *A Comparative Reliability Analysis of Boost-Type Three-Phase PFC Rectifiers*, DOI: 10.1109/ET50336.2020.9238190, XXIX International Scientific Conference Electronics, ET 2020, ISBN: 978-172817426-6, pp. 1-4, Bulgaria, 2020.

A Comparative Reliability Analysis of Boost-Type Three-Phase PFC Rectifiers

T. Papanchev, A. Marinov, E. Bekov, J. Garipova

The paper presents an approach for performing a comparative analysis of the reliability of two types of three-phase electronic converters for power factor correction (PFC) - fully controlled Six-Switch PFC Bridge rectifier SSBR and three-level Vienna rectifier, known as VIENNA Rectifier VR. The PFC unit is usually part of the power supplies for fast charging of rechargeable batteries.

After analyzing the topology of the two circuits, it is accepted that for the comparison of the reliability properties it is enough to evaluate the reliability indices of the power semiconductor elements. The necessary mathematical apparatus for calculating the electrical stress of the power semiconductor elements in the circuits - diodes and field-effect transistors, has been compiled. The average and r.m.s. values of the currents through the elements are calculated, as well as the dissipated power in them.

To assess the reliability parameters, the methodology for reliability prediction presented in FIDES Guide 2009 has been applied. A detailed "life profile" has been compiled for the use of the studied schemes in electric vehicles.

The studied three-phase topologies are compared at the same input and output parameters of the operating modes. The electrical, thermal and ambient stress factors are discussed and evaluated according to the semiconductor components. Silicon carbide (SiC) MOSFET transistors and SiC Schottky diodes are chosen for the present analysis.

The obtained values of currents and dissipated power in the semiconductor elements, as well as the obtained estimates of the failure rate of the elements individually and of the circuits as a whole, are presented in tables.

After analysis of the operating modes and evaluation of the reliability of the two studied topologies, the following conclusions were made: (1) The SSBR rectifier is composed of fewer semiconductor elements and has a simplified circuit, but it does not lead to better reliability, and the resulting estimate of the physical failure rate of the circuit is about three times higher than that of the Vienna rectifier VR. (2) The reason for this is found in the more severe operating mode of SiC MOSFET transistors in SSBR, due to the significant power dissipation in the anti-parallel diodes in the transistors. (3) Using external antiparallel diodes would ease thermal stress of the transistors in SSBR and improve the reliability of the system.

[B.4.10.] Zlatev D., J. Garipova, T. Papanchev and A. Georgiev, *Experimental validating of reliability model of MOSFETs in resonant full bridge inverter*, DOI: 10.1109/SIELA49118.2020.9167071, 21st International Symposium on Electrical Apparatus and Technologies, SIELA 2020, ISBN: 978-172814346-0, pp. 1-4, Bulgaria, 2020.

Experimental validating of reliability model of MOSFETs in resonant full bridge inverter

D. Zlatev, J. Garipova, T. Papanchev, A. Georgiev

This paper represents the next stage of the authors' research to develop updated reliability models of modern power semiconductor elements, especially MOSFETs. In order to validate the previously developed mathematical models for reliability estimation of field-effect transistors in the considered inverter topology, experimental studies are planned and implemented.

For the purposes of the tests, a physical model of a bridge resonant inverter was built. An experimental study was performed, including electrical measurement of the losses in the semiconductor elements and thermal analysis of the circuit by means of a thermal imaging camera.

The table presents the results of experimental studies of the resonant bridge inverter. These include the values of the input voltage of the inverter, the r.m.s. value of the voltage on the coil, the capacitance and inductance of the resonant circuit, and the maximum heating temperature of the transistor cases. The temperatures of the radiators and the semiconductor switches were measured by means of a thermal imaging camera. The input voltage is set so that the output power remains constant. A thermal image of the power semiconductors is shown, at a value of the characteristic impedance of the load circuit of 23.07 Ω .

Using the obtained data on the heating of the transistors, experimental estimates were derived for the reliability function of the MOSFET transistors. A comparative analysis is made between them and the theoretically obtained values for the same reliability indicator based on the developed reliability model. The theoretically and experimentally obtained curves of change of the reliability function of the transistors depending on the value of the characteristic impedance of the load circuit are presented in graphical form. Differences in the range of 1.5% to 0.5% have been identified, which can be considered as confirming the validity of the developed theoretical model.

Based on the information accumulated in the experimental studies, suggestions have been formulated for further improvement of the theoretical reliability model.

[B.4.11.] Marinov A., E. Bekov, F. Feradov and T. Papanchev, *Genetic algorithm for optimized design of flyback transformers*, DOI: 10.1109/SIELA49118.2020.9167071, 21st International Symposium on Electrical Apparatus and Technologies, SIELA 2020, ISBN: 978-172814346-0, pp. 1-4, Bulgaria, 2020.

Genetic algorithm for optimized design of flyback transformers

A. Marinov, E. Bekov, F. Feradov, T. Papanchev

The paper presents an approach into designing transformers for flyback converters. The approach is based on the concept of computer aided design, where at its core is the utilization of a genetic algorithm. The genetic algorithm allows for optimal selection of critical transformer components and parameters, where the objective function - based on user preference - may include efficiency, cost, geometric size, thermal dissipation, weight and other parameters critical to the design. Each step of the design approach is presented and explained in details. The algorithm is realized and integrated into a computer application. The approach and the developed application are verified over a test design, where a selected example is presented in detail in order to highlight each step of the algorithm. The approach allows for the development of optimal designs over several algorithm generations.

