SZENT ISTVÁN UNIVERSITY

QUALITY ASSURANCE OF INTELLIGENT MEASURING AND CONTROL SYSTEMS WITH SPECIAL REGARD TO THE HIGH SAFETY REQUIREMENTS

Theses of Doctoral Dissertation

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1 INTRODUCTION

Intelligence is considered by the public opinion as an exclusive feature of human beings. Whatever modern and complex features the artificial systems – created by humans – have, these are not able to show emotional life and much less could use the emotional factors during their operation by modifying their results significantly. However, these intelligence elements shall not necessarily be transferred to the intelligent machines and their anticipated functions. Namely, it might be satisfactory to provide the machine intelligence with learning and adaptive abilities as well as with the elements of combination decision making, selective and expedient data collection (recognition) and basic associative self-development. Although these features are common for the human race, they are – however – not identical at each individual (e.g. many times the individual attributes of human intelligence grow worse because of doubtfulness, incapability of decision, lack of adaptability and absence of striving for perfection in learning and/or gathering information as well as occasional lack of physical or other abilities and/or efficiency, or simply owing to inattention, excessive engagements, weariness etc.). In these cases the machine – which carries out the control of system and can not be emotionally influenced, and disturbed psychically or by the circumstances – is able to make the required decisions and supervise the person who accidentally makes a mistake as well as is capable to replace the intelligent human being (to a limited extent, however, in some cases it is absolutely important). In this meaning, these devices are intelligent. I am going to use in the present dissertation this limited definition for the intelligence of machines.

The technical development of our age can be described not only by the increasing number and the improvement of functions of technical devices but also by the safety solutions working in the background and having a very important share. We have to mention here not only the different electronic solutions but also the mechanical, logical, software or other applied techniques. In addition, the life-test linked up closely with the failure test of the produced equipment and the incidental statistical methods shall be included in this group as well.

Special professional knowledge is required for the monitoring, supervision and improvement of the computer-aided and processor controls, programmed automatism and safety functions applied in the modern technology. The benefits of technologies are to the advantage of modern people only if their hazards are not significant or can be eliminated by steady inspection. The design of modern devices is unrealizable without the adequate evaluation of safety and lifetime because its necessity is justified by the safety and accident prevention requirements as well as by weighty economical aspects.

Thanks to the development of technology of the last few decades (first of all in the field of electronics and software) more and more devices/equipment (engineering appliances) have been marketed the users of which do not suspect or are simply unable to examine or consider their hidden potential risks.

The importance of this problem is justified by the fact that the complex inspection and qualification (indicated by the CE symbol) of the marketed devices and equipment have been made obligatory in the EU from 1998. Of course the inspection requirements considerably depend on the purpose of application. This system has been established – with the aim of minimize the possible risks – relying on the steady professional analysis of products of high complexity and technical level or products operating under potential risks during its everyday use.

In my dissertation I am going to show the structure and results of the widely applied and high-safety intelligent system developed by me. On the basis of the available observations I am going to introduce and implement a testing method that expressly contributes to the operation of machine intelligence and to the steadiness of complex control, associative forecasting and balanced operating conditions. By following the adaptive nature of devices (ageing processes, environmental effects, „learning" algorithms and processes) my method allows the visualisation of maintenance demands prior to the symptoms of failure. At the same time, the monitoring of balanced development and harmonic operation might be achieved. Special feature of this approach is that it does not set the target of adding up, assembling, evaluating, considering of individual and independent pieces of information then carrying out the decision-making process on the given ensemble, but its aim is to make strategic and forecasting decisions by using collective information obtained on the basis of the interactive features of complex systems. Accordingly, not the search for the linearly independent bases is important in terms of description, but the relationships and their dynamical determinacy will serve as a basis of decision information.

2 OBJECTIVES

The objective of my dissertation is to develop the quality control of complex systems produced at the production of machines and instruments as well as the dynamic discussion of the quality control of intelligent controls/regulators regarding their safe operation. For this, I am going to implement processor circuits that fulfil the „single fault condition"[1] of the high-safety intelligent systems and can be universally applied for the implementation of control and regulating tasks in the field of agricultural, fine-industrial machines and precision engineering (e.g. veterinary and medical equipment, biological controls, monitoring and inspections systems). My intention is to supply a measurable and continually controllable set of parameters that will be able to follow the actual state of equipment and its operation safety with a high reliability, and to predict the maintenance/service demand prior to the actual breakdown by helping the user to make the strategic decisions. By this, we are able to achieve a significant reduction in risks, not to mention the economical and conditional system advantages.

