SILESIAN UNIVERITY OF TECHNOLOGY

WYDZIAŁ AUTOMATYKI, ELEKTRONIKI I INFORMATYKI

KIERUNEK: INFORMATYKA

Summary of the doctoral dissertation

Increasing the operational reliability of power unit equipment through the use of predictive analytics

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Spis treści

1 Abstract

The subject of the dissertation is related to the design of information technology solutions based on advanced data mining methods to support production processes in a power plant. Advanced technologies enable the potential of existing datasets to be utilised, providing an opportunity to improve areas previously unsupported by information technology due to high costs or lack of appropriate tools. One of the application areas for this type of advanced analytics is predictive maintenance, which involves the early detection of faults based on existing measurements. Predictive maintenance, by identifying the first symptoms of a potential fault in production equipment long before a failure occurs, makes it possible to reduce both unplanned and planned downtime, thereby increasing the availability factor of a piece of equipment or an entire plant.

The main objective of the study was to find areas where it becomes possible and effective to use techniques associated with predictive maintenance and to develop tools and analytical models to perform these tasks. Due to the complexity of technological processes, particular attention was focused on modelling methods that do not require a lot of engineering knowledge, but allow scalable solutions to be achieved that meet the set expectations for model reliability. The specific research objective was to develop an analytical model on the basis of data collected from information and technology systems to predict upcoming faults and failures. Based on historical measurement data and failure information, a heuristic predictive model was proposed based on selected data mining techniques.

Considering the subject of fault detection techniques covered in the literature, a technique based on the regression method was proposed, allowing the detection of potential faults in the future on the basis of the observed anomalies between the measured signal and its digital reconstruction. The prediction model developed makes it possible to predict and prevent equipment failures and, consequently, it provides improved planning support for maintenance, overhaul and procurement processes.

The scope of research in the area of predictive maintenance in power plants includes the analysis of the operation of specific power plant equipment with documentation of their failures and technical condition. One of the issues considered is how to prioritise and present the data from the analytical systems in a user-friendly format. Often, relevant data is beyond the perception of the addressee, getting lost in the information noise. It also proposes how to normalise the results and how to interact with the user by visualising the results and triggering alarms. A correct assessment of the reliability and value of information is the basis for changing decision-making from intuitive to data-driven. Significant issues addressed in the paper were therefore the problems associated with the implementation and subsequent maintenance of the solution. A process for creating and parameterising predictive models was proposed. The proposed methods were applied in an experiment to confirm the feasibility of automating the creation process and transferring the solution to other

devices.

Concerning issues of solution maintenance, a method is proposed to reduce the negative impact of concept drift on the predictive capabilities of the model.

The results obtained from the experiments confirmed the effectiveness of the proposed method in the task of detecting major faults in power equipment. In the work in progress, a detection and fault identification system was designed and developed methods to automate the process of creating and updating predictive models.

1.1 Publications

The research results of this dissertation were presented in the following publications:

1. Moleda Marek, Dariusz Mrozek. "Big data in power generation." International Conference: Beyond Databases, Architectures and Structures. Springer, Cham, 2019. Punktacja MNiSW: 15 pkt.

2. Moleda Marek, Alina Momot, Dariusz Mrozek. "Predictive maintenance of boiler feed water pumps using SCADA data." Sensors 20.2 (2020): 571. Punktacja MNiSW: 100 pkt. Impact Factor: 3.275

3. Moleda Marek, Alina Momot, Dariusz Mrozek. "Regression Methods for Detecting Anomalies in Flue Gas Desulphurization Installations in Coal-Fired Power Plants Based on Sensor Data." International Conference on Computational Science (ICCS). Springer, Cham, 2020. Punktacja MNiSW: 140 pkt.

4. Moleda, Marek, Alina Momot, Dariusz Mrozek. "Concept Drift and Avoiding its Negative Effects in Predictive Modeling of Failures of Electricity Production Units in Power Plants." 2020 28th International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS). IEEE, 2020. Punktacja MNiSW: 140 pkt.

5. Moleda, Marek, Dariusz Mrozek, Weiping Ding. "Evolution of maintenance approaches towards smart power industry - a review". Journal of Engineering Applications of Artificial Intelligence (w trakcie recenzji). Punktacja MNiSW: 140 pkt. Impact Factor: 6.212

1.2 Motivation

The power system requires high availability of power units to ensure both the required level of electricity production and to secure an adequate power reserve. Traditional approaches and processes related to power plant maintenance and asset management, can be complemented or replaced by solutions based on advanced data exploration methods. These solutions allow decisions based less on intuition and more on knowledge and facts. A contributing factor to the growth of such an approach is the increasing technological progress that allows the application of modern solutions and the extension of the use of existing systems for purposes other than the initial purpose.

Due to increasing computerisation and digitisation, large amounts of data of various types are processed in industrial plants, both in technological systems and information systems. Measurement data from production systems, data from relational databases, monitoring images or manually created records and documents are processed. The scope of processed data, the complexity of technological processes, the fact that the data sources are scattered and the unclear correlations between them make it difficult to make optimal use of them, giving the benefits of the knowledge obtained through data analysis. Knowledge concerning the possibilities of using these data, their correlations with business processes and the development of innovative analytical tools will optimise the benefits of implementing modern solutions in the area of predictive maintenance, as well as show their potential impact on business and technological processes carried out at TAURON Wytwarzanie S.A. Implementing predictive maintenance requires high investment in the form of additional measurement systems, as well as an IT system and specialised expertise. Therefore, the main motivation in the work is to use existing data repositories and, to a limited extent, expert knowledge to create a system that implements tasks in the area of predictive maintenance.

1.3 Thesis of the dissertation

Taking into account both the research and implementation objectives of the project and the mentioned challenges, the following research thesis were formulated:

1. The use of regression-based analytical redundancy methods operating on large datasets from industrial systems allows the task of predicting failures and faults in a situation of:
    - a limited number of analysed features and events,
    - varying working conditions due to frequent renovations and the influence of external factors.
2. An adaptive sliding window algorithm based on the analysis of the mean partial values of the elements of this window allows the quality parameters of the fault detection model to be maintained, while reducing the need for periodic supervised updating of the models.

3. The process of data engineering and creating predictive models based on machine-generated data from industrial equipment can be automated for application against new equipment, maintaining similar predictive capabilities.