The relevance of the developed approach and the computer application is verified by performing constructive design of a pulse transformer for flyback converter. The operating mode of the transformer and the selected optimization parameters are described - efficiency and weight, with weighting factors of 0.7 and 0.3, respectively. The selected example is presented in details to describe each step of the algorithm. The current results of the application of the genetic algorithm in several cycles (epochs) are presented in tabular form, as well as the final choice of the most optimal variant.

As a result of the performed researches the following conclusions can be formulated: (1) The developed approach is suitable for integration into a computer application for performing multi-purpose optimization with respect to pre-set parameters of the transformers. (2) The approach allows for the simplified selection of key transformer component such as core type, core material and core size. (3) Several problems related to premature convergence and generation of physically incompatible designs were noted. (4) The results from this initial study suggest that the approach can be extended to the design of other power electronic blocks as well.

[Indicator Г.7] Scientific publications indexed in internationally recognized databases

[F.7.1.] Papanchev T., *A fuzzy control of peltier-based thermal chamber for reliability tests*, DOI: 10.1109/SIELA49118.2020.9167106, 21st International Symposium on Electrical Apparatus and Technologies, SIELA 2020 – Proceedings, ISBN: 978-172814346-0, Bulgaria, 2020.

A fuzzy control of Peltier-based thermal chamber for reliability tests

T. Papanchev

The paper studies possibilities for applying artificial intelligence techniques to control the thermal cycling modes of a thermal chamber for reliability tests. Peltier elements (PE) are used to be achieved consecutive heating/cooling cycles. A fuzzy logic approach is applied to control the temperature inside the chamber according to previous given requirements.

A block diagram of the control unit of the developed thermal chamber for cyclic thermal stress is presented. The walls of the chamber are thermally insulated with thermal insulation materials.

The application of fuzzy logic aims to achieve effective control of the operation of thermoelectric modules in conditions of uncertainty regarding the thermal characteristics of the chamber and the test product. The process of building a control module by means of fuzzy logic is described in detail. The input and output parameters of the fuzzy logic control algorithm are selected. For fuzzy logic algorithm implementation an embedded fuzzy logic library eFLL is used. The max-min approach and minimum Mamdani fuzzy inference system are applied, with centroid method to defuzzification in a continuous universe used. Triangular and trapezoidal membership functions are implemented for input and output parameters which are constructed with four points a, b, c and d, with fixed or opened border conditions. The specific numerical characteristics of some of them are shown graphically. The accepted categorizations of the input and output parameters and the formulated fuzzy rules are described. After the conducted experimental study, the obtained heating temperature profile of the chamber when the designed fuzzy control unit is used. The oscillation observed, when desired temperature 55°C is reached and must be kept constant, is 2°C peak to peak.

On the basis of the performed experiments the following conclusions can be formulated: (1) It is observed that, with the current equipment of the chamber, the fuzzy controller manages to provide the required slope and maintenance of the temperature of the plateau of the temperature profile in heating mode. (2) In cooling mode, there are again good results in maintaining a constant temperature, but the set slope was not maintained in the entire range of temperature change. (3) A solution of this problem will be sought in increasing the power of the Peltier elements and improving the thermal insulation of the chamber.

[Г.7.2.] Garipova J., A. Georgiev, T. Papanchev, *E-Bayesian Point Estimation and Comparative Analysis of the Operational Reliability Related to Electronic Items for Medical Purpose*, DOI: 10.1109/SIELA.2018.8447115 SIELA 2018, XXth International Symposium on Electrical Apparatus and Technologies, ISBN 978-1-5386-3419-6, Bulgaria, 2018.

E-Bayesian Point Estimation and Comparative Analysis of the Operational Reliability Related to Electronic Items for Medical Purpose

J. Garipova, A. Georgiev, T. Papanchev

This paper presents an approach for analysis of the collected data for failures from the maintenance of medical equipment and calculation of the values of the statistical point estimates of operational reliability parameters. The approach involves the application of two assessment methods used to calculate the values of reliability indices - assessment by applying the method of maximum likelihood (Maximum Likelihood Estimation MLE) and assessment by determining the empirical Bayesian assessment (also known as E-Bayesian assessment).

An equation for the failure rate likelihood function in a set of complete and censored data has been obtained, from which a formula for estimating the value of the failure rate by the MLE method is derived. As Bayesian estimator, the Gamma distribution conjugate prior function of failure rate λ is modeled. An expression is constructed for the density function of the failure rate, from which, after applying the Bayes theorem, the equation of posterior density function of the of the failure rate λ is obtained.

The presented approach is used for evaluation and comparative analysis of the reliability parameters of three types of measuring medical devices containing electronic and mechanical modules. The results obtained by both methods are shown in graphical form.

Based on the research and the results obtained, the following conclusions have been formulated: (1) The presented approach is suitable for defining the deadlines for preventive procedures. (2) The information gathered and the results obtained can provide guidance in the design of electronic equipment with improved reliability. (3) E-Bayesian techniques provide more flexible reliability analysis and ongoing update of reliability parameters values when the new data is accumulated.

[Г.7.3.] Papanchev T., A. Georgiev, J. Garipova, *A Smart Sensor Modules Reliability Estimation by Thermal Cycling Tests*, DOI: 10.1109/ET.2019.8878668, 28th International Scientific Conference Electronics, ET 2019 – Proceedings, ISBN: 978-172812574-9, Bulgaria, 2019.

A Smart Sensor Modules Reliability Estimation by Thermal Cycling Tests

T. Papanchev, A. Georgiev, J. Garipova

This paper presents the study of the reliability of modern modules for data measurement and transmission. Consideration is given to the ability to assess reliability when it is not possible to test a large number of modules. The evaluation capabilities based on cyclic reliability tests in combination with reliability prediction methodologies are shown. An experiment was conducted with smart pressure and temperature sensors.