Fundamentally, I am going to utilize the fact that the intelligence and the inherent decisions are assigned to collective data sets and can not be connected to local decisions since the decision making can be considered as intelligent if it is associative and takes the relationships into consideration. Generally, the machines assist in the tactical (actual) decisions of humans without the signs of intellect since they support the functioning by the control of operation and by the correction and supervision of the inaccurate and risky human decisions (e.g. safety devices in cars). In the present dissertation I am going to propound a strategic decision-making mechanism that is able to make strategic predictions – „prophecies" – on the set of the actual pieces of information.

I think that by applying the results presented in my dissertation, high-safety automatic system controls can be implemented that is able to carry out a realistic estimation of the occurring problems arising in the future, and helps in the significant improve of the quality of intelligent computer-aided systems and its maintenance, as well as, will be able to provide high-quality and predictable conditions with a higher efficiency compared to the methods known up to the present.

1 Single Fault Condition (SFC). If the equipment has this single failure or a negativ change of a single condition assumed for the safety operation then this will not result in a safety risk. (MSZ EN 60601-1:1997)

3 MATERIAL AND METHOD

„Anything that can go wrong, will go wrong!" This "eternal Murphy's law" has become a common knowledge. Anyway, the truth of this fact demands a suitable system of safety and – in general – the assurance of quality. Therefore, each device has to be monitored and repaired which is a technical and commercial requisite for every device and equipment. This is especially important at the high-complexity and combined systems because of the following reasons:

- the number of potential failures increases,
- the time and cost demand is very high,
- the cost of breakdown is high (actual and moral),
- the cost of failure prevention and regular inspection is high,
- system failures can occur because of the frequent replacement of parts,
- the required follow-up of development can cause further coordination problems,
- steady monitoring of many sensors is necessary for the safe operation.

The most important requirements of high-reliability:

1. Redundancy conditions. This serves for the temporary or permanent substitution of the equipment's faulty part or for the prevention of fatal failures. (E.g. SFC in medical devices, auxiliary cable or brake at lifts etc.)

2. Functionality conditions:

    The equipment works consistently.

    The operation of equipment is always monitored.

3. Service/maintenance conditions:

    The servicing conditions of the equipment are specified.

    The breakdown can be prevented by maintenance.

In my thesis the operation is continuous. I am going to focus on the steady monitoring and the options of preventive maintenance. I am going to discuss in detail the basic principles applied for the mathematical evaluation of failure and the relevant statistical methods.

Classical statistical methods are the hypothesis tests. This means that the truth of a pre-defined hypothesis is verified or refused by a large number of tests. However, this method can not be used for complicated intelligent systems or a huge number of test materials should be applied for the presentation of each probable case, which is impossible for the considerable part of cases since we shall take individual, not numerous devices and a very wide-range of applications as well as almost unpredictable variation possibilities into account when examining the operation of the equipment. Also the software control itself does not make this type of classical hypothesis test possible. In order to achieve a suitable evaluation, the system is divided into well-treatable subsystems and the failure statistics is carried out for each of them separately. Therefore, if the individual inspection of each subsystem is available then the maintenance schedule can be made by using the statistical evaluation of subsystems. At the same time, this method does not take the failure probability of the complex system into consideration since it concludes to the whole system from the failure statistics of the subunits only.

For this, we need a method. It has been recognized that the pre-defined test functions (test distributions, hypotheses) mislead us many times because of the constraint paths (bias) that should be avoided for the sake of objectivity and suitable fidelity. Therefore, a new theory named as „Bayesian statistics" has been introduced into the science. This new statistical paradigm has been elaborated by Bayes who described the connection between the antecedents (apriori) and the consequences (aposteriori) by using conditional probabilities in such a way that the initial apriori distribution gets irrelevant on the ensemble of events applied in a recursive way and arranged into chain. This requires the existence of conditional distributions instead of direct distributions, the specification of which is often very complicated. The chosen method is based on this paradigm (it is getting more popular) and the method of recursive self-organization.

Self-organization occurs through the mutual determinacy and complex operation of partial systems requiring the operation of each other inevitably and specifying the dynamics of one another casually. The modern multi-functional and computer-controlled sophisticated engineering and actuating devices, the versatile complex systems working in relationship with their environment are in general not in the steady state and have a high-level hierarchic structure. The subsystems forming this structure are connected to each other in different ways through their physical and chemical processes or other information network. The amplitude, characteristic time or other features of physical, chemical and information signals generated by the single subsystems can vary in a wide range. E.g. also the simplest biological systems manifest all kinds of processes on the individual time scales connected to each other by scaling.

