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INTELLIGENT SYSTEMS INTEGRATION: GUIDING PRINCIPLES, EXAMPLES AND LESSONS LEARNED

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ABSTRACT
The adoption of support systems based on computational intelligence (CI) techniques in nuclear power plants presents a number of challenges that need to be addressed in order to maximise the added value of this type of systems. This paper tackles issues related to the integration of CI systems and identifies three different levels of integration that should be taken into consideration. These are the data level, the operational level, and the functional level. The data level includes all aspects of data communication between the CI system, the plant instrumentation, and the other computerized support systems present at the plant. The operational level includes all those aspects of integration that influence the way in which the operator interacts with the CI system, with a clear emphasis on Human System Interface (HSI) integration. The functional level includes those aspects of integration that deal with the functionality of the CI system and how this can support or be combined with the functionality offered by other support systems with the aim of exploiting synergistic effects and achieving new functions. Additionally, the paper identifies a set of guiding principles of integration that can be applied at all three levels of integration. Examples taken from experiences gathered at the OECD Halden Reactor Project are also included.

KEYWORDS
intelligent systems; operator support systems; system integration.

1. INTRODUCTION

Computational Intelligence (CI) based systems have been recently receiving increasing attention from the nuclear industry. The OECD Halden Reactor Project (HRP) has been particularly active in this respect with the development of systems such as PEANO for sensor on-line calibration monitoring (OLM) and Aladdin for early fault detection and diagnosis (EFD&D). The Electric Power Research Institute (EPRI) OLM program has also been successful in demonstrating the applicability of OLM systems for calibration reduction (EPRI, 2000, 2004a-b-c) and their attention is now moving towards systems for equipment condition monitoring and fault diagnosis.

The success of the practical implementation and adoption of CI systems in nuclear power plants strongly depends on a number of factors that need to be addressed. The two most prominent are in our view the issues of licensing and integration. The licensing of OLM techniques and systems are beginning to be addressed, at least in the USA (EPRI, 2000, 2004a-b-c), but much work is still needed in order to identify and refine acceptable methods for the estimation of the uncertainty associated with the information generated by CI systems.

This paper tackles the second set of issues that are crucial for the success of CI systems, namely issues related to all aspects of the integration of CI systems in plant systems and operations.

The importance of integration becomes evident when one analyses the shortcomings associated with the lack of integration that is typical of a big part of computerised operator support systems (COSS) applications to date. Control room staff often report on COSSes being brought into the control room as an add-on to their existing set of support systems. Their introduction often fails to contemplate how the use of the system could be fitted to whatever tasks, working procedures or other support systems that the operators are actually using. One typical mistake is that the COSS is in the wrong place in the control room (often relegated to some corner of the control room). Another possible mistake is that it might require considerable extra input from the operator due to lack of communication with other systems already possessing this information. A third potential mistake is that the human-system interface (HSI) of the auxiliary system is not fitted to the tasks of the operator resulting, for example, in excessive navigation and unnecessary focus on secondary tasks. Even though the system in itself is well designed and implemented, the lack of integration often results in interface proliferation, workspace clutter, low usability, gradual fading of interest on the part of the operators, and higher operation and maintenance costs.

This paper recognizes three levels of integration that need to be addressed to take full advantage of CI implementations in nuclear power plants. These are the data level, the operational level, and the functional level. Each of these will be discussed in a dedicated section in the remainder of the paper. Additionally, four general integration principles have been identified, and will be discussed in Section 4.

2. COMPUTATIONAL INTELLIGENCE SYSTEM AT THE HRP

Before addressing later in the paper, in sections 3 and 4, the issues related to the integration of CI systems, this section briefly describes two examples of CI systems developed at the OECD Halden Reactor Project (HRP), namely the PEANO and Aladdin systems.

2.1 Fuzzy Logic and Artificial Neural Networks for On-Line Calibration Monitoring: The PEANO System

To ensure safe, efficient, and economical operation of nuclear power plants one needs to calibrate the safety-related instrument channels. Current practice of the calibration processes is to periodically determine the performance characteristics of an instrument and make adjustments if necessary. Typically, this is done once every fuel cycle, irrespective if the instrument is in need of calibration. This is a costly and labour-intensive approach and does not guarantee detection of instrument failure during plant operation, when it could contribute to optimisation.

On-Line monitoring (OLM) evaluates instrument channel performance by assessing its consistency with other plant indications. Industry and EPRI experience (EPRI, 2000, 2004a-b-c) at several plants has shown this overall approach to be very effective in identifying instrument channels that are exhibiting degrading or inconsistent performance characteristics.