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AUTOMATIC RECOGNITION OF ARMATURE CURRENT OF DC MOTOR WITH APPLICATION OF FFT AND GSDM

AUTOMATYCZNE ROZPOZNAWANIE PRĄDU TWORNIKA SILNIKA PRĄDU STAŁEGO Z ZASTOSOWANIEM FFT I GSDM

Paper presents the concept of investigations of signals of armature current of DC motor. Algorithms of signal processing and analysis have been used. System is based on the FFT algorithm and GSDM (*Genetic Sparse Distributed Memory*). Software of armature current recognition of DC motor was implemented. Studies were carried out for imminent failure conditions of DC motor. The results confirm that the system is useful in diagnostics of electrical motors. System can be used in inspection of metallurgical equipments.
Keywords: Diagnostics, Recognition, Classifier, Armature current, DC motor

W referacie przedstawiono koncepcję badania sygnałów prądu twornika silnika prądu stałego. Algorytmy przetwarzania i analizy sygnału zostały użyte. System rozpoznawania prądu oparty jest na algorytmie FFT i GSDM (*Genetyczna rozrzedzona pamięć rozproszona*). Zaimplementowano oprogramowanie do rozpoznawania prądu twornika silnika prądu stałego. Przeprowadzono badania dla stanów przedawaryjnych silnika prądu stałego. Wyniki badań potwierdzają, że system jest przydatny w diagnostyce silników elektrycznych. System może być wykorzystany do kontroli sprzętu hutniczego.

1. Introduction

At present there are many methods of signal processing. Most of them are based on data processing. Advantages of these methods are: fast calculations and high efficiency of recognition. Mechanical and magnetic properties of materials were investigated [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27]. The tribological properties of high speed steel based composites were investigated [28]. Other diagnostic methods were developed [29], [30], [31], [32]. In the literature, popular methods are based on a study of electrical signals [33], [34], [35]. So it is important for electrical equipment. For example, electrical motors are widely used in steelmaking and in smelting of nonferrous metals. Typical EAFs operate at power levels from 10 MW to 100 MW [36].

The mechanism of fault detection in DC motor was proposed and developed. System makes possible to identify current of armature of DC motor. Application can classify feature vectors [37]. Feature vectors are created as a result of data processing and FFT. There was applied GSDM as a classifier. System works automatically. It can be noticed, that current of faultless DC motor is different from current of faulty DC motor. It can determine the state of DC motor. It could be used in other applications. These studies can be used to the diagnostics of electrical machines, mechanical machines, hydraulic machines, pneumatic machines. The paper presents new implementation of the diagnostics of imminent failure conditions of DC motor.

2. Process of recognition of armature current

Process of recognition of armature current contains pattern creation process and identification process.

At the beginning of pattern creation process signals are normalized and filtrated. Afterwards data are converted through the Hamming window. Next data are converted through the FFT algorithm and GSDM. FFT algorithm creates feature vectors. Features vectors contains harmonics of frequency. Features vectors are used in writing operation of GSDM. Pattern creation process and identification process are based on the same signal processing algorithms.

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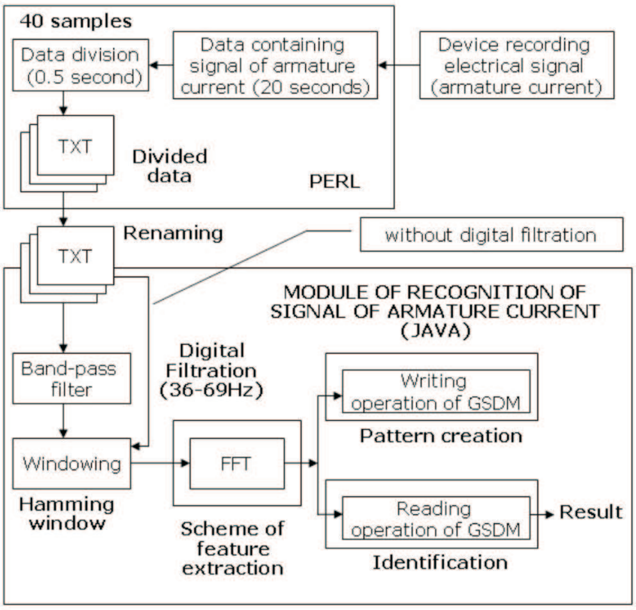

Fig. 1. Process of recognition of armature current

In the process of identification of armature current, algorithms of signal processing are the same as for the pattern creation process. Significant change occurs in the classification. There is reading operation of GSDM. It identifies category of armature current. Process of recognition of armature current is illustrated in the block diagram (Fig. 1).

The measuring set-up consisted of antialiasing filter, data acquisition card, and personal computer. The data were recorded with the following parameters: sampling frequency was 40000 Hz, number of bits was 16, number of channels was 1 (Fig. 2 and Fig. 3).

2.1. Preprocessing and analysis of signal of armature current

Armature current of DC motor is written to data file (.txt). System divides data into small blocks. There are following advantages of such solution: precise determination appearing of armature current, precise identification of armature current. Next system reads data. Next filtration and windowing are used. Digital filtration is used to modify the frequency domain of the input sample.

After that the Hamming window is used to avoid distortion of the overlapped window functions. FFT transforms time domain to frequency domain. It is applied instead of discrete Fourier transform because of shorter time of calculations. It takes a window of size 2^k and returns a complex array of coefficients (harmonics).

