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Model of Emergency Shutdown System of TOKAMAK KTM

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Abstract. The computer model of emergency shutdown (ESD) system of Tokamak has been developed. Xcos extension of the package Scilab of linux operating system was used for developing the model. The simulated system monitors the most ultimate in terms of the integrity of the preproduction equipment and personnel safety parameters and provides an opportunity to prevent accidents. In the accidents occur the system executes algorithms of protective effects providing the complex transfer to a safe state, which allows to reduce consequences of possible accidents.

Introduction

The thermonuclear reactor, Kazakhstan Tokamak for material testing is an important step in the ITER program. Kazakhstan Tokamak is used for studying the materials for the next generation of fusion reactors. Before beginning the materials experiment this reactor need to be built and debugged. It is impossible to imagine Tokamak operation without a complex system which design plays an important part in the development of the entire automation system experiment. An overview of systems for previous tokamaks shows that such systems are usually created from scratch, each system is unique. The development of new systems, as a rule, follows from the previously developed ones based on their models taking into account the errors and the disadvantages of the hardware component. Also the achievement of a number of design characteristics of the plasma parameters in tokamaks is impossible nowadays without creating effective models and program systems aimed at modeling processes in the plasma as well as managing these processes. An important part of the study on tokamaks is executing preliminary "numerical experiments" in modeling the plant operation with the expected script before the real experiment. The “numerical experiment” is the study of plasma processing both in the open condition and the closed-loop control system by mathematical modeling. Computational and theoretical models of plasma which are available today and the accumulated experimental database allow to perform such "numerical experiments" at the design stage of tokamaks of the next generation [1].

Emergency protection system model

The actually existing Kasakhstan tokamak for material testing (KTM) has been taken as a basis in the simulated system. This device is managed by scada, the system trace mode. The developed model of emergency shutdown (ESD) system ensures by the automatic execution of the following functions:

- continuous monitoring the main technological parameters of the installation KTM and the production of control actions in case of emergencies;
- maintaining a database of accidents with the possibility of automatic identification of the current equipment state and variants of locating faults with the performance of one of the protective effects.

When designing a model the following events that may lead to emergency situations have been mainly considered:

- overheating of the chamber walls and the uneven heating of the chamber and structural elements;
- plasma touching the vacuum chamber walls;
- exceeding the feasible plasma displacement horizontally or vertically;
- occurrence of locked MHD modes;
- occurrence of disruption instability;
- development of small plasma disruption; exceeding the limiting values of mechanical stresses.

Operation algorithm

The algorithm of the system action shown in Figure 1 consists of obtaining the values of the controlled parameter, which dependence of the change is modeled in advance or is readable from an external device. Further we compare the parameter with its control value. If its value comes short of accepted standards the control actions take place, which in its turn will lead a normal value. If for some reason the system could come to equilibrium, an ESD procedure should be carried out. To provide the inability of interruption of protective actions the system has a linear structure, in other words until the system performs one of the actions, it cannot be interrupted or unperformed. The exception is if the action is interrupted by the operator. The algorithm controls each of the parameters for the correct decision.