An approach is developed and proposed, for estimating the value of the acceleration factor of accelerated reliability tests, in particular cyclic temperature tests, based on the Norris-Landzberg model. This model contains two coefficients whose values are generally unknown, and therefore require multiple tests, the results of which can be used to obtain reliable estimates of those coefficients, for example, by applying a regression analysis.

The approach proposes that in case when complex electronic devices reliability has to be evaluated, and there are no available many samples for testing, or the device's price is significant, an opportunity to evaluate the value of the acceleration factor is by means of mathematical instruments of the reliability prediction methodology presented in FIDES Guide 2009. At the core of the approach is the precise description of two so called "life profiles" of tested electronic device, one of the device's normal operating conditions and the other of the parameters of the applied cyclic temperature tests. In the next step, values of physical failure rate for both "life profiles" have to be calculated, and using these values to obtain an estimate of the tests acceleration factor.

The proposed approach was applied in a practical experiment on four smart sensor modules based on the BMP280 sensor ten days by cycling thermal stress. The tested modules and their working thermal conditions in normal use are shown. The temperatures of the module's electronic elements were measured by means of a thermal imaging camera.

The obtained results are presented in tabular form. The value of the acceleration factor of the applied tests, the time of normal operation, equivalent to the test duration, as well as an estimate of the mean time to failure of the tested modules are calculated.

[Г.7.4.] Garipova J., T. Papanchev, A. Georgiev, *Non-Parametrical Approach for Operational Reliability Assessing Related to Medical Electronic Items*, DOI: 10.1109/ET50336.2020.9238264, 29th International Scientific Conference Electronics, ET 2020 - Proceedings, ISBN: 978-172817426-6, Bulgaria, 2020.

Non-Parametrical Approach for Operational Reliability Assessing Related to Medical Electronic Items

J. Garipova, T. Papanchev, A. Georgiev

This paper is focused on the non-parametric reliability analysis of medical items by means of applying graphical methods to determination and assessment the survival function distribution of measuring items in medicine containing electronic elements.

An analytical approach has been developed, containing an adapted and optimized set of algorithms for stochastic mathematical models, allowing operation with complete and censored data on the devices' failure times. The two parts of the approach are described in detail: (1) Application of Kaplan-Meier product limit estimation for statistical description of the cumulative density function CDF of time to failure (the same represents the probability of failure of the studied devices); (2) Formulation of a substantiated conclusion for belonging of the collected statistical data to any of the applicable distribution laws. The Weibull law is applied, through which other basic laws of distribution of failure times can be expressed, which covers a large part of the cases of reliability analysis in the field of electronics.

Using the suggested approach, the statistics on operating times to failure, collected during the maintenance of semi-automatic blood pressure monitors (SABPM), are analyzed. The process of collecting information presupposes the availability of complete and censored data. The results obtained from the application of the Kaplan-Meyer PL estimation for the survival function and CDF are shown in tabular and graphical form. In the next step, a linear transformation is performed, aiming in a relatively simple way to answer the question of whether the obtained distribution function can be described by Weibull law with sufficient confidence. The performed transformation is presented in tabular and graphical form, within a 95% confidence interval.

Based on the obtained results, the following conclusions can be made: (1) The proposed approach provides sufficient reliability of the results, using a simplified mathematical apparatus, which makes it attractive for field reliability research. (2) The obtained graphical results show a certain deviation from expected Weibull straight line, which is due to a failure registered much earlier than the others in the statistical database. This allows this failure to be removed from the dataset. (3) The remaining data distribution is close to Weibull's law, and the resulting form points to the influence of evolving degradation processes. As this is not typical for electronic components, the attention of designers should be focused on the other components of the device.

An extended analysis of reliability test data

T.Papanchev, J. Garipova

This paper discusses the possibilities for detecting and evaluating additional information on the influence of various stressors on electronic devices when data from two-stress factors accelerated tests are collected. Two approaches are considered - standard, with one fixed stress factor, and estimation by severity of impact by solving partial differential equations.

This paper presents a study of the possibilities for extracting additional information and assessing the influence of impact factors, by analyzing data collected from two-factor reliability tests of electronic devices. The main factors influencing the reliability of electronic devices are temperature and electrical stresses. For this reason, when performing accelerated reliability tests, temperature and one selected electrical parameter - voltage, power dissipation or others - are often combined as stress factors. As a result, the tests duration is shortened.

Data from such tests may also be used as a source of information on the specific influence of each of the stressors on the tested elements. This would give designers information on where to focus their main efforts to achieve the set levels of reliability. One of the options for studying the influence of individual stress factors is to consider the results of tests in which one factor does not change. In this case, the Arrhenius equation is usually used to estimate the influence of temperature, and the inverse power law is applied to the electric stress factor.

The approach presented in the report proposes the use of the generalized Eyring equation, in which both stress factors participate simultaneously. If first-order partial differential equations are derived with respect to the two stress factors, their impact on the reliability of the tested electronic products can be investigated.

The proposed approach is applied to the collected data from accelerated tests of multilayer ceramic capacitors, with three levels of applied voltage and two levels of temperature. As a result, the influence of each of the factors on the rate of change of the mean time to failure is presented in graphical form.

The following conclusions can be drawn: (1) The use of the proposed approach can be successfully applied to obtain additional information on the dynamics of changes in the reliability of electronic devices during their operation. (2) Such an analysis gives an idea of which of the factors to pay attention to in specific operating modes and environment of use of the studied electronic products.

