Reflections on recent developments in the field of instrumentation and control[1]

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Abstract: The paper gives a broad overview of recent development and thinking in connection to the application of digital instrumentation and control systems in nuclear power plants. It is based on work carried out in the Technical Working Group Nuclear Power Plant Control and Instrumentation (TWG-NPPCI) of the International Atomic Energy Agency (IAEA), modernisation projects in Finland and Sweden and preparations for the fifth nuclear power plant to be built in Finland.

1 INTRODUCTION

The development in the field of instrumentation and control (I&C) has been very rapid over the last two decades [1]. New generations of equipment with improved performance have been introduced to the market at a high rate. The new systems take advantage of technological achievements to accommodate sophisticated treatment of measurement and control signals, for speed and reliability, but also for flexibility and versatility. The introduction of the new system in nuclear power plants has been considerably slower than in the conventional industry, mainly due to the fact that very few new nuclear power plants have been built during the past twenty years. Today the new systems are introduced in modernisation projects at nuclear power plants all over the world [2]. There are many indisputable benefits of the new I&C systems, but the licensing of them have showed to be difficult.

There are different forces driving nuclear power plants to modernise their I&C systems. Among them is an increasing obsolescence of the old systems, which sometimes makes it very difficult and expensive to get spare parts. Pressures to be more cost effective on competitive electricity markets introduce the need for better control, but it is often almost impossible to implement new functions without a modernisation of the I&C. Even when these problems can be solved it has shown to be very difficult to get people who understand the old systems. Taking into account that many nuclear utilities are planning to extend the operational life of their nuclear power plants, modernisation is therefore often the only possible solution, also because license extensions involve safety retrofits to comply with new safety regulation.

In entering I&C modernisation projects there are many challenges that have to be addressed. The most important issue to be addressed is the licensiability of the new system. The new technology has shown to carry the possibility of unexpected pitfalls, which should be addressed with prudence and diligence to ensure a smooth and timely completion of a modernisation project. In spite of difficulties to apply the new technology there are many modernisation projects, which have been completed in a timely manner with large success. This experience has lead to that IAEA and especially its Technical Working Group on Nuclear Power Plant Control and Instrumentation (TWG-NPPCI, [3]) has been active in creating guidance

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for the modernisation project through the collection and documentation of both positive and negative experience from the projects.

2 THE CHANGING TECHNOLOGY

In assessing the changing I&C technology there are a few important observations to be made. Firstly there has been a transfer from analogue to digital technology, which implies that control solutions have moved from continuous to time sampled control. Secondly the new systems are programmable, which makes it possible to implement a large range of algorithms with the same hardware. Thirdly the development has been very rapid, which means that product generations have become very short and introduced a different kind of obsolescence. The consequence of the introduction of the new technology has been that a new range of requirements has to be taken into account and reflected in the engineering processes.

The new technology carries many important technical benefits as compared with old analogue and relay based I&C technology. It is for example basically drift free and there are large possibilities to implement advanced computational algorithms. It is also possible to use advanced fault response mechanisms to increase the reliability of the I&C. Further signal multiplexing on cables can be used to achieve a very high throughput to make it viable to use redundant cabling routes. With the shift of technology there has been a shift from conventional control rooms with handles and meters to control rooms based on soft control and visual display units (VDU), which give far better operability and overview in various situations. The new systems make use of computers in the design process to ease both documentation and the verification and validation (V&V) processes.

The new I&C systems have also brought with them new challenges. Concerns have for example been raised that the I&C may contain software errors, to cause the systems to fail unexpectedly and in an unpredictable way. This may happen if some important system function is prevented in a crucial situation or if some unintended function is initiated when certain trigger signals are combined. Software errors have a deterministic appearance and introducing redundancy and diversity can therefore in principle not solve system reliability, because there is always a possibility that redundant and diverse channels are influenced at the same time in the same way due to some common failure mechanisms. Extensive testing cannot solve the problem either, because the complexity of the software usually makes a complete testing unpractical. These issues has made it somewhat difficult to find an agreement on what should be considered sufficient evidence that suggested solutions are fit for their purpose [4].

Another issue connected to the licensing process is the requirement that human factors engineering should be used to ensure that the main control room and other control stations are adapted to their users in all situations such as normal operation, start-up, shut-down, disturbances and emergencies. This requirement naturally applies also to the old systems, but the structuring of information between VDUs and displays represents a new challenge for control room designers. Also here it has shown to somewhat difficult to agree on what should be considered to be sufficient evidence that the human machine interfaces are fit for their purpose. Guidance for the review process has been developed, but a proper balance between a superficial and a too heavy procedure is still to be found. The new I&C systems are also expected to be more sensitive both to harsh external conditions and to malicious acts.

In spite of the generic difficulties in providing adequate input for the licensing process, there is however ample evidence world-wide both from new plants and from modernisation projects

that digital I&C technology is possible to use and actually has a large advantage as compared to the old I&C systems. The crucial component here is to ensure that all phases of the I&C project, including system specification, implementation and testing, are carried out with prudence and diligence.