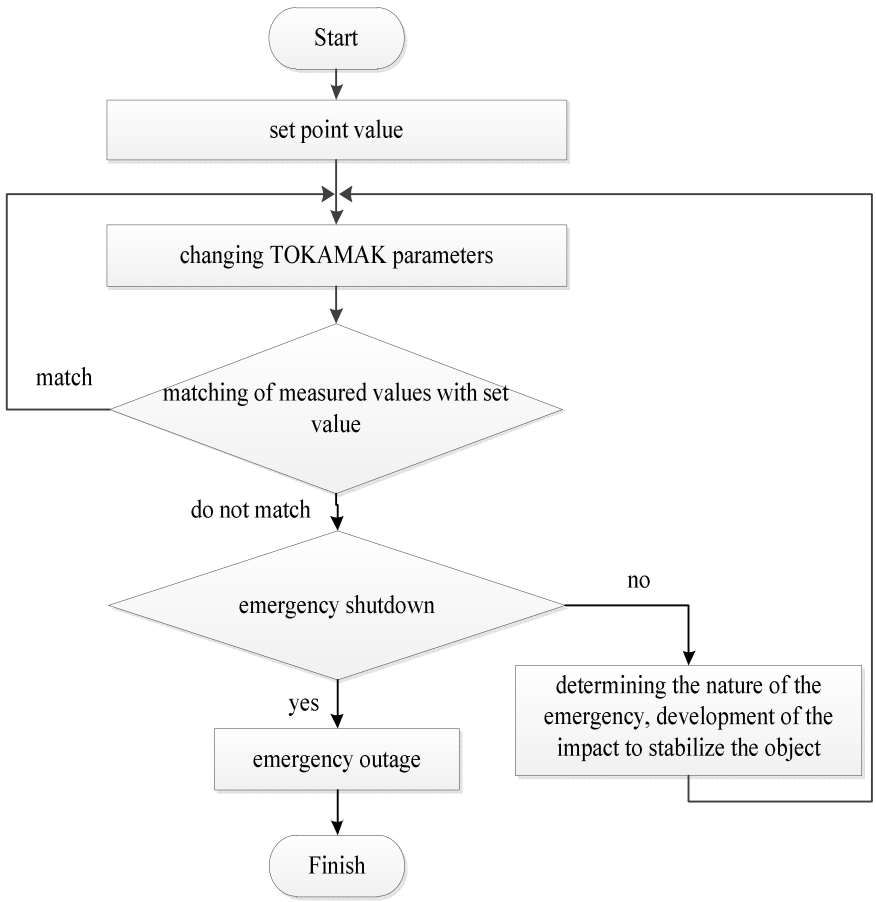

Figure 1. Algorithm of functioning model of ESD system

The first version of the model of ESD system has been developed using the Matlab package. But considering the complexity of the program there were several unsolved problems with versions continuity. The price of the basic software package ranges from $ 3,000 to 4,000, and the cost of windows 8 licensing that can be used in the model development, is 7000-8000 rubles. Taking into consideration only these aspects we decided to change the operating system and the development framework. After the analysis of the currently existing development framework we decided to use an open and free open source. Further development has been carried out under linux in the development framework Scilab. At the present time it is broadened under CeCILL free license. Due to a high degree of compatibility with Matlab the basic algorithm has been managed to transfer without loss. There is an extension in Scilab similar to simulink named Xcos with the help of which a model system has been implemented (Fig. 2). A number of minor problems and errors has been occurred associated with data sources, their type and displaying of results. All the problems and errors have been successfully corrected and the model feasibility has been recovered.

Next, a series of tests have been carried out which showed a significant reduction in the program speed and the error-free operation, and besides the amount of resources level taken on the execution of algorithms has significantly decreased as compared with the implementation of the model in matlab framework. The positive aspect is a continuity of versions in Scilab besides the fact that this package of applied math programs provides a powerful open environing for engineering, technical and scientific computations. A system has a sufficiently large number of extension packages that can help in the further development. The next step in the model designing is conjugating of a computer model with a real object. Whatever the object is, the driver is required for its conjugating with a computer. A device driver in linux is a low-level program containing a specific code to work with a device that allows both user programs and the operating system to work in the device in a standard way. Devices can be divided into symbol, reading and writing of the device goes symbol-by-symbol. Examples of such devices are the keyboard and sequential ports. Reading and writing devices are only possible in blocks, typically 512 or 1024 bytes. A driver can be written using any text editor. Most of the driver code coincides with the original kernels codes that are in the open access and vary depending on the version of the operating system. It does not matter which device interacts with the model. Since ultimately the value compared with fixed will be important for us.