[F.7.6.] Marinov A., F. Feradov, T. Papanchev and E. Bekov, *Random forest algorithm in determining the viability of the implementation of synchronous rectification/operation in power electronic converters*, DOI: 10.1109/ICA150593.2020.9311322, 2020 International Conference Automatics and Informatics (ICAI), Proceedings, pp. 1-4, ISBN: 978-172819308-3, Bulgaria, 2020.

Random forest algorithm in determining the viability of the implementation of synchronous rectification/operation in power electronic converters

A. Marinov, F. Feradov, T. Papanchev, E. Bekov

The paper presents the implementation of “Random forest” algorithm applied to decision making, when designing power electronic converters.

An expert system is suggested, that can support the decision making process of electrical engineers when designing power electronic converters. The suggested system can make quick assessments with low computational and memory requirements, making it suitable for web-based CAD tools. The operation of the proposed system is aimed at deciding between synchronous operation/rectification or the application of conventional diode rectifier, when designs are weighted based on their cost and energy efficiencies. In the paper there are described in detail all the steps and prerequisites for training and implementing the envisaged “Random forest” algorithm, and therefore building the expert decision making system.

In order to verify the suggested expert system and evaluate its accuracy all of the described steps above are consolidated in a script and tested for the topology of a buck converter. This converter was chosen due to its relative simplicity and easy evaluation of its efficiency. In order to produce valid designs certain limitations to the proposed algorithm are set and clearly described.

Several accuracy tests were performed. 20 designs were compiled by hand. The designs were chosen to be as close as possible to reality. Topology selection was made based on calculations, simulations and expert engineering decision. Running the compiled designs through the expert system estimates accuracy at 0,95. As an additional verification feature importance was extracted and evaluated. The obtained feature importance is presented in a table.

Based on the obtained results, the following conclusions can be made: (1) The proposed expert system is effective and provides sufficient accuracy. (2) As the expert system is developed in the open source Python scripting language it can be easily integrated in existing CAD software. (3) Some limitations of the expert system can be noted: lack of accountancy for parallel operation and need to develop training sets for each topology. Future work will focus on those limitations and try to account for them.

[Г.7.7.] Malev E., T. Papanchev, *Simulation model development for evaluation of battery parameters*, DOI: 10.1109/ELECTRONICA50406.2020.9305149, XI National Conference with International Participation “Electronica 2020”, Proceedings, pp. 1-4, ISBN: 978-172817531-7, Bulgaria, 2020.

Simulation model development for evaluation of battery parameters

E. Malev, T. Papanchev

This paper presents the development of a microcontroller system and a mathematical model that perform experimental studies of the battery to define basic characteristics and to assess the current state of the battery. The mathematical model is based on a microcontroller system and simulates its behavior. Also, thanks to the model, different types of batteries can be simulated and evaluated, by graphically presenting their discharge current, battery voltage, temperature and other parameters during charge and discharge processes. Based on these data, complex battery parameters such as State of Charge SOC, State of Health SOH and others can be estimated.

The block diagram of the simulation model is presented, as well as the results obtained in the simulation study of models of lithium-ion batteries with different capacities - time diagrams of discharge currents, heating temperatures, terminal voltages, internal resistance of the studied models.

A module for control of the processes of charge/discharge of batteries has been developed. Its purpose is to evaluate the main parameters and characteristics of lithium-ion batteries, such as SOC, SOH, internal resistance, battery temperature during charge and discharge under certain conditions, within two charge/discharge cycles. The instantaneous values of the current through the battery, battery terminals voltage, and battery temperature are measured and recorded. A block diagram of the module is presented, and in the paper there are described in detail the designed circuit and the developed computational algorithm. The results of an experimental study of three lithium-ion batteries are shown. The obtained results are presented in graphical form.

Based on the research, the following conclusions can be formulated: (1) The developed module provides detailed information about the current state of the tested battery for a relatively short time - one to three charge/discharge cycles. (3) The data collected during the research did not allow the reliable assessment of the internal resistance of the batteries, which remains a goal in the further work of the research team.

[Indicator Г.8] Scientific publications indexed in non-indexed journals and proceedings

[Г.8.1.] Papanchev T., *Research and analysis of methodologies for reliability prediction*, Proceedings of papers, Annual Journal of TU-Varna, 2014, ISSN: 1311-896X, pp. 65–70.

Research and analysis of methodologies for reliability prediction

T. Papanchev

This paper presents the results of the study and analysis of the application of basic methodologies used to predict the reliability of electronic products in the initial stage of their construction, when there are no prototypes or samples from mass production. The methodologies selected for testing are: MIL-HDBK-217F, IEC TR 62380, FIDES Guide 2009 and Bellcore / Telcordia SR 332. They cover a vast area of application of electronic products with increased requirements in terms of their reliability, as devices for military purposes, telecommunications, automobile and aviation equipment. The methodologies' specific features are described in order to optimize the process of selecting the appropriate methodology for each specific case.

A summary comparative presentation of the considered methodologies by several indicators is made in a table, and for some of the methodologies a comparison of the used computing apparatus is presented.

To compare the results obtained by different methodologies, calculations of point estimates of the failure rates of several electronic elements on each of them were performed. The obtained results are shown in tabular and graphical form.

Based on the experiments and obtained results, the following conclusions can be formulated: (1) Significant differences were found in the estimates of the failure rates according to the different methodologies. The reason can be sought, on the one hand, in the lack of detailed information on the operating conditions of the elements, and on the other hand, in the differences in the basic concepts of the methodologies and databases they use. (2) The methodologies provide an opportunity for analysis of the reliability of the electronic products even with limited information about the operating conditions. (3) The in-depth knowledge of the methodologies gives an opportunity to choose the most suitable one in solving specific tasks for predicting the reliability of electronic elements and systems.

