Management of The Safety of Automation Challenges The Training of Ship Officers

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Abstract: Management of the safety of the increasing automation onboard ships is a challenging task for ship officers. In this paper, the competency requirements and the training of deck and engine officers on this area is discussed. Ship officers must be able to operate the automation systems safely, not only in normal operational situations, but also in abnormal situations. Preserving the safety is a key issue also in the maintenance of these systems. The safety of automation can be ruined by poor maintenance. As the training of officers is considered, It is crucial to define correctly the knowledge and the skills that the officers should possess on this area. What and how should be trained? On one hand, the training should not be too general, and on the other hand, it should not be loaded with in-depth information about the finesses of digital technology. It is important to understand what is essential for succesfull management of safety of automation. The aim of this paper is to give some answers to these questions. A draft syllabus for a training course on management of the safety of automation is presented. The proposed course syllabus is created in the ongoing SURPASS project, which is carried out by Satakunta University of Applied Sciences together with four other European institutions. The general outline of the SURPASS project and its goals are briefly described in this paper.
Keywords: Ship automation, safety, training

1. INTRODUCTION

Automation has had a major role in the development of the modern society during the past decades. It has been possible to improve the productivity, the effectiveness and the quality of production on many branches of the industry by utilising new automation technology. Automation has also given a significant contribution to the development of the safety. During the course of years, automation has gained a very important role also on ships.

The modern automation is based on digital information technology. Even though our world is not digital, all the information collected from the real-life systems to be controlled is processed, stored and transmitted in digital form. This branch of technology has been - and still is - under fierce development on the component level. Distributed digital machinery automation systems for ships were introduced on the late 1970's and in the beginning of 1980's. On the bridge the computer appeared a few years later. Although the core tasks of the automation systems have not changed so much and the users of the systems are still ordinary human beings, the technology to implement these systems has been replaced several times. New processor generations, new memory technologies, new ideas of transmitting the information from one place to another have been introduced within a few years' interval. For instance, although the architecture of the machinery automation systems in the late 80's were already distributed, the data transmission was still based on point-to-point connections reaching the capacity of a few kilobytes per second. Nowadays the systems utilise buses and networks on different levels of the system. Typical networks within a ship automation system is able to transmit information with ten thousand times bigger bitrate than the old serial connections only twenty years ago. Also the integration has occupied ever-increasing areas as the shipping industry has been looking for better efficiency and safety. Examples of extreme integration related with ships are the satellite based navigation, communication and Search-And-Rescue systems, Automatic Identification System (AIS) and the e-navigation concept. that are all based on the utilization of advanced automation, digital data processing and modern information transmission technologies [1].

This rapid development on a most critical area of the operation of ships is a major challenge for all parties involved in such a conservative business as seagoing. Technology changes but the user is still the same human-being, who must be able to operate and to maintain these systems correctly. The importance of the human element is not eliminated or even reduced as automation has been increased, especially when the safety aspects are considered. The new automation systems must be maintained and operated in a safe way, even under abnormal conditions. These tasks require good knowledge about the operation and about the structure of the systems. This is a big challenge for the education of seafarers. Rapid development of the technology must not lead into a situation where a large part of seafarers have a formal education and the licences required by IMO and the national seafaring officials, but in fact are not able to maintain and operate the latest technlology in a safe way. We mus ask if the Maritime Education and Training institutes are really able to give the students such education that fulfills the demanding requirements set by the latest technology. And what about those seafarers who have got their education twenty or thirty years ago? Are they still able to cope with the computer-based systems they are operating on new ships? It is quite clear thet the older seafarers did not get any training about the safe usage and maintenance of the latest system generations when they were students at the Maritime University.

