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FAULT DIAGNOSIS OF NATURAL GAS PUMPING UNIT BASED ON MACHINE LEARNING

This paper presents a method for fault detection of natural gas pumping unit. It is a very difficult object for diagnosis. A lot of combinations of technical equipment, different operational conditions, and other factors require design and implementation of reliable diagnosis methods. Acoustic signal based fault diagnosis of natural gas pumping units is well known and widely used in a number of applications. Statistical modeling and frequency analysis are among the most popular. In this paper, we share our experience in the use of the classification model based on an artificial multilayered dense feed forward neural network and a deep learning approach for software-implemented diagnosis of a GTK-25-i type of pumping unit. The paper reports the overall accuracy of 0.98 and minimum F1-score of 0.8. This is competitive compared to the latest industry research findings.

Keywords: *deep learning, neural network, fault diagnosis, fault detection, natural gas, pumping unit, digital signal processing, classification, acoustic emission, vibration.*

There is a large number of GTK-25-i natural gas pumping units (GPU) manufactured by Nuovo Pignone company within the natural gas transmission system (GTS) of Ukraine. These GPUs have been operating for decades. This led to malfunctions and to emergency stops. Thus, high-quality continuous monitoring of the technical condition and technical diagnosis are very important tasks.

Parametric diagnosis methods and techniques have been presented in papers [1]. It has been shown that Bayesian networks, fuzzy logic or probabilistic networks can be used to implement a decision support system for parametric diagnostics. A large amount of research papers has been devoted to the methods of GPU diagnosis based on vibration signals [2]. Many papers have presented the acoustic signal based diagnosis [3]. The monitoring system of pumping units based on frequency analysis has been described in [4]. The paper [5] has proposed the method of the technical condition assessment of natural gas pumping unit based on step response. Artificial neural network approach has been presented in [6].

The research was conducted with the vibration and acoustic data sampled in operating mode of GTK-25-i pumping unit. Sampling rate: 44.1 kHz, ADC resolution: 16 bit, ADC full scale: 32767 LSBs corresponds to +4 dBu level (1.228 Vrms, 1.736 Vpk, 3.472 Vpp). The total size of the dataset is 36878 signal fragments: 10339 fragments for the "nominal" state, 25033 fragments for the “normal” state, and 1506 fragments for the “faulty” state. Entire dataset has been split into training, validation, and test sets using the following ratio 70% : 10% : 20%.

Architecture of a deep dense feed forward neural network was developed. It was trained using the back propagation algorithm. Input dimension of the neural network is 12. The output layer contains three neurons for each state. The neural network contains two hidden layers containing 256 and 128 neurons respectively. This number of neurons is selected based on the need to provide the required network capacity. The hidden layer uses the ReLU [7] activation function, and the output layer uses the SoftMax activation function. Batch normalization is applied between all layers.

The model was trained on a specialized server equipped with a high-performance graphics adapter Tesla P4 GPU with 7611 MiB of video memory (NVIDIA-SMI 460.56, Driver Version: 460.32.03, CUDA Version: 11.2). The training procedure lasts approximately 62.5 μs per one sample, 2 ms per one step (batch), 370 ms per one epoch. The number of samples per update of the optimizer gradient (batch size) is 32.

Evaluation of the developed model was performed with the test set size of 1475 fragments of signals. The obtained value of test accuracy is 0.98. Testing was performed in a post-predict manner, when the test data passes through a predict procedure. After that, the predictions were compared with the ground truth and the confusion matrix was obtained.

The overall goal of the study was to prove the possibility of effective fault detection of natural gas pumping units using deep machine learning and artificial neural networks. The main results of the study show that the use of simple feed forward neural networks has acceptable outcome.

The research has provided a more complete understanding of the processes occurring during technical diagnosis of natural gas pumping units. Current findings suggest that classification of the status of the GTK-25-i GPU can be successfully performed with an artificial dense feed forward neural network using combination of acoustic emission and vibration signals as model features. For more detailed information please refer to [8], [9]. Using of entropy as a feature [10] for the model will be a subject of our future work.

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