In the case of open, dissipative systems (basically, every event with non-spontaneous changes, e.g. heat engines, biological systems, electromagnetic radiators etc.), the reduction of noise is impossible by fixing the interactions because the open, dissipative characteristic assumes a definite interaction with the environment. Consequently, at the real and irreversible dynamical systems we have to reckon with noise (fluctuation) in any case, and – at the most – we might use dynamical methods that suppress the noise and as far as possible enhance the „useful" signal. However, we shall observe that the noises include the whole dynamics and practically contain – by embracing the whole system – every dynamical variable the interactions of which participate in the production of the given (required/useful) signal. This allows the complete monitoring of the system and the analysis of the system operation from the actual noise spectrum. Each failure resulting from wearing, tearing and fatigue (in general through stochastical changes) will cause the continuous change of noise spectrum. The continuous measurement and trend evaluation of noise spectrum allows the prediction of wearing (fatigue etc.) processes.

In the event of a complex system we get the *1/f* type (pink noise) noise-performance density function. In this case the correlation lengths extend to the system, namely, the subdynamical event participates in every dynamical operation of the system. („A drop in the ocean" principle.) On the basis of this, the changes in the system operation can be followed, and by applying a suitable automation and software monitoring the incidental failures can be predicted and the maintenance demand can be defined.

Accordingly, the test is suitable for the continuous follow-up of the system's normal ageing properties (progress of time). The system-dependent noise of normal operation gives account about the specific ageing processes. On the basis of a suitable evaluation, the failures resulting from the ageing of system can be predicted and reckoned with at the preventive maintenance.

Let us take a trouble-free machine at which the expected and faultless function can be observed in its periodicity. The majority of the mechanical and machine engineering solutions can be characterized by rotation. (The artificial dynamical solution differs also in this property from the processes generated by the natural biological development since the rotation motion, the recurrent full turn and mechanical rotations do not occur in neither of the living materials as a base of the system dynamics. This is self-similar and has a uniform behaviour in every scale. Of course, the equipment shows steady and dynamical interaction both with its own internal parts and its environment. If these interactions do not change the operation significantly then they are imposed on the measurable periodicity only as a noise. The Fourier transform of the equipment's time behaviour will include only one characteristic frequency that is imposed on the measured periodic signal as an uncorrelated noise (white noise, without frequency-dependence). Apparently, each turn is independent from the previous one and the consecutive turns do not seem to influence each other. At the same time, if the equipment is wearing (the interaction of turns changes) then the succeeding turns will be carried out under the conditions defined by the previous turn, that is, a „superimposing" will occur, and we get newer and newer results because of the continuous superposition. If the changes „left behind" by the turns are not significant, namely, the whole system is reversible and does not age then there is not any measurable change regarding the frequencies. At the same time, if the aging makes the system non-reversible then each turn is carried out in different circumstances and the frequency spectrum changes. On the other hand, the characteristic frequency remains the same but other frequency components can be observed as well. If the processes modify the speed in a superimposing, recursive way then the frequency change will be no more an uncorrelated white noise, but it appears regularly in the power spectrum density with a decrease towards the higher frequencies by favouring the lower frequencies. Therefore, the recursive information will be measurable, the ageing process can be inspected for the whole system and the dynamics of the process can be estimated. This is apparently the monitoring of the recursively applied Bayes chain where the successive superimposing of the apriori and aposteriori conditions serves as a basis for the operation of equipment. As we have shown earlier, the actual function of the initial probability distribution becomes insignificant after sufficient number of steps.

4 CONTRIBUTIONS

4.1 Test results

The development results of the high-safety intelligent systems can be divided into three areas:

1. A versatile, safe and intelligent control system has been developed that is applicable also at medical devices. The system is certified also by a reputable testing institute and able to control the equipment safely as well as fulfils the single fault condition. The whole project has been managed by me and the software for the system control has been developed by me alone. The production of multiprocessor hardware required for the software control has been planned and managed by me. This system forms an indispensable and essential part of the commercially available medical equipment. The whole control system – under steady inspection of a German testing institute – keeps pace with the most up-to-date electronic and technical solutions as well as with the changes and latest results of medical practice. The software provides for the safe operation of microprocessor functions by controlling the equipment under the SFC principle.
2. The user interface of software has been built on the usual windows environment, however, a DOS-based operating system has been developed to prevent the errors and occasional software viruses as well as to fulfil the single fault condition. This system does not require the exit and entry waiting that is usual at the Microsoft systems, and there are no system crashes if the machine shuts down or breaks down unexpectedly. At the same time, I used the windows environments of Microsoft in the interest of facilitating the work of users because in this way they can handle the program in a well-known environment.
3. A special test has been developed by means of which the high-safety intelligent (complex) systems can be continuously controlled in their whole complexity, their maintenance can be planned and their operation can be kept in a secure range. This product is based on the fluctuation test of complex systems and its application has been developed to a level of international patent.