3 EXPERIENCE AVAILABLE TODAY

Computers and VDUs can already today be seen in most nuclear power plants. These enable advanced monitoring of signals, alarm processing, presentation of information adapted to operational needs and so on. More seldom the computers are used for actual process control. In parallel to the computerised plant information system, there is also an increasing reliance on computers for administrative information. For example work permit systems have been computerised, various computerised outage planning systems are used, e-mail is used as an important mode of communication, access to procedures and other documentation is given through web-browser applications, etc. In the growing number of applications that relies on modern information technology there is a growing demand to have the systems to communicate with each other.

At many nuclear power plants research based applications have been introduced to prepare for the new technology. These applications include large screen displays, computerised procedures, advanced alarm handling, monitoring and surveillance systems, early fault detection, operator support systems, etc. Especially the OECD Halden Reactor Project [5] has been active in creating such application ideas.

A rapid technological development often brings along a difficulty to agree on suitable standards. Today major vendors of I&C systems often base their products on proprietary solutions and protocols, which sometimes makes it very difficult to exchange information between systems from different vendors. The development of the licensing requirements has also taken different paths in different countries, which has lead to a situation where there is a large national variety in requirements placed on digital I&C. This development has led to a situation where it sometimes is difficulties to use systems outside their countries of origin. Only a reasonable harmonisation of requirements can and a forceful development of standards can turn this trend [6].

There are also mechanisms of change that may have an impact on the nuclear power plants. Many countries in Europe and states in the USA have deregulated their electricity markets, which has placed a need for the plants to be more cost effective. In the harsher business climate it may be difficult for the plants to invest in I&C modernisation. Changing societal priorities has at the same time made it more difficult for the nuclear power plants to renew their staff in response to ageing staff and retirements. Finally also vendors have difficulties to maintain competency and skills necessary to follow the development of the new systems.

4 AN OUTLOOK FOR THE FUTURE

In taking an outlook for the future the main question is how the nuclear field will develop. If there are no new plants built the future may be meagre. Within the industry many persons predict a new coming of nuclear power in the world, but they at the same time note that it may take a long time. A recent green paper on the situation within the European Union stated that the nuclear option must be re-examined in terms of its contribution to security of supply and

greenhouse gas reductions [7]. This statement represents a change in views as compared with earlier positions on nuclear power in Europe. The new plant to be built in Finland may represent an opening in this direction [8].

Looking especially into the I&C area, it can be expected that the present fast development information and communications technology will continue, as there are no signs that present development towards smaller, faster and more efficient chips will stop. This implies that we may expect more computing power and more functions within the I&C. This development can be expected to influence not only control room operators, but also more generally the whole staff at the nuclear power plants. In this development we may in the future see maintenance people at the plants inquiring the condition of various equipment using handheld computers over a wireless link. Also remote diagnostics of disturbances and advanced simulation are other possible tools for both design and training.

For the new plants it can be expected that they will rely on far more automation as I&C functions come down in price and are becoming more reliable. It is also to be expected that there will be more sensors and that they will be smart. Most equipment will be intelligent, remotely controlled and have advanced possibilities for condition monitoring. More generally it can be expected that future plants will have considerably smaller staff as compared with present nuclear power plants. In building those plants it can be expected that specification, design, construction, testing and documentation of the I&C system will be supported with integrated information systems [9]. This will also help in maintaining documents at the plants during their operational life [10].

In the control rooms and during maintenance activities computerised procedures will be used [11]. Control rooms will be reviewed using virtual reality (cf. [12]) tools and advanced simulators [13]. For the hardware and software solutions it is to be expected that open interfaces make it easier to interconnect different systems. It may even be expected that I&C products will be implemented by system integrators combining a large number of commercial-off-the-shelf (COTS) products. Finally the present interest in safety culture and learning organisations can also be expected to influence the requirements set on the I&C [14].

5 CONCLUSIONS

The nuclear industry can be considered small in a global I&C market. This means that the nuclear industry has to rely on solutions developed for other applications. The special requirements that is placed on I&C for nuclear applications to provide proof for functional fitness should therefore to be taken care of by collecting all available evidence their design features, from the development process, from the testing and from the operational experience. Sometimes it may be necessary to introduce diversity in the systems at the additional cost of increasing complexity. Properly approached the special needs of the nuclear industries should be possible to handle with components that have been created for other similar safety oriented applications.

The long operational life for the nuclear power stations makes it necessary to plan for perhaps 2-3 modernisations from the beginning to cope with the rapidly developing technologies. That would imply for example reliance on functional design that can be made independent of used system platforms. The need for implementing modernisation's over a longer period during several consecutive refuelling outages makes it also necessary to implement a flexible updating procedure for the physical equipment as well as for plant instructions and documentation.

A country opting for a nuclear power programme should be aware of the implicit commitments that are made. The country should be able to maintain knowledge and skills to operate the plants and to keep them in good order. This evidently depends on what knowledge and skills can be acquired on an international market. To make any coping strategies efficient the needs have been identified and reacted on a governmental level. This policy has been adopted in Finland with a large success, where national needs have been identified in good co-operation between utilities, the regulator, research establishments and universities [15]. Presently the national nuclear safety research programme [16] is approaching an end and a new 4 year research programme is in its initial phase. VTT is a major player in the nuclear field in Finland and has taken a proactive approach in this regard [17]. Considering strategies for a small country, I&C is one important area, where there is a potential to maintain a good understanding also in a time of rapid technological development.

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