2. THE LIFETIME APPROACH TO THE SAFETY OF AUTOMATION

The safety of complex technical systems, such as nuclear power plants, can be managed by looking at the whole lifetime of the safety-critical entity. The lifetime approach is very useful also in management of the safety of automation systems of ships. The lifetime of an automation system can be divided into several phases, one following the other. Typical phases are the specification, the design of the hardware and the software, the manufacturing, the testing, the assembly of the system onbord, the commissioning, the maintenance and operation and finally the dismounting and wrecking the system. The system is safe, or the integrity of the safety is maintained, only if all safety aspects have been properly treated and all requirements are fulfilled during each phase of the entire lifetime of the system. The standard IEC 61508 is one of the basic regulations of management of the risk of safety-critical systems, based on the lifetime, or safety life cycle, approach [2].

Many rules and regulations have been published in order to ensure that the safety aspects have been properly taken into in different phases of the lifetime of the critical systems of ships. Publishers of such documents are International maritime Organisation (IMO), International Hydrographic Organisation (IHO), International Standardisation Organisatio (ISO), European Union, national maritime authorities, the classification societies and the International Electrotechnical Commission (IEC), among others. For instance, IEC has published regulations about the testing of the equipment used onboard ships [3]. Classification societies refer to this document in their rules and regulations.

It is interesting, that the vast majority of these regulations are targeted at proper design and testing of the systems. The most important rule related with the maintenance and the operation of automation systems on ships is in fact the STCW 1995 convention by IMO. The STCW 1995 with its amendments defines the minimum standard for the training and the competence of seafarers all over the world. It is quite obvious that in this phase of the lifetime of the automation system, the human element plays the most important role. Even the system designed, manufactured, tested and commisioned according to all rules and regulations is safe only if it is operated and maintained in a proper way. There are several examples in the history of safety-critical systems about serious accidents caused by poor or neglected maintenance or wrong usage of a well designed system.

3. THE SURPASS PROJECT

The STCW-1995 with the 2010 amendment sets the minimum standard for the training and the competence for users of the automation onbord ships. However, the importance and validity of this standard - as so many other official regulations regarding new technology - is weakened by the rapid development of the technology. An official standard of this kind can not be too detailed and it cannot be updated immediately after every new technical innovation. And even if it was possible, there would still be a long delay between the introduction of the new technology and the time when trained seafarers enter the labour market with knowledge about this particular matter. This delay is caused by different factors on the management and the way of operation of the maritime education and training providers.

There is a need for special training for seafarers to update their knowledge about the safe use and maintenance of the latest automation technology. The level of the skills and the knowledge on this area is not even. The older generations that have got their education two or three decades ago are less familiar with new technology than the younger generations that have become familiar with computer systems in their everyday life. But even for the younger generations, it is important to give education about proper maintenance and use of safety-critical computer systems. Operating the Integrated Navigation System (INS) of a big passenger ship is not the same as playing a computer game!

Satakunta University of Applied Sciences together with five other European organisations has initiated an EU project called SURPASS, in order to give a solution for this apparent trainig need. The project started in October 2009 and will be concluded in September 2011. The The main aim of the project is to create a special training course for seafarers to enable them to have a better understanding of the structure and operating principles of automated systems and of these systems' weaknesses and limitations and the management of the safety of these systems. The course material to be produced will support web-based learning [4].

4. THE GOALS AND THE METHODS

An essential question is: what should be trained if the goal is to give the officers the skills and the knowledge to cope with modern automation technology onboard? The answer to this question about the contents of the training can be found by thinking about the tasks of the officers onboard in relation with the automation systems. It is quite obvious that the officers have only two main roles. The first one is to use the systems and the other one is to take care of the maintenance of the systems. Hence the training should focus on proper maintenance of modern automation systems onboard and on a safe and efficient way of using the systems. Maximising the safety and minimising the probability of an accident, especially due to a human error, should be the general perspective in designing the contents of the training.