   The invention conception is based on the recognition that the noise/fluctuation contains the whole dynamics and – basically – all those dynamical variables the interactions of which influence the generation of the given (required/useful) signal. The noise/fluctuation spectrum gives account of the correlations within the system as well. This allows the complete monitoring of the system and the analysis of system operation from the noise spectrum. Each failure resulting from wearing, tearing and fatigue processes (in general through stochastical changes) will cause the continuous change of noise spectrum. The events of the subsequent moment superimpose on the regular deviations resulting from the incidental wearing or incompatibility occurring in each point of time. Namely, the deviation existing in each moment is imposed on the previous deviation; consequently, it can be derivable in a recursive manner (Markov chain). This recursiveness gives the regular changes of fluctuations therefore this will be the universal characteristic of the system. If the system characteristics depend only on the previous moment in each point of time then the fluctuation behaviour of the system can be generally described by the properties of the Brownian motion and by the Brownian noise. However, if the complexity of the system specifies long correlations within the system then the noise – as a system characteristic – is similar to other coloured noise, in ideal cases, to the pink noises that can be described by the 1/f behaviour. Therefore, the assumption of noise spectrum makes the prediction of wearing (fatigue etc.) processes possible. The size of time-interval – that can be considered as the „unit" of recursive process – is specified by the characteristic frequencies of the given system. It is practical – but not imperative – to assume a base frequency that can be compared with the characteristic frequencies included in the given analysis.

I have proved in practice that my results on the self-organising fluctuations are correct. In my dissertation I have tested and measured the following three devices:

1. The first one is a complex cancer treatment device. The software security and control of this device has been developed by me as outlined above.
2. The second one is a processor controlled Peltier liquid-cooler. The software of this has been made also by me as outlined above. The third device is one of the subunits of the cancer treatment device.
3. By using the obtained data I have made the evaluation of the ageing process of an installed wind turbine.

4.1.1 Test results of the medical treatment device

Two different loads were tested and measured: the first one is a dummy load without imaginary part in the impedance which means that the load is a pure ohmic load, while in the second case the load is the patient itself where the impedance can be expressed only by complex number (significant capacity members, cell membrane, dielectric changes in the tissue, conductor, the dielectric material is far away from the ideal etc.), namely, the load is not ideal and not pure ohmic. One example for the results is set forth in Figure 1.

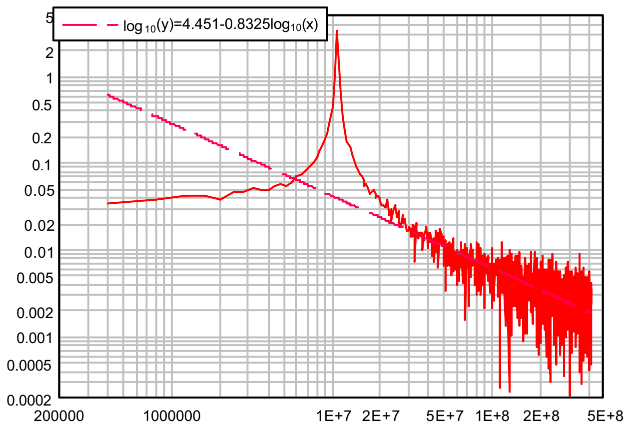

Figure 1: One measured result of the RF amplifier

The measurements carried out by applying 10 MHz scanning under different circumstances are set forth in Figure 2. In each case the average of five independent measurements is calculated for the exact measurement of the invariant quantity.