A review of reliability modeling methods for electronic devices

T. Papanchev

This paper presents an overview of the most common methods for modeling the reliability of electronic devices. A classification in terms of the information used in modeling is done. Problems and limitations of the methods are discussed. Guidelines for further work are outlined for improvement of the credibility of the obtained estimates of reliability indexes and the ultimate usefulness of the conducted reliability modeling.

This paper presents an overview of the methods for reliability modeling in terms of the information available at the time of the assessment. The term "information" is used as a summary for data on failure times, number of failures for a certain time interval, types of failures, data for environmental conditions and operational stresses, etc. A classification from such a point of view is presented, in which the methods are divided into three groups - physical methods (Arrhenius and Eyring equations, etc.), structural methods (reliability block diagrams RBD, fault tree analysis FTA, etc.) and complex methods (Monte Carlo, Bayes). These three groups are considered in detail, their main features and possibilities for application at the design stage are indicated. Problems and limitations of the methods are discussed.

There are two seemingly contradictory requirements in reliability research. On the one hand, in order to achieve the best result in the "incorporation" of sufficient reliability as the main quality characteristic of the devices, the analysis in terms of reliability must begin with the first design stages. On the other hand, in these first stages there are quite incompletely specified parameters related to various aspects of the actual operation of the products. This uncertainty is a prerequisite for obtaining results with unclear accuracy.

Based on the comparative analysis and the results obtained, the following conclusions can be made: (1) The development of new and improvement of existing simulation and analysis modules of modern systems for automated design offers additional data for performing reliability analysis at the design stage. (2) The most serious drawbacks during the reliability analysis of electronic devices are encountered in their early "life" stages - design and preparation for serial production. (3) This is due, on the one hand, to the opposite requirements for increasing the reliability and shortening the terms for putting into operation of electronic products, and on the other hand, to the missing or limited database for registered failures in real operating environment.

[Г.8.3.] Dimitrova E., T. Papanchev, V. Valchev, *Designing magnetic components in ORCAD/PSPICE*, 3rd International scientific congress “Science and education in the future”, Proc. of papers, Vol. II, ISBN 978-954-20-0551-3, pp. 185 – 190, Bulgaria, 2012.

Designing magnetic components in ORCAD/PSPICE

E. Dimitrova, T. Papanchev, V. Valchev

This paper examines the design of magnetic elements in programming environment OrCAD and PSpice by integrated application Magnetic Parts Editor MPE. A design algorithm and particular example are presented and approach to implementation of PSpice model and graphic symbol are discussed. Difficulties in the process have been identified and discussed in order to be minimized and to achieve the optimal results.

The design of magnetic components is a complex process of combining electrical, physical and magnetic properties of different materials, as a result of which pre-set electrical, economic, reliability and safety requirements are met. The use of a software environment for this purpose presupposes in-depth knowledge of it, the calculation procedures used by it, the variety of optional components and materials, the description of their properties, and the possibilities for customization. In this aspect, the selected integrated application Magnetic Part Editor MPE of electronic design automation software environment OrCAD is studied. The properties of the module are described in detail - opportunities and limitations in the process of design and obtaining the final result. The possibilities for expanding the database of materials for transformers are considered. After a thorough acquaintance with the functioning of the application, a design algorithm is constructed, described step by step, emphasizing the possible difficulties and necessary settings. The main formulas used in the design process are also presented.

Using the described algorithm, a pulse transformer for a flyback converter is designed. A simulation PSpice model of the transformer has also been created. The obtained parameters of the designed transformer are presented in a table, and the program code of the simulation model is shown.

The presented methodology is suitable both for use in the learning process and for practical application in the design of specific electronic products, such as power supply modules, converters and others.

[Г.8.4.] Georgiev A., T. Papanchev, *Strictly periodic maintenance strategy for electronic systems*, Journal „ELECTROTECHNICA & ELECTRONICA E+E”, Vol. 48. No 3-4/2013., ISSN 0861-4717, pp. 18 – 23.

Strictly periodic maintenance strategy for electronic systems

A. Georgiev, T. Papanchev

This paper focuses on the composition, quantity and alternation of recovery procedures performed during the operation of various types of electronic systems (ES). The impact of these procedures on operational reliability is studied. The characteristics of maintenance of electronic equipment are analyzed by application of a principally new concept for assessing the rationality of maintenance. Several maintenance strategies are formulated, and the emphasis in the analysis is put on the Strictly Periodic Maintenance Strategy.

A classification of the maintenance strategies for electronic systems has been compiled according to two criteria: (1) According to the way of alternation of the prophylactic and emergency recoveries, the MS can be classified as: Emergency Maintenance Strategy; Block Maintenance Strategy; Strictly Periodic Maintenance Strategy. (2) According to the determining factor in deciding on the type and scope of preventive activities, the MS may be divided into: Maintenance Strategy According to Operating Time, and Maintenance Strategy According to the State.

The Strictly Periodic Maintenance Strategy is presented in detail. A diagram of transitions and optional states is shown, describing the functioning of the strategy, as well as a generalized time diagram showing the alternation of the intervals of continuous work and the intervals of stay. Equations for estimating the mean time (expected value) to stay of the ES in each of the states, equations for estimating the availability and unavailability are derived. A new parameter has been introduced - a coefficient of costs and loss of profit, estimating the downtime losses of the electronic system, taking into account the losses from a non-manufactured end product and the costs of preventive or emergency recovery activities. The data from the implementation in practice of the Strictly Periodic Maintenance Strategy are analyzed.