Training of users of technical systems is often focused on operation of the system under normal conditions, while the management of abnormal situations gets very little attention. However, the user must be able to cope with different kinds of abnormal situations as well. These situations can be caused by hardware failures, software errors, different kinds of disturbances or by extraordinary environmental conditions. It is important that the user can efficiently monitor the system and that he/she is also able to notice abnormal variations on the performance of the system. If the user can not do this, he/she becomes totally dependent on the system's built-in ability to perform self-diagnostics, to detect malfunctions and failures and to give alarms or warnings to the user in such situations. There are several accident cases, however, showing that the users should not rely on the self-diagnostcs of complex automatic systems [5]. Especially in complex systems, consisting of several computer-based units and subsystems, it is practically impossible to create such self-diagnostics that would be able to give an alarm of every possible failure mode. Consequently, there is always a risk of such failure mode that can not be identified by the self-diagnostics. When the system does not give the user a proper alarm about a serious malfunction or a failure, a dangerous "automation surprise" takes place: The system suddenly behaves in a way that the user did not expect and the consequence can be an accident. The event-tree of an accident resulting from poor monitoring and incomplete self-diagnostics of a safety-critical system is shown in Figure 1.

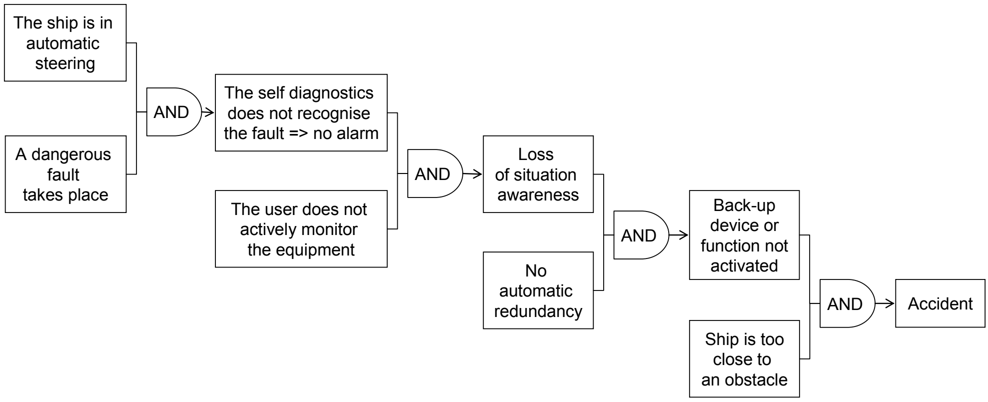

Figure 1. The event-tree presentation of a typical accident after a failure in a safety-critical automation system

Training of management of abnormal situations, however, is not a simple task. Efficient management of failure situations and proper monitoring of the performance of the system require good understanding of the structure and the operation of the system. This should be an essential part of the training, but on the other hand, training can not be loaded with too many technical details and theoretical information about the algorithms and functions. Moreover, such information is usually very system-specific, which means that every system and every ship should be studied individually. That is impossible in real life. So the conclusion is that the general training of users can contain principles of the structure and operation of modern automation systems. Also understanding of interrelations and dependencies between various sub-systems in a large integrated system and the data transmission between the sub-systems should be handled. Technical problems within automation systems are very often connected somehow with transmission of signals. But no detailed ship-specific subjects can be included. These skills and knowledge must be studied onboard. The general course should contain material to motivate the students to complement their knowledge onboard. Accident cases from real life would perhaps be useful for this purpose. The ship owner has the responsibility of arranging appropriate training for all users on the ship-specific subjects. An extremely useful tool for training of managemenet of abnormal situations is a type-specific simulator. Air traffic industry has used type-specific simulators for decades to train cockpit personnel to handle different kinds of abnormal situations. Unfortunately in shipping industry this is not usually possible, because ships are more or less individuals and each ship should require its own type-specific training simulator.

In training of proper maintenance of modern automation systems, it is important to pay much attention to human errors. Both in understanding why human errors occur and in learning how to prevent them. A useful book on these subjects is "Managing Maintenance error" by Reason and Hobbs [6]. The book gives information about the nature of human error and draws some guidelines towards error-free maintenance.

When the contents of the user training is being planned, it is wise to utilise modelling of the human behaviour. One alternative is the famous three-level model of human behaviour by Jens Rasmussen. This model divides the behaviour of a human operator into three levels: the Konwledge-based level, the Rule-based level and the Skill-based level. There are also other classifications available. A model for maintenance of situation awareness would also be very useful. Figure 2 illustrates the structure of this model.