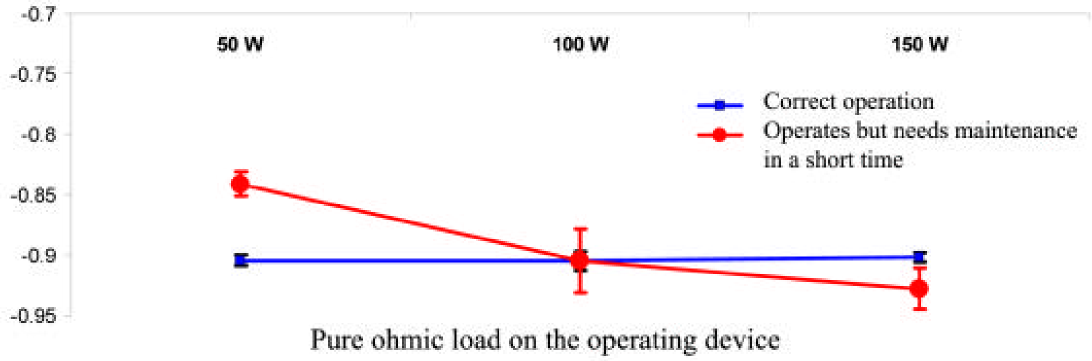

Figure 2/a: Influence of operating conditions on the invariant parameter of RF amplifier (the values are given for 50 W, 100 W, 150 W output power in the case pure ohmic load).

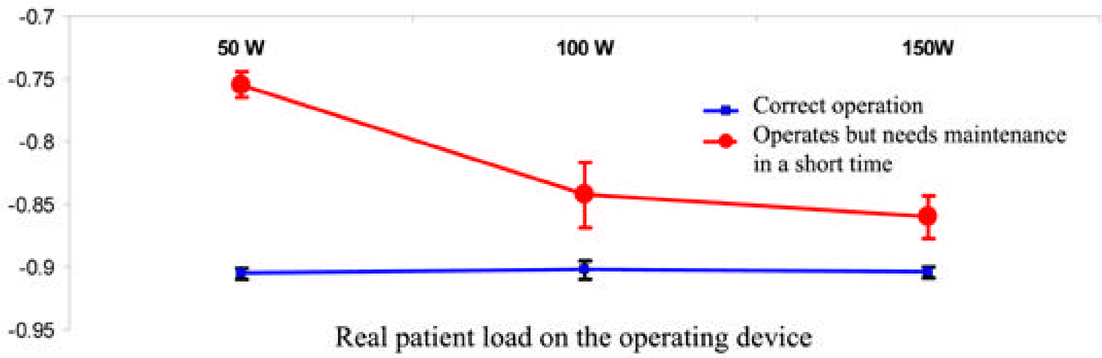

Figure 2/b: Influence of operating conditions on the invariant parameter of RF amplifier (the values are given for 50 W, 100 W, 150 W output power in the case complex load).

As it clearly appears from the result, the invariant quantity of the optimally working device is the same in practice under any circumstances independently from the fact that the measurement was carried out by using dummy loads or real impedance. However, in the event of non-optimal operation (requires maintenance) the invariant quantity changes significantly depending on the circumstances in both loading cases. At the same time we might observe that the pure ohmic load does not give such a difference as the complex impedance that expressly deteriorates the value of gradient for each output power.

4.1.2 Result of the liquid-cooler's test

The summary of measurements carried out in different conditions is set forth in Figure 3. The „Reference" shows the faultlessly operating system. The „Bad ventilation" and the „Low water flow" show the arising of identical and not serious faults, while at the „Low Peltier efficiency" we might see a more serious fault that is however does not deteriorate severely the system operation. The mixed faults are shown in the measurement results of the last two points. Every point is the reproduction of at least five measurements. The measuring error can be seen on the figure.

Measured gradient values

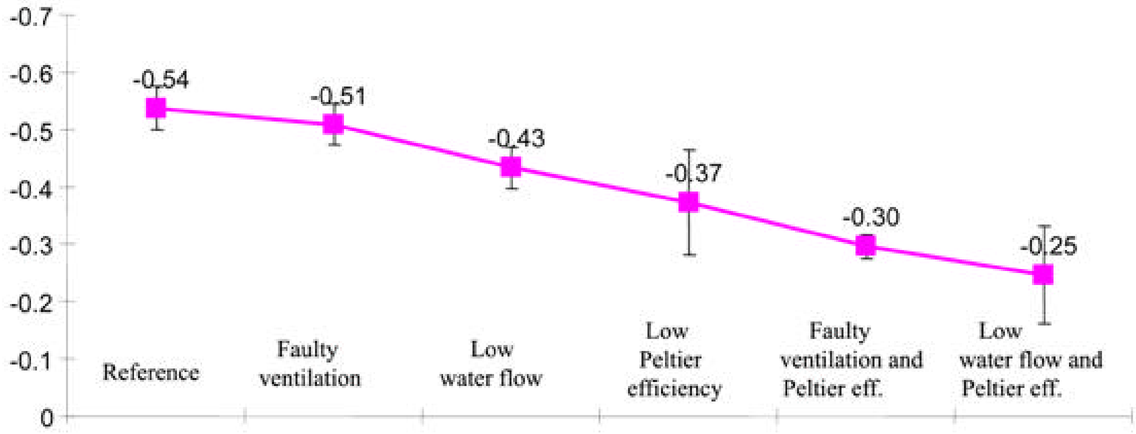

Figure 3: Measured results of the cooler's different operation states. The gradient is given from the matched invariant.

