Chapter 28
Evaluation of Human Machine Interface (HMI) on a Digital and Analog Control Room in Nuclear Power Plants Using a Fuzzy Logic Approach

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ABSTRACT

Nuclear Power Plants (NPPs) are nowadays facing a transition from analog to digital control rooms, mainly in the form of new interfaces for displaying sensor information as of Human Machine Interface (HMI) were one-sided, taking into consideration either the human or the machine perspective. The approach presented in the present article considers human machine interfaces met in nuclear power plants as a joint system, where the performance of the NPP operator is evaluated according to the cooperation level achieved with the machine. In particular, the purpose of this study is to provide a methodology to evaluate the degree of flexibility of an operator during the transition period from an analog to a digital system. The proposed methodology has been implemented by utilizing fuzzy logic inference and realized with the fuzzy toolbox embedded in Matlab software.

1. INTRODUCTION

A Human Machine Interfaces (HMI) is an essential mean in improving the efficiency and the performance of many tasks put through in nuclear power plants (NPP). A nuclear power plant operator faces a plethora of critical decisions on daily basis and has to deal with a large display panel and a number of control monitors. By taking into account the number of installations that reach their planned lifetime, then the necessity of assessing and upgrading the current infrastructure becomes apparent and urgent for many reasons ranging from security issues to energy protection initiatives (Alamaniotis et al., 2010). The guidelines confirming the above are available from the Electric Power Research Institute (EPRI) in (Naser, 2016).

Several studies have been conducted stressing the importance of an HMI capable of evaluating human performance and addressing nuclear power plant safety, for example in (Lin 2005), (Dudenhoeffer et al., 2007), (Carvalho et al. 2007), (Santos et al. 2008) and others. Fumizawa (2003) developed a simulator of the operator-computer (machine) interaction in the environment of a nuclear power plant that minimizes human error by reducing the operator's workload. The operator's mental condition and various design deficiencies of the HMI are the main issues studied in (Ha, 2009). More specifically, the aim of that study is to identify the factors which force an HMI system to behave poorly. Sheridan et al. (2000) have developed a criterion, based on expected-value decision theory, that determines if automation is preferable to human intervention or not. In (Pulliam, 1983) the authors denote that the integration of human operation with automated systems is critical, especially in cases of control procedures in nuclear power plants. Other studies address HMI issues by focusing either on the human or machine factor, trying to eliminate the drawbacks of each one. In (Jiang, 2015), many factors are presented in detail that may affect the human's reaction in emergency cases in the control room of a nuclear power plant. In (Boring, 2014), upgrades for two types of NPP control rooms are described, encompassing human factors design and verification, and validation capability. In (Rauterberg, 1996) quantitative test metrics are employed to validate user interfaces. Different points of view about how a user can realize human-machine interactions are presented in depth.

In (Choi, 1996), an HMI for a nuclear power plant has been developed where the HMI design aims to enhance user confidence and duration of plant availability, by elevating NPP reliability. The proposed HMI consists of large display panels monitoring the status of the power plant, and of several workstations - one for the supervisor, a second for the safety advisor, two for the operators and one auxiliary control station. The full-scope simulator for Yonggwang Units 1, 2 is used to validate the proposed HMI. In (Qianqian, 2010) an HMI is described ensuring availability and the safe operation of a nuclear power plant in China. The nuclear power plant is based on two-modular high-temperature gas-cooled reactors. In contrast to the design of the HMI presented in (Choi, 1996), the key elements of this one are the display panels and the control consoles. In (Ha, 2009) the HUman Performance Evaluation Support System (HUPESS) is proposed, which measures, analyzes and evaluates the human performance in NPP Main Control Rooms (MCRs). The factors utilized to evaluate the human performance were (a) the plant performance, (b) personnel task performance, (c) experience, (d) workload, (e) teamwork and (f) anthropometric and physiological features. Additionally, in (Yoshikawa, 2005) the authors focus on the configuration of an ideal human-machine interaction based on a joint human-machine system and discuss in detail various ideas on how automated systems act towards humans. The article (Hugo, 2016) deals with the new generation of NPPs and the design of Human-System Interfaces that take into

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