In conclusion, it can be reasonably claimed that Strictly Periodic Maintenance Strategy shows a number of advantages over other strategies such as Emergency Maintenance Strategy and Block Maintenance Strategy. It was found that the significant increase in the mean time between failures is mainly due to fewer post-maintenance failures in the studied electronic systems.

[Г.8.5.] Nikolov N., A. Georgiev and T. Papanchev, *Indices for Reliability Assessment of a Star Structured Complex Electronic System*, 51st International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST 2016, Proceedings of papers pp. 321-324, ISBN 9989-786-78-X , Macedonia 2016.

Indices for Reliability Assessment of a Star Structured Complex Electronic System

N. Nikolov, A. Georgiev, T. Papanchev

This paper concerns reliability assessment of a star structured complex electronic system (CES). The common approaches to reliability indices selection and reliability requirements determination are presented. Some specific reliability indices and basic dependences valid for reliability assessment of a star structured electronic system are presented and described.

For to declare reliability requirements technical objects at three different levels have to be distinguished. These are systems, subsystems and components. Determination of reliability requirements to a CES can be achieved, following three approaches. It might be based on: (1) Expert advice, design engineer experience and practice; (2) Prototype analysis, or statistical data for a CES similar as purpose, structure and/or component base to the current one; (3) Reliability level which is optimal for the current system. The process of assessing the reliability of two types of star structured CES is considered in detail - a star structured CES as a monotonous structure, and a star structured CES as a system with an additive factor of effectiveness.

A complex electronic system, which is built up in line with a centralized star topology is considered. The system structure also can be described as „a star within a star,“ which is typical for most of the SCADA systems. Mathematical equations concerning the effectiveness of operation of this type of structures are derived. The equations give the opportunity to determine the system effectiveness by the specific failure rate and also by the individual contribution factor of each system element. The latter depends not only by the element function but also by the characteristics of the object served.

Based on the obtained results the following conclusions can be made: (1) The main problem in reliability assessment of a star structured CES appears to be the evaluation of the contribution of each peripheral element to the entire system effectiveness. These might be estimated upon an expert advice for each specific CES application. (2) The reliability indices can be evaluated using data obtained by testing of prototypes, or might be estimated upon data for similar or identical elements at disposal.(3) It is also possible for this purpose to be used data obtained during operation of the same or similar elements for long enough time.

[F.8.6.] Papanchev T., A. Georgiev and N. Nikolov, Problems in assessing the reliability of electronic components and systems by reliability testing, 51st International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST 2016, Proceedings of papers pp. 317-320, ISBN 9989-786-78-X, Macedonia, 2016.

Problems in assessing the reliability of electronic components and systems by reliability testing

T. Papanchev, A. Georgiev, N. Nikolov

The paper presents a study of some aspects of the procedures for reliability assessing of electronic devices on the basis of information obtained from reliability tests. Attention is paid to some of the observed problems in the implementation of such tests. Some ideas for corrections in planning and conducting the tests and the analysis of the obtained results are presented, the views of the authors for future work in this direction are outlined.

A classification of reliability tests is presented, prepared under the criterion "conditions of the tests." Accordingly, tests can be divided into two groups: (1) Environmental tests, which are held in conditions similar or identical to the most common in the real working conditions; they could be performed within normal operating conditions, but close to the border values of the main factors determining normal working conditions; (2) Accelerated tests, which are held in conditions beyond the specified normal operating conditions. The paper focuses on test planning and some specific forms of tests such as: electrothermal training or Burn-In; environmental tests used to demonstrate the compliance of the actual assessments of reliability parameters of the devices with the specified once, regarding the requirements, reliability demonstration tests RDT; highly accelerated reliability tests HALT; highly accelerated stress screening (HASS); accelerated aging tests (ADT) and others.

Existing problems and conflicts have been formulated in ensuring "sufficient" reliability at different stages of the device's life cycle.

In conclusion, the following problems related to the application of reliability tests are described: (1) There is no developed procedure for reliability assessing of devices after Burn-In tests; (2) There is a necessity to be evaluated the effectiveness of the tests performed, the cost / benefit ratio; (3) There were reported, during tracing of conducting the accelerated tests, difficulties in establishing a set of indicators defining the right moment for termination, replacement or continuation of a particular test. It is obtained a divergence of the chosen indicators goodness-of-fit r^2 and error function E_j , therefore it is necessary work to identify additional markers for decision making.

[Г.8.7.] Georgiev Ts., A. Georgiev, N. Nikolov and T. Papanchev, *New opportunities for accelerated extraction of reliable and accurate information for the purpose of medical-diagnostic research*, Scientific forum „Innovation and Business”, Proceedings, pp. 86-91, ISBN: 978-954-20-0768-5, TU-Varna, 2016.

New opportunities for accelerated extraction of reliable and accurate information for the purpose of medical-diagnostic research

Ts. Georgiev, A. Georgiev, N. Nikolov, T. Papanchev

In this article are discussed new opportunities offered from Empirical Bayesian methods to be possible obtaining the correct suitable medical-diagnostic information, for short time. The correct application of these methods can increase the reliability of data and reduce time to achieve the end result of medical research. The proposed Bayesian procedures are suitable for use in the ongoing monitoring and evaluation of the operational reliability of electronic systems on the basis of data from their maintenance or performed reliability tests.