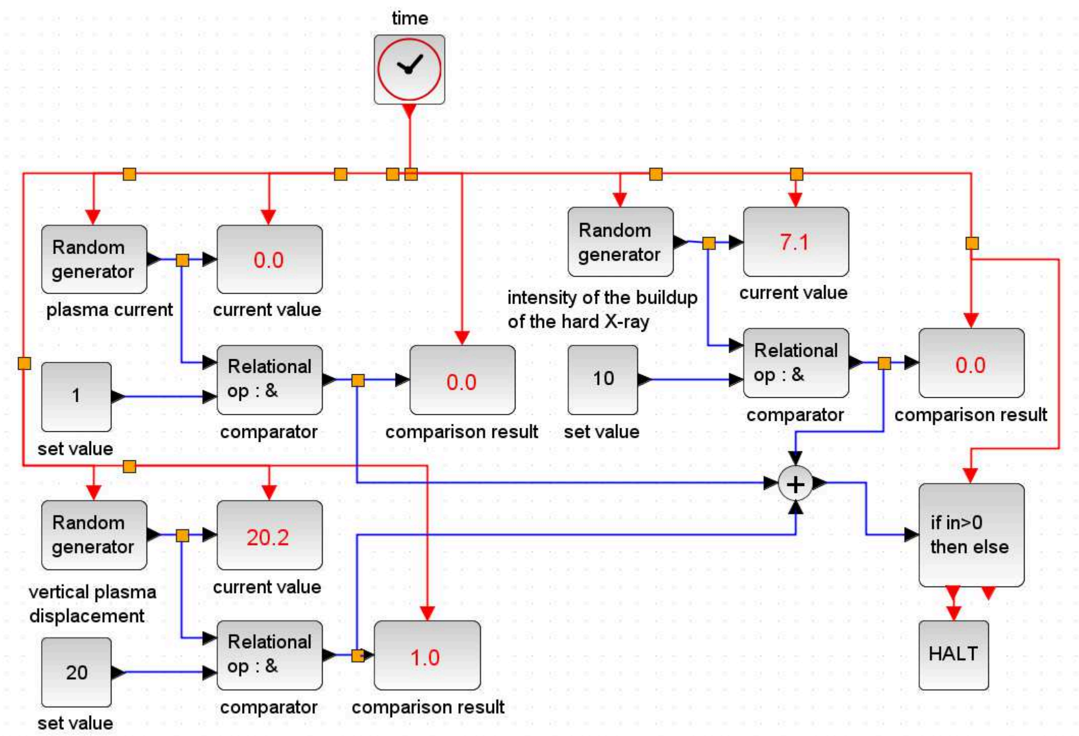

Figure 2. Fragment of the emergency protection system

Besides the device from which it is planned to read the information we elaborated the variant of the output and reading control commands. Information will appear on the display of the operator station simultaneously displaying the value of discrete and analog signals at the remote push-button station of the control command input and the indication control signals. Control commands namely commands of launch approval, start, stop and emergency stop buttons have been implemented through the push buttons with light indication. Then the problem of selecting a database under linux has been emerged. There are many options with their advantages and disadvantages. Based on the need to view and edit the content of the database in various operating systems, the choice has made in favor of OpenOffice Base. It has a nice intuitive interface, all the necessary functional, the openness and the ability to work in different operating systems. Conjugating with the model has been performed using the built-in tools in Scilab.

Using of reliability models

Application of reliability models allows assessing of the effectiveness of these changes. Thesae are, for example, Mills reliability model or more advanced Lypov model. Using this model requires artificially inserting a number of known errors in the program before beginning a test. Errors are made randomly and recorded in the artificial errors logging form. While testing the program for some time, the statistics of error are gathered (Fig.3). On the basis of the statistics we can conclude how effective the applied methods are. We have the statistics of failures for specific time intervals since the development of the program. The regularity is evident: at the early stages its number has been significant, but over time the model has been improved and the number of failures has been minimized. The further development enables the absolutely fail-safe operation. We also gathered the information on the equipment used for the model implementation. Discarding features this dependence is quite static in nature and does not change with time. At the same time the number of failures is much higher than the level of software, which negatively affects the overall picture. It is evident from the statistics that software should be improved and further development of the model we have to use FPLD or a single-board computer.

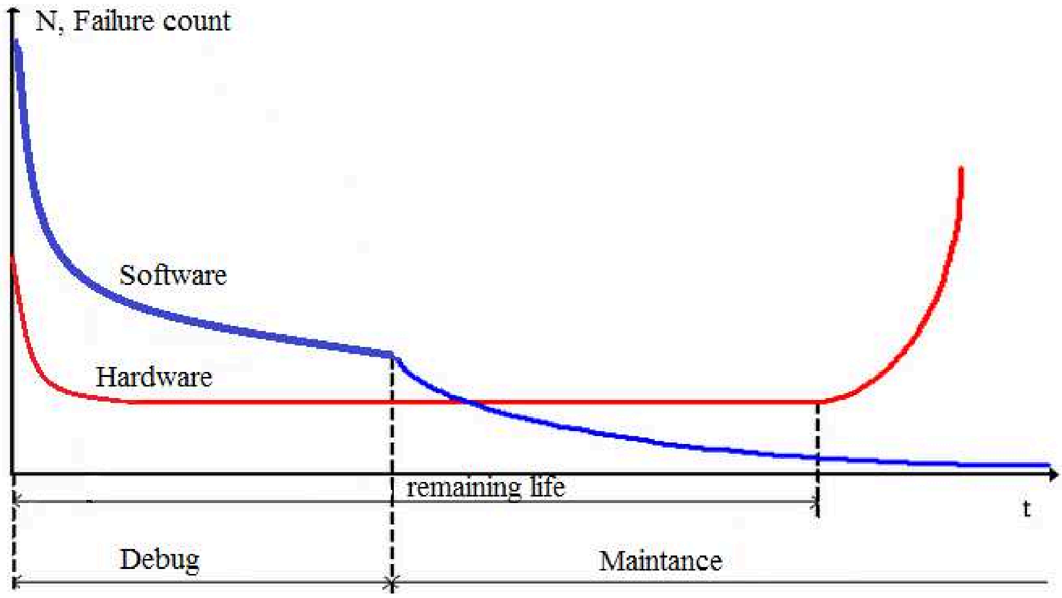

Figure 3. The number of failures during operation model

Finally a working model of tokamak emergency shutdown system meeting all requirements and performing all of its basic functions has been obtained. The model implements the control of 15 parameters, which is a half more as compared to the previous version with the ability to increase or decrease the number of monitored parameters. The system reliability analysis was carried out; the statistics allows concluding that the discovered algorithm is reliable and meets all the requirements imposed to the system. Relatively simple and loss-free transfer from one operating system to another, as well as framework change reveals the feasibility of both the model and the algorithm. Moreover, the transfer has a positive effect both on the operability and the reliability of the developed model.

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