DETECTION OF A SELECTED CLASS OF STEAM BOILER DAMAGES IN A THERMAL POWER PLANT WITH THE USE OF INTELLIGENT CLASSIFICATION OF SIGNAL FEATURES

Modern manufacturing plants, which are usually very complex and expensive, should provide sufficiently high level of reliability and guarantee safety of technical personnel. Despite the continuous technological progress and increasing reliability of all the plant elements as well as substantial development of the computer-based plant control systems, various faults of technological components, measurement, control devices and staff errors can cause serious material or human losses. Currently, when the most important objectives of enterprises may include reducing production costs, it is reasonable to draw much more attention to one type of boilers damage that generate more than 60% of the time emergency exemptions.

Water/steam leakages are typical faults that frequently occur in boiler systems. Early detection of faults can help to avoid power plant shut-down, breakdown and even catastrophes involving human fatalities and material damage. Most methods of leakage detection described in literature have not been implemented in industrial practice.

The dissertation presents the problem of boiler leak detection using selected methods of artificial intelligence. The proposed techniques allow assessment of the current state of the process by appropriately applied methods of neural networks and pattern recognition, which apply wavelet decomposition of signals.

This PhD dissertation has eight chapters. The order of the chapters, except introduction (the first one) and conclusions reflects the chronology of research work.

The first chapter discusses the incentive to work and presents the thesis of the dissertation. The problem considered in this dissertation concerns the extraction of information from measurements for diagnosis issues. The approach was based on the assumption that faults are reflected in the statistical parameters of signals (boiler measurement variables).

The second chapter provides an overview of the technological process, in which the steam boiler is a critical element. It identifies the key features and specifics of the process and its major characteristics. Boilers are inherent nonlinear processes and they often run in the condition of changing set points due to varying boiler loads, what is a big challenge for all methods. The working conditions of thermal systems depend on the ambient conditions. Despite their importance in industrial processes, the methods of their detection are rarely encountered in books or journals.

The third chapter contains the currently used methods of pipeline leak detection in boilers. There were described, specified and characterized methods used to assess the state of the process by:

a) acoustic monitoring,
b) steam/water balance testing,
c) monitoring of flue gas humidity,
d) methods based on models of the process,
e) methods using artificial intelligence (AI),
f) using PCA models.

The fourth chapter proposes the concept of the diagnostic system to monitor the status of the process based on statistical methods with the modified principal component analysis (PCA), based on a comparison of data containing periods of trouble-free operation and faulty periods. Developed methods of diagnosis were based on analysis of the essential characteristics contained in the time course of measured process variables. The final part of the chapter introduces the results of investigations on boilers leak detection. PCA analysis allowed to clearly map data distribution from the n-dimensional space into the three-dimensional space. The results of numerical experiments conducted on the basis of the real plant operation data supplied by Elektrociepłownia Białystok are presented and discussed.

The fifth chapter contains a theoretical discussion of the MPCA algorithm and a few examples of the MPCA method for detection of leaks in the boiler.

Early warning, obtained through the PCA or MPCA model may be transferred to operators in a very simple and understandable way (as visualization of the process). The measurement signals recorded in the database of archival work during the course of the development of fault-free and damage were given to the input of the classifier to establish the state of the process.

The sixth chapter is devoted to the use of neural networks for diagnostic inference employing a method of pattern recognition. The problem of detecting damage was considered as a classification task. Neural networks provide good mathematical tools for dealing with nonlinear problems, which can extract the signal features from historical training data, using a learning algorithm. The significance of this technique is based on its ability to reserve old data in equitable probabilities during the training process. The MLP and LVQ neural networks were trained based on the set of characteristics selected by analysis of PCA. There were prepared the strings of learning and test sequences for several cases of emergency shut down of the boiler.

In the seventh chapter wavelet analysis was applied as the initial signal processing method. Fault detection and diagnosis algorithms based on wavelet decomposition and classification of input/output mapping are studied and the accuracy of classification techniques are evaluated. The optimal number of features which unambiguously characterize the condition of the process, allowing for reliable and accurate diagnosis, was identified and established experimentally. The classifiers studied in the chapter were using LVQ neural networks with selected features of wavelet decomposition.

Chapter eight is a summary and comparison of the methods of artificial intelligence and an indication of the optimal solution of an early leak detection system based on a database of diagnostic patterns.

The tests and the results presented in the dissertation prove the thesis that: it is possible to detect and locate of pipeline leak in a steam boiler working in an automatic control system by an intelligent classifier using selected features of the time-frequency transforms of signals. The main thesis of dissertation has been proved.