Empirical Bayesian methods can be classified into two large groups: (1) parametric, which are appropriate when the parametric distributions of the a priori data are known; (2) nonparametric methods which are used if a reliable assumption can be made that the distributions of the available data belong to a larger or smaller non-parametric distribution class.

The group of parametric methods suitable for merging information from medical research can be divided into two subgroups: (1) Methods which are based on an empirical approximation of the Bayesian decision rule, without approximating the a priori distribution; (2) Methods which are based on the empirical approximation of the a priori distribution followed by a reference to the standard Bayesian procedure. The two parametric methods are considered in detail, and expressions for the a posteriori mean $E(\theta|x)$ of the estimated parameter θ are derived.

As a result of the performed analysis the following conclusions can be made: (1) The Bayesian procedures are particularly relevant for practical application, because after a certain increase of data (observations) quantity the empirical Bayesian estimate begins to be unaffected by the type and parameters of the a priori distribution; (2) In the absence or insufficient amount of actual data in a particular study, a priori distribution supports analysis of available data (previous and following) and accelerates decision-making, without impairing the confidence and accuracy of the results.

[F.8.8.] Nikolov N., A. Georgiev, T. Papanchev, D. Zlatev and T. Georgiev, *Reliability assessment of sensor networks*, Scientific forum „Innovation and Business”, Proceedings, pp. 92-96, ISBN: 978-954-20-0768-5, TU-Varna, 2016.

Reliability assessment of sensor networks

N. Nikolov, A. Georgiev, T. Papanchev, D. Zlatev, T. Georgiev

This paper concerns the reliability assessment of sensors networks (SN), shaped in line with hierarchic structures. Proper reliability indices for this purpose are suggested and mathematically expressed. An approach to reliability assessment of sensor networks is also suggested and applied to two case studies concerning medical purpose implementation and thus the approach is illustrated and clarified. Results are presented by graphs derived trough the case studies analysis.

This work concerns a large class of SNs which are shaped as hierarchical, non-symmetrical (with different number of branches at each hierarchical level) electronic systems. Their structure is derived from bus, tree or star network structures. In reliability perspective such systems are defined as Complex Electronic Systems (CES).

For reliability indices of a CES to be estimated it is necessary the typical reliability indices for system elements, such as their availability, to be known.

The approach to reliability assessment of a CES suggested includes: (1) composition of system reliability mathematical model; (2) substitution of reliability indices denotations in the model by real numerical values, valid for the same, or similar to system elements electronic devices, obtained by separately performed reliability tests of such; (3) calculation of the system effectiveness estimated value. For this purpose, the components of the system are evaluated with "contribution index" to the effectiveness of the system. The total contribution of the system structure to its effectiveness is also evaluated.

The described approach is applied in the analysis of a sensor network with three hierarchical levels, the lowest (second) level being the level of the sensors, followed by the middle (first) level of controllers and the highest (zero) level of the central control unit. The dependences of the system effectiveness on factors such as the number of operating branches in the first level, the number of operating sensors (second level), are shown in graphical and tabular form.

Based on the obtained results, the following conclusions can be made: (1) The contribution of each particular sensor must be precisely assessed for reliable estimated value of system effectiveness to be obtained. The exact values of sensors contribution indices must be set by the experts representing the system user, i.e. medical experts in the cases analyzed. (2) The total system contribution is growing faster than the system effectiveness with the system development/enlargement. (3) The system effectiveness decreases slower than the total system contribution with the system deterioration caused by the system elements failures occurred.

[Г.8.9.] Georgiev A., N. Nikolov and T. Papanchev, *A method for mathematical optimization of the terms for prophylaxes of complex technical systems in accordance with the level of their reliability required*, Journal of Computer Science and Communication, Vol. 5, Issue 1, 2016, pp. 19-27, ISSN: 1314-7846.

A method for mathematical optimization of the terms for prophylaxes of complex technical systems in accordance with the level of their reliability required

A. Georgiev, N. Nikolov, T. Papanchev

The paper proposes a new method for optimizing the terms of prophylaxes of complex technical systems in accordance with the level of reliability that they have to perform. To present the new ideas, mathematical dependences are derived, convenient for practical application. They are used in the implementation of experimental studies, the results of which are presented in the last section of the paper.

The requirements regarding the reliability of technical systems are most often formalized by normalizing the reliability function - a requirement is set that during operation their probability of flawless operation is not less than a certain predefined value $P(t)_{\text{def}}$. The main idea of the developed method is that given the specific value of $P(t)_{\text{def}}$ and the calculated statistical point estimate of the parameter of the flow of failures $\omega(t)^*$, for the specific technical system and under the specific conditions of environment and operation modes, the optimal value of the term of prophylaxes can be determined. It is accepted that preventive activities lead to complete recovery of the system. The terms for prophylaxis are shown in direct dependence on the parameter of the flow of failures of the concrete technical system, for the concrete period of time preceding the prophylactic service, under the concrete working conditions and modes of operation. Mathematical dependencies have been compiled, according to which the terms for prophylaxes of electronic systems could be calculated.

As a result of the performed researches it can be confirmed that using the derived equations, the statistical point estimates of the time for emergency recovery T_R^* and of the parameter of the flow of failures $\omega(t)^*$, the values of the terms for prophylaxis of both the technical systems and their peripheral devices can be easily optimized, with a set (desired) value of the probability of flawless operation.

[F.8.10.] Malev E., T. Papanchev, *Design and analysis of process monitoring unit for reverse osmosis system*, Proceedings of the Union of Scientists – Varna, Technical Sciences series, Issue 1' 2020, pp. 7-10, ISSN 1310-5833.