4.1.3 Test results of the wind turbine

I was given for processing [2] the test run data of a wind turbine. These include the test data of a half-year operation measured in every ten minutes. In the data set the data series of wind turbine and environmental effects in more than 32 thousand points are registered In my analysis I tested the fluctuations of the electric output power. I grouped the data by $2048 = 2^{11}$ points then made their Fourier analysis. For this, I have used the software developed by me.

By representing the obtained results, the trend of data shows well the ageing process of the wind turbine. The absolute value of gradient has a declining tendency from the initial value of 0.9 (Figure 4), and also the quality factor (second power of the matching's Pearson dispersion) decreases steadily (Figure 5).

By gaining enough experience we might create a calibration curve that is suitable for the definite indication of the expectable faults and also the maintenance demand. It follows from the actual data that this is under the limit value of -0.65 (since we got this measurement point from the fluctuations) that is better than a maintenance demand of about 9 months. The actual demand is most likely at the -0.5 limit, namely, after 35 time units, which means that the wind turbines shall be preventively serviced by one and half years approximately (this statement is made without reference measurements).

[2] Many thanks to professor Dr. László Tóth who gave me the data and explained the „secrets" of wind turbines.

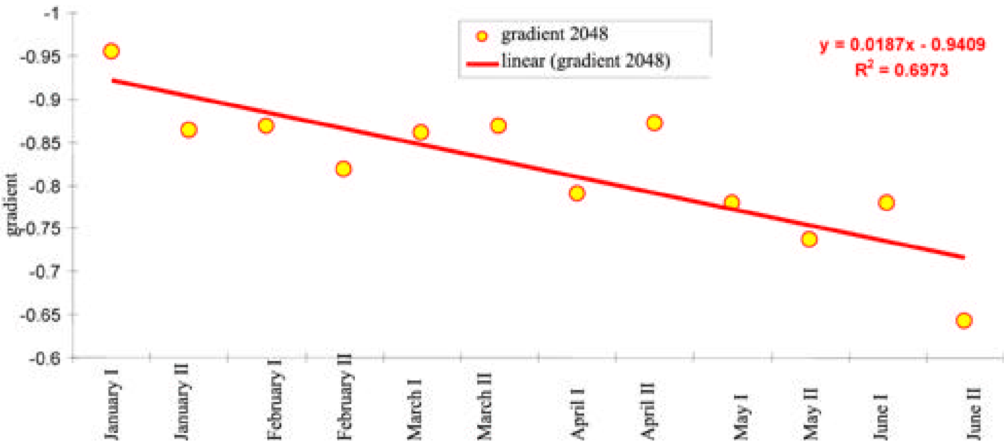

Figure 4: Trend of the invariable quantity of wind turbine

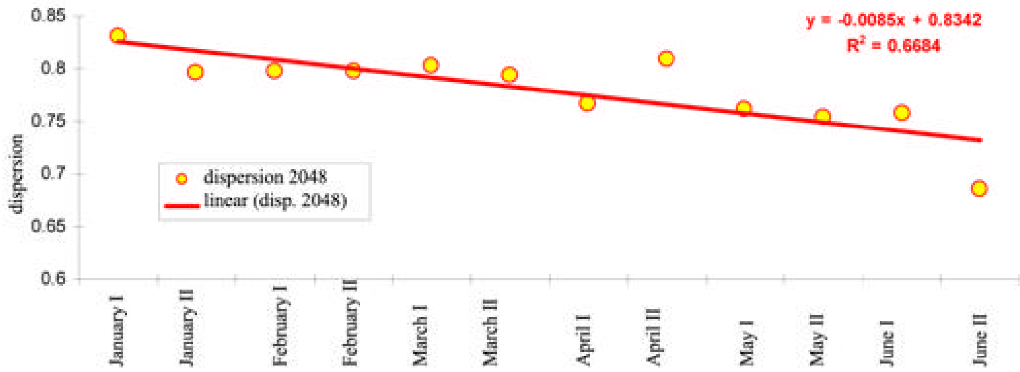

Figure 5: Dispersion function by time

If we group the data in different ways we might observe (Figure 6) that the absolute value of the matched gradient decreases while that of the matching dispersion increases. The constant monitoring of this is in progress at present.

