ARTIFICIAL NEURAL NETWORKS IN THE NUCLEAR ENGINEERING

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Introduction: The field of Artificial Neural Networks (ANN), one of the branches of the Artificial Intelligence (IA), is waking up a lot of interest in the Nuclear Engineering (NE). ANNs can be used to solve problems of difficult modeling; when the data are fail or incomplete; and in problems of control of high complexity. Several problems related with training and with generalization are to be solved to a safe utilization in nuclear plants systems. Eight years ago we started the research in this field. After few months we decided to focus on three ANNs concepts: feed-forward neural networks, self-organized maps (SOM), and multi-synaptic neural networks, one of our developments. The first discussions covered control applications. Few years later we start to work with approximation of functions and pattern recognition. Few set of problems were studied using three types of ANNs: feed-forward neural networks with the back-propagation algorithm; multi-synaptic neural networks (MULSY) applied to control and approximation problems; and self-organized maps (SOM), used in a typical pattern classification problem: transients classification and in the logistics of gasoducts. We offer a graduation course every year, since the year of 2000 and we have many students working with ANNs.

The control of dynamic systems: ANNs are the most powerful tools to control complexes systems. Multi-synaptic neural networks were developed at IPEN and proved to be the best choice to solve problems of control. We had invented a control unit able to work with complex dynamic problems as robotics and very slow non-linear process control. In 2004 we finalized an application to provide automatic control of the natural circulation loop at the thermal-hydraulic laboratory of IPEN.

Systems behavior training: An ANN receives the same input signals of a process an is trained with the system outputs to learn its behavior. Thermal and hydraulic systems are non-linear processes suitable to be "learned" by ANNs. The simulation of these complexes processes can be seen as the building of numerical models to estimate its behavior. This is a very important task in optimization and to develop monitoring and diagnosis systems.

Approximation of functions: The approximation of complexes functions is another typical application of ANNs.

Pattern classification: We also have worked with self-organized maps (SOM) in typical pattern classification problems: accident and transient classification; and gasoduct supervising systems. We found that SOM, an ANN trained by an unsupervised learning method, can be one of the most powerful tools for pattern classification. In 2004 we got a research project approved by FAPESP.

PROBABILISTIC SAFETY ASSESSMENT AND RELIABILITY ENGINEERING

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The research projects of this area are divided in two groups: Probabilistic Safety Assessment of Plants - It involves the evaluation of the safety of nuclear and industrial plants by the determination of the frequency of accidents and the analysis of site and environmental consequences. Reliability Engineering - It provides the theoretical and practical tools whereby the probability and capability of items (parts, components, equipments, products, and systems) to perform their required functions for a desired period of time, without failure, in specified environments, and with a desired confidence, can be determined, designed in, predicted, tested, and demonstrated. The project carried out in this sub-area is: Development of the Reliability Database for IEA-R1 and IPEN/MB-01 Research Reactors - In March 2001 the Nuclear Engineering Centre of IPEN signed a research contract with the International Atomic Energy Agency (IAEA) to develop a component reliability database for IEA-R1 and IPEN/MB-01 Brazilian research reactors as part of the Agency Coordinated Research Project (CRP) "To Update and Expand the IAEA Reliability Data For Research Reactor PSAs". The database software has been developed in order to process operational, maintenance and failure data of IEA-R1 and IPEN/MB-01 components. It also includes the storage of components descriptions and provides the user with several types of reports. Tha data collected and reported in this study have covered major components of selected systems of the two Brazilian research reactors.

Concerning IEA-R1 reactor, 185 failures of 49 different component types were compiled within an observed period from January 1999 to December 2003. In relation to IPEN/MB-01 reactor, 151 failures of 59 different component types were investigated within an observed period from October 1997 to March 2004. The component failure rates and associated 90% confidence limits derived from data collected at the reactors were tabulated and sent, via Internet, to the IAEA. The descriptions of the component types of both reactors were also provided. These results will be incorporated in the IAEA Reliability Database together with data collected by other participant Institutes in their research reactors. The research work developed at IPEN/CNEN-SP during these three years of IAEA CRP has brought several benefits to the Institute besides arising the interest of the managers of the two research reactors in the subject of reliability data and Probabilistic Safety Assessment (PSA) of nuclear facilities.