Design and analysis of process monitoring unit for reverse osmosis system

E. Malev, T. Papanchev

The paper presents an overview of a low-cost intelligent system for monitoring the processes in a Reverse Osmosis (RO) System. The monitoring system collects and analyzes the number of parameters that are measured in a RO – power plant in order to monitor and/or evaluate its characteristics in the production of this new type of renewable energy. The main purpose of designing such a system is to determine the main parameters on which the productivity of the water turbine depends and to determine the relationships between water salinity, pressure, on the one hand, and electricity produced, on the other.

The paper describes the basic principles of the process of conversion of osmotic energy into electrical energy, by two main methods - pressure-retarded osmosis and reverse electrodialysis. Simplified diagrams of a reverse osmosis power plant and some basic units in it - the water turbine and the reverse osmosis module are shown. The mathematical description of the processes in the reverse osmosis membrane is presented.

A monitoring system has been constructed, which involves the collection of data from actuators and sensors and its transformation into graphical information, giving information about the processes that develop in the system. A block diagram of the system is shown together with an example algorithm of its functioning. The main sensors for collecting information are pointed out and expressions for the development of mathematical models for simulation experiments are derived. A model of a monitoring system has been developed, consisting of: (1) three water pressure sensors; (2) two salinity sensors realized by pH sensors; (3) water turbine; (4) an unit for simulating the change of water pressure.

As a result of the performed simulation researches the following conclusions can be made: (1) Developed in MATLAB Simulink environment, the model for monitoring the processes in a reverse osmosis system fulfills the set requirements for measuring water pressure and salinity, and monitoring the condition of the water turbine. (2) The constructed model of a low-cost monitoring system provides a basis for future work on improving the system, more in-depth analysis and creating a physical model.

[F.8.11.] Georgiev A., T. Papanchev, G. Hristova, *Investigation the reliability of electronic devices*, Annual Journal of TU-Varna – 2012, Vol.II, Proceedings of abstracts, pp. 63-64, ISSN: 1311-896X.

Investigation the reliability of electronic devices

A. Georgiev, T. Papanchev, G. Hristova

The research objectives of this project are aimed at: increasing the reliability of electronic products through early detection of unreliable elements; analyzing the influence of the various parameters and factors of the accelerated tests on the reliability evaluation of the tested products; optimization of accelerated tests; study the applicability of image recognition methods in compiling appropriate algorithms for classification by appropriate reliability parameters.

Methods and tools from the following scientific areas were used to perform the tasks: mathematical statistics, probability theory, theoretical reliability and applied reliability foundations, image recognition methods, accelerated tests to determine the reliability parameters of electronic elements and devices (Accelerated Life Tests), cluster analysis and others.

An algorithm for reliability classification using cluster analysis and image recognition methods has been developed and presented. The algorithm offers the possibility for "intuitive" classification by the values of a set of reliability parameters of the device, and positioning it unambiguously in the multidimensional space of the measured features. The algorithm allows for accurate reliability analysis in cases of limited or missing preliminary statistics on the reliability characteristics of the studied devices.

Research and analysis of the reliability of basic electronic components during their operation under different electrical stresses and environmental conditions have been performed. Accelerated reliability tests were performed with a thermobaric chamber, designed on the idea of the research team.

Significant parameters for the elements and their behaviour were monitored during the test period. An assessment of the reliability of the tested products was performed.

A procedure is proposed for assessing the informativeness of the individual tests with regard to the early classification of the tested products by reliability. The tests performed on multilayer ceramic capacitors provided detailed information on their behaviour in various environmental conditions and electrical stresses, which can be used to predict their reliability in normal or aggravated working conditions.

[Г.8.12.] Georgiev A., T. Papanchev, N. Nikolov, D. Zlatev, *Research into reliability of a network structured electronic system*, Annual Journal of TU-Varna – 2016, Vol.II, Proceedings of abstracts, pp. 77-78, ISSN: 1311-896X.

Research into reliability of a network structured electronic system

A. Georgiev, T. Papanchev, N. Nikolov, D. Zlatev

The research objectives of this project are focused on the research, analysis and solving problems concerning the reliability of network structured electronic systems. The work performed is on relevant reliability assessment criteria selection regarding a network structured electronic system, during their design, composition and operation, as well as on reliability assessment approach suggestion in regard to their structural and operational reliability assessment. On this basis options for obtaining precise estimates of network structured electronic system reliability indices valid for the systems structured by analogy with the tested one are examined.

To fulfill the research objectives, methods for analysis of the structural reliability of complex systems are applied, such as method of modeling Fault Tree Analysis FTA and Reliability Block Diagram RBD. Methods based on probability theory and mathematical statistics, as well as methods for predicting the technical condition and reliability of the system and its elements have been applied to evaluate the reliability parameters.

A mathematical model of the reliability of an electronic system with a hierarchical centralized network structure is derived. An effective approach for analysis, prediction and assessment of structural reliability, valid for industrial electronic systems with such a structure, is proposed. An approach for selection of the most appropriate parameter, characterizing the reliability of systems similar in structure and composition, is presented. Basic considerations in setting requirements regarding the degree of reliability of an electronic system are systematized.

An electronic system with a network structure has been designed and implemented. As a result of conducted experiments and simulation modeling, the main dependences determining the effectiveness of the studied system are obtained in graphical form, as the main parameter characterizing the reliability of the system. The change of the effectiveness of an electronic system of the studied type during its real operation is presented in graphical form. Equations for the effectiveness of an electronic system with a hierarchical centralized network structure, applicable in practice, are derived. Basic rules are suggested, compliance with which ensures high operational reliability of electronic systems.