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Leak detection in high pressure pipe-type cables using artificial neutral networks

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Abstract: *This paper describes a study to develop a methodology based on application of artificial neural networks to monitor the status of High Pressure Fluid-Filled (HPFF) cable systems, detect leaks as small as 1 gallon per hour and to sound an alarm when the operation of the system deviates from normal. The goal was to develop an economical and effective system to detect leaks and provide the system operator with information to make prudent decisions and minimize environmental impacts, which may result from pipe leaks.*

Résumé: *Ce rapport décrit une nouvelle technologie basée sur la méthode des "réseaux neuraux artificiels" pour détecter la présence de fuites aussi faibles que 4 L par heure dans des cables à huile à haute pression (HPFF) et pour alerter le personnel de surveillance en cas de fuite. L'objet de ce développement est d'obtenir une technologie fiable et économique pour détecter ces fuites. Ce système permet au personnel de surveillance de prendre les mesures nécessaires pour ménager l'environnement.*

Introduction

The project was divided into three interrelated activities: (1) development and testing of the Artificial Neural Network (ANN) model, (2) an experiment in the lab to test the validity of the approach and to develop a prototype structure of the ANN to be used in field application, and (3) the development of the computer software for the dielectric fluid leak detection in a pipe-type cable system using the ANN methodology.

The development of a neural network model examined various combinations of input and output parameters, which could be used as indicators of an abnormal system operation. To detect small leaks between one and five gallons per hour, we have selected a combination of oil temperature and pressure as suitable parameters for analysis through an ANN model. Larger leaks require information on the operation of the pressurizing pump, which is switched on when the oil pressure drops below a design value and the operation of the pressure relief valve. During phase one of the project, two ANN models for the detection of small and large leaks were built. Both models were tested on sets of real field data supplied by Consolidated Edison Company of New York Inc. The results of the lab experiment for a static system were used to select the ANN model used for testing of the field data. Through the analysis of data obtained from lab experiment and from field measurements on one of Con Edison's 345 kV pipe-type cables, we have shown that the methodology shows significant promise. Field tests have been undertaken.

Neural network model

Detecting dielectric fluid leaks from a pipe-type cable can be viewed as a state classification problem. Two classes of system states are defined in this case: (1) normal operating conditions (that means that there is no fluid leak), and (2) abnormal operating conditions (this may mean that there is a leak or a system fault or other conditions for which the system was not trained). An acceptable neural network, after a suitable training period, should be able to classify a given system state into one of the two categories.

There are several steps in the development of the model for this application. The most important are: (1) selection of network topology, and (2) selection of the learning rule. The definition of the input space of the network is also an important step. Two types of network structures were considered for this problem: (1) a network with output branches feeding back into input nodes (called autoassociative networks), and (2) feedforward networks (called heteroassociative). Autoassociative networks require only one set of input parameters representing a single time instant, whereas heteroassociative networks require measurements taken over several time instances. The disadvantage of autoassociative networks lies with the difficulty in conducting computer simulations and perceived problems with learning during field operation. Therefore, we have decided to use a feedforward network with the input layer containing as many nodes as needed to represent the data from several consecutive measurements.