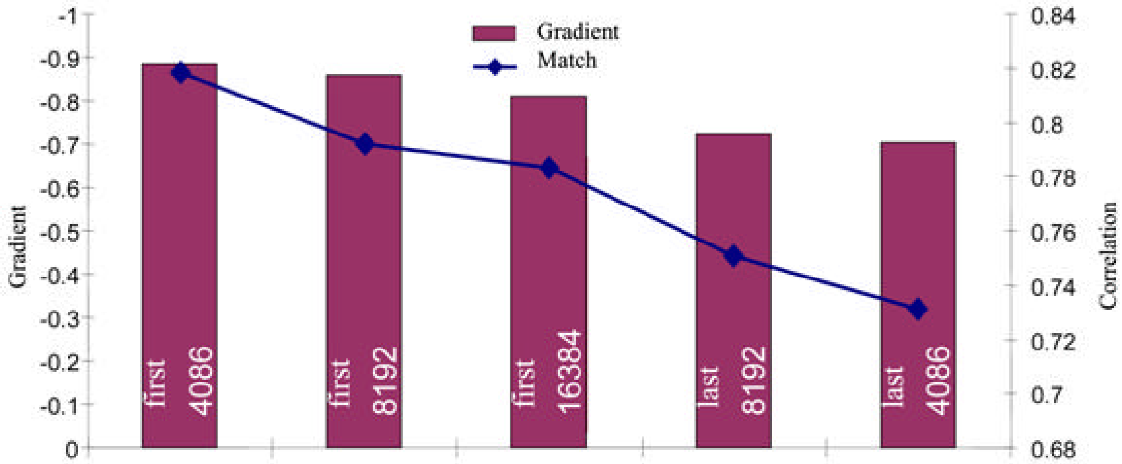

Figure 6: Influence of subgroup selection on the matched gradient and dispersion

4.2 New contributions

1. An intelligent and high-safety control system has been developed and implemented. The system accomplishes the functions of a complex intelligent system by the joint work of several microprocessors. The intelligent control meets the single fault condition (SFC) that is adequate for the medical practice. The system has been functionally inspected and certified by a noted German testing institute. This system forms the part of a medical device commercially available on the European market.

2. An application software executable on intelligent and high-safety personal computers has been developed and implemented The intelligent control meets the single fault condition (SFC) by using a solution which applies the usual windows environments but it runs not under the Windows operation system. For that purpose, a high-safety DOS-based operation system has been developed The system has been functionally inspected and certified by a noted German testing institute. This system forms the part of a medical device commercially available on the European market.

3. On the basis of the gained experience during the operation of control, that fulfils the condition of single fault (SFC) principle, a new system has been developed which has been built into the new generation of medical devices. This system allows the safe connection of the controls operating under my own operation system and the Microsoft Windows-based office computers.

4. A theory for the introduction of a system-invariant parameter has been developed and it has been showed that the adequate processing of noises and fluctuations is suitable to control the operation of sophisticated devices, to predict the required repairs and to estimate the lifetime.

5. It has been demonstrated that this system-invariant parameter does not depend on the primary distribution of origin and can be applied to every sophisticated open system.

6. Conditions for the measurement of system invariant have been developed, and the options of system invariants in different sophisticated systems have been proved by measurements. This method has been patented, and there have been some inquiries from Japan and Germany after its application possibilities.

7. This developed process and invention is built into the control of new-generation medical devices by the help of which the scheduled maintenance can be safely organized without the need of sudden interruption of the treatment or stopping the treatments because of unexpected failures.

5 CONCLUSIONS, PROPOSALS

5.1 Improvement of the medical device

The operation and general use of the device created definite demands for the improvement. From software and safety engineering/quality assurance points of view this implied the emergence of the following demands:

1. As the device is used for the treatment of patients, its failure may cause the cancellation of treatment and might endanger the recovery of patients. Accordingly, a new method had to be developed that is suitable to predict the incident faults by monitoring the equipment in operation therefore the required servicing can be accomplished without the unscheduled stoppage of device. Otherwise, this objective is connected also with a general quality assurance and profitability problem: the time, scope and effectiveness of the required maintenance have to be specified. I have developed and patented this new method in order to achieve this objective then implemented successfully both in the actual phases of development and in the planning of the next generation devices. Next, I am going to describe this method.
2. The device has increasingly come into use in the world, its servicing required considerable logistic and economic background. Accordingly, the central servicing (which is also a safety engineering problem) could be provided only if the device is made up of modules, and after the postal delivery of modules the replacement of module is allowed to be carried out by semi-skilled workers as well as the device is able to carry out by oneself the suitable adjusting measurements, tunings and identification of module. This implies the processor control of each module and the modification of the whole control system. This system has already been planned, and in addition some phases of them have already been implemented and are under evaluation. However, I am not going to detail this large-scale electrical engineering material because it goes beyond the scope of this dissertation.
3. The newly developed results, the relevant professional achievements and the overall upgrade have to be built into the device. This subject is a medical-biological problem that shall be made comprehensible for the engineering practice, and provided by quality assurance and software. This subject goes beyond the scope of this dissertation therefore I am not going to discuss it.

