Machine Learning Applications to Power Systems

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1 Introduction

The recent developments in the power system area, i.e. the on-going liberalization of the energy markets, the pressing demands for power system efficiency and power quality, the increase of dispersed, renewable generation and the growing number of interconnections and power exchanges among utilities, dictate the need for improvements in the power system planning, operation and control. At the same time, the power equipment industry faces new challenges in nowadays ever-increasing competition. Artificial Intelligence techniques together with traditional analytical techniques can significantly contribute in the solution of the related problems. Indeed, during the last 15 years, pattern recognition, expert systems, artificial neural networks, fuzzy systems, evolutionary programming, and other artificial intelligence methods have been proposed in an impressive number of publications in the power system community.

Among the various power system functions, security remains a source of major concern. Power system deregulation and the increasing need to operate systems closer to their operating limits imply the use of more systematic approaches to security in order to maintain reliability at an acceptable level. Security assessment has proved therefore one of the most versatile ML applications leading to a large number of publications and an advanced application stage. Research started with Pattern recognition in the late sixties T.E. Dy Liacco [5], and seventies , C.K. Pang et al [13], etc. New methods have been developed next, able to handle the complexity and non-linearity of power system security problems, like ANNs and machine learning methods [6], [3]. Since the mid-eighties significant interest is expressed by various electric Utilities that has contributed significantly to formalize the application methodology and to develop software tools. L. Wehenkel [21] provides an excellent overview of these developments.

Forecasting is another very popular application of ML techniques, developed since the early seventies. A number of ANNs have been proposed, mainly in the areas of short-term load forecasting, e.g. Papalexopoulos et al. [14], and various real-life applications have been presented. The increasing wind power penetration mainly in isolated power systems poses the need for short-term wind power forecasting for efficient operation scheduling. Fuzzy models, genetic approaches and neural networks have proven to outperform traditional approaches [11].

Power system operation optimization is another versatile field for ML applications. The problems of Unit Commitment and Economic Dispatch, traditionally tackled as non-linear, constrained optimization problems, have lent themselves recently to genetic algorithm approaches, e.g. Sheble [17]. Other applications of ML techniques

G. Paliouras, V. Karkaletsis, and C.D. Spyropoulos (Eds.): ACAI '99, LNAI 2049, pp. 308-317, 2001.

concern the areas of monitoring, ranging from monitoring of individual devices and power plants to sophisticated system monitoring. For example, ML applications to transformer monitoring and power plant monitoring based on real time measurements of high accuracy can detect critical situations and predict failures. Modeling of the physical behavior of the system is yet another area open to ML applications, e.g. load modeling. ML techniques have also been used to accelerate traditional analytical techniques, as Finite Element methods, to calculate electromagnetic inference problems.

The papers presented in this Workshop broadly correspond to the above areas of ML applications. These papers are classified in two groups, the first deals with ML applications at power system level, while the second focuses mainly on applications at power system component level. In the first group the problems of Dynamic Security Assessment and Control, Economic Dispatch, Power Flows and Restoration are tackled. The second describes applications in Transformer Manufacturing, in Wind Power Forecasting, in prediction of electromagnetic fields due to Inductive Inference and in aiding the application of the Finite Element method to solve electromagnetic field problems. It should be noted however, that this list is only indicative of the large potential of ML applications in the Power system area. The interested reader can find an impressive number of related publications in the Proceedings of various Conferences, particularly ISAP (Intelligent System Applications to Power Systems), PSCC (Power System Computation Conference) etc., in CIGRE publications and in journals, such as the IEEE (Transactions of Power Systems), IEE (Proc. Generation, Transmission and Distribution), EPES (Electric Power and Energy Systems), EIS (Engineering Intelligent Systems), etc. Admittedly however, today only a few large Utilities in North America and Europe actually use ML applications for planning, operation and control of their power systems. In Europe, at least one of them (EdF) is presently using the ML methodology for dynamic security assessment in real field studies. Field tests on load forecasting by ANNs have been reported by Electric Companies like Pacific Gas & Electric Co., ABB Systems Control, Tractebel S.A., Siemens A.G., Puget Sound Power & Light, EPRI, EdF, etc. [6]. A number of ML functions tailored to island systems with increased wind power penetration have been developed within the European project CARE [1] and applied to Load and Wind Power Forecasting, Unit Commitment, Economic Dispatch and On-line Dynamic Security Assessment. The CARE system has been integrated in the Control Center of Crete and provides operating advice to the system operators.

2 Description of Workshop Papers

This section presents an overview of the papers presented during the workshop on "Machine Learning Applications to Power Systems" organized as part of the Advanced Course on Artificial Intelligence (ACAI ’99) [22].

2.1 Machine Learning Applications at the Power System Level

The paper by Sobajic et al. [18] describes an intelligent neural controller for optimal regulation and maximal stabilization of a power system. This is achieved by adding an additional neural network-supplied control signal into the excitation system