The process of situation awareness is recoursive, consisting of reception of information from the real world, combining it with the expectations, updating and maintaining the mental model of the reality and finally the task of controlling both the information reception and the real system in concern. Which ever model is used, it helps to ensure that all important areas and aspects of the human behaviour are taken into account.

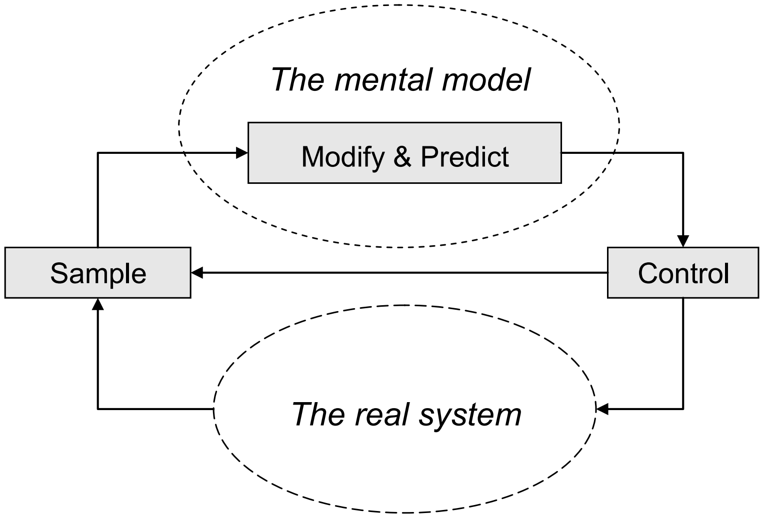

Figure 2. The recoursive model of Situation Awareness [5]

5. THE PROPOSED CONTENTS OF THE TRAINING COURSE

The proposed contents of the training course on the safe use and maintenance of automation systems is presented in Table 1. It can be seen that there are quite many different subjects to be included in the syllabusof the course. It is, indeed, quite challenging to design a course on a rather demanding technical subject for people that do not necessarily have much earlier training on electronics, computers or automation. However, if there is not enough knowledge about the structure and operation of the system, the user may not be able to manage critical fault situations safely. Also the deck and the engine officers of the ship must know something about risk analysis techniques and about avoiding the human error during maintenance, in order to succesfully handle the maintenance of the automation systems onboard.

The course contents shown in the table is not the final one, and it will be adjusted according to the feedback from seafarers and other interest groups during the SURPASS project.

Table 1. The proposed course contents

1. Introduction of applications of automation on ships - machinery automation systems - bridge automation systems 2. Principles of real-time digital data processing and digital data transmission - the idea of real-time digital computing - from analog to digital and from digital to analog - digital data storages - the software - principles of digital data transmission in automation - the importance of the Human-Machine Interface 3. Principles of the safety of automation - basic terminology - ensuring the safety during the whole lifetime of the automation system - the human element in safety of automation 4. Knowing the risks of ship automation - Introduction of common risk evaluation techniques 5. Safe use of an automation system - minimising operator errors - coping with failures and disturbances during the operation 6. Safe maintenance of ship automation - critical areas in maintenance - eliminating the human error in maintenance 7. Special safety issues - typical disturbances - proper earthing - uninterruptible power supplies - galvanic isolation

6. CONCLUSIONS

If the development of the training of seafarers can not keep the pace of the development of the technology, the users will not be able to use and to maintain the modern automated systems of ships safely and efficiently. STCW-2010 does not set precise requirements for the knowledge of automation-related issues and for the training of these subjects. Obviously these official requirements must be complemented, as the development of technology goes on. The aim of the SURPASS project is to develop special training course for seafarers to update their knowledge of the structure and the operation principles as well as the safe use and safe maintenance of modern automation systems. The syllabus of the proposed training course is rather wide. There are a great number of different subjects to be covered by the training course. The SURPASS project is still going on and the final result of the project are not available before the end of 2011.

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