5.2 Fluctuation test on the steadiness of construction

By carrying out the noise test for a given complex system the steadiness of the construction can be specified as well: if any of the dynamical partial functions or units participates in the operation of equipment with a higher dominance as a steady and ideal case involving only the necessary redundancy then the noise spectrum will deviate increasingly from the harmonic $1/f$. This method helps in the planning phase.

5.3 *Fluctuation test of the non-wearing faults*

Of course, the abruptly occuring processes without any antecedents (in general, these events are not generated by the normal operation but sudden influences, unexpected conditions, abnormal operation etc.) can not be followed in this manner. At the same time, these sudden faults without antecedents are not the result of normal and regular operation of the system (the failure was caused by an effect that had not occurred and had not played any role in the dynamic operation of system up to that time, therefore, its effect could not be evaluated). Consequently, the unauthorized, untrained, incompetent and illegal use of the system as well as the failures caused by unprofessional manipulations of user or by changing the operating conditions untechnically can be eliminated. This method allows also the identification of tampering (technical inspection of the unit) or unauthorized re-installation if any of the dynamical parameters changes and – as a consequence – leaves its mark on the noise spectrum. Accordingly, the failure without any preceding noise or accompanied by suddenly changing noise spectrum points to general treatment/environmental/vis major situations, and their elimination can be solved by the help of monitoring the noise spectrum and steady control (computerized data collection) too.

5.4 *Active fluctuation tests*

Other possible solution of noise tests might be the use of outer noises for the „screening" of system. If the system is not enough complex but contains cyclical variables then it may behave as a filter on the effect of white noise and indicate the faults or suitability of system operation [Szendro and Vincze 2001] with a special response (like a trial test).

5.5 *Inspection of overhaul and upgrade works*

The overhaul is a usual practice instead of the replacement of high-value devices and/or equipment fixed to a place/building/infrastructure. In the same way, the overhaul is a concomitant of the electronic and high-tech development also at smaller modern devices since the speed dictated by this very fast development could not be followed by the replacement of devices because of the high costs. Normal requisite of the built-in modules/parts/devices is at the overhaul or upgrade that the new component shall be more up-to-date and – possibly – have much better properties, but in any case it shall be produced by the help of a manufacturing technology that differs from the previous one. At the accomplishment of these replacements the compatibility of the replaced part might cause a definite risk which is – however – revealed in most cases (since the assurance of formal and operating interface identity is evident) not in the course of the direct replacement but during the operation, sometimes after the occurrence of significant damages. This serious problem can be supervised because of the development of electronic devices consisting of domino-like modules as well as owing to the remotely controlled service-technical solutions and the demand for the overall modular compatibility. Also the adequate compatibility can be provided in every respect. Namely, if we prescribe the suitable invariant quantity for noise test then the incidental hidden compatibility failure can be immediately detected and repaired. This might be especially important at the compatibility test of devices that are purchased in modular units (e.g. computers and peripheral units) because their compatibility problems might prevent the whole operability of the system.

5.6 Newer research prospects

In the future, we are going to bring this method into a wide-ranging use. We are convinced that a simple and well-usable procedure has been successfully developed that might bring new tendencies even in the analysis of such complex systems as the biological organism as well as high-complexity systems operating on the base of human-machine relationship. The research in this field has already begun.

6 LITERATURE PUBLISHED IN THE SUBJECT MATTER OF THIS DISSERTATION

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6.2 Journal papers:

SZÁSZ A., SZÁSZ O., SZÁSZ N. (2001): Hipertermia az onkológiában: onkotermia. (Hyperthermia in oncology: oncothermia) Medicus Anonymus 2001/11, 32-34 p.

SZÁSZ A., SZÁSZ O., SZÁSZ N. (2001): Electrohyperthermia: a new paradigm in cancer therapy. Deutsche Zeitshrifts für Onkologie, 33, 1-9 p.

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