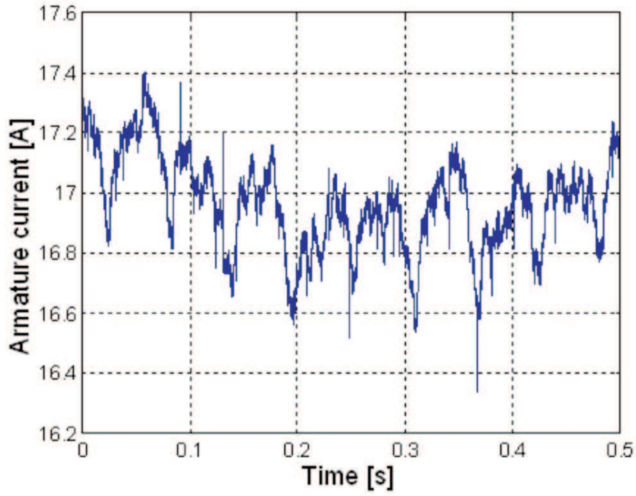

Fig. 2. Signal of armature current for faultless DC motor (0.5 s)

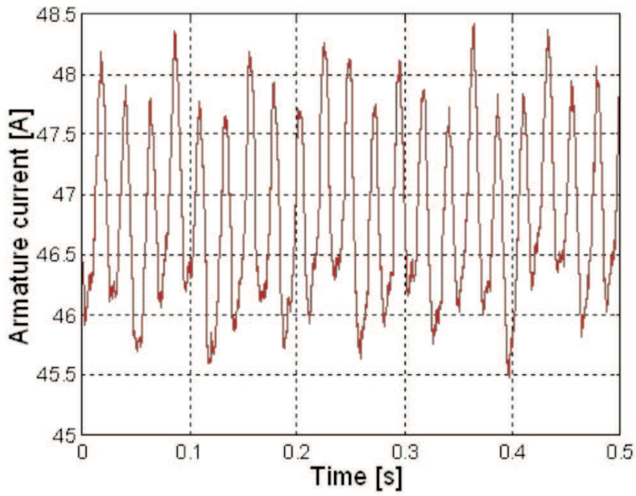

Fig. 3. Signal of armature current for DC motor with shorted rotor coils (0.5 s)

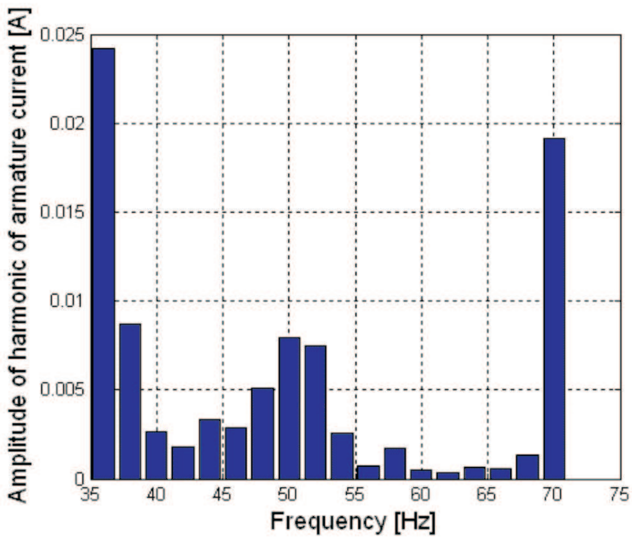

Fig. 4. Frequency spectrum of armature current for faultless DC motor (35-70 Hz)

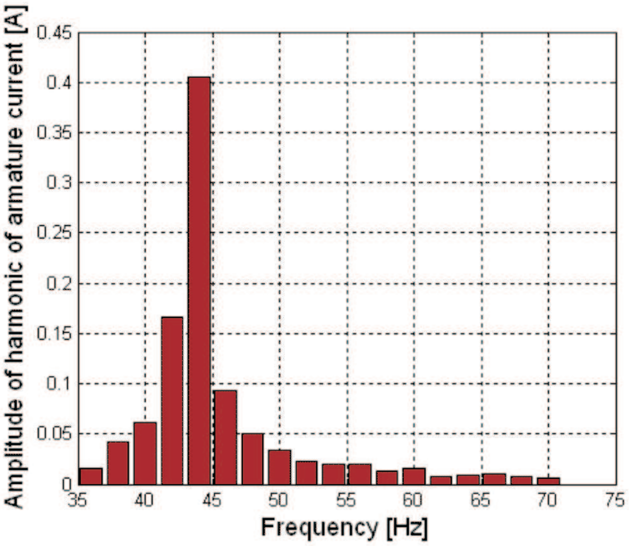

Fig. 5. Frequency spectrum of armature current for DC motor with shorted rotor coils (35-70 Hz)

These coefficients create feature vectors which are used in calculations (Fig. 4 and Fig. 5). Feature vectors contains 1-8192 coordinates.

2.2. Classification

In the literature there are many methods of classification [37], [38], [39]. Sparse Distributed Memory (SDM) is one of the self-organizing neural networks that mimic closely the psychological behaviour of the human brain. In this paper, Genetic Sparse Distributed Memory (GSDM) model combines SDM with genetic algorithms.

In fact, the reading operation of GSDM is the same as that of SDM. The only difference is that an effective writing operation guided by genetic algorithms is added. However, each genetic operator is applied to different situations. Initially, GSDM has a finite number of storage locations, say N, with empty addresses and contents. The address, **p**, of a training pair (**p**,**d**) is sent into memory to get selected storage locations by calculating the Hamming distance. Three cases will occur:

1. if the number of selected storage locations, **s** is equal to zero then pattern **p** is reproduced as a candidate address. Then a small number of random bits of a candidate address are selected and changed – this constitutes a mutation operation. The newly generated address is added into address array if there is an empty address, otherwise it is discarded.
2. if **s** is larger than a threshold, then the writing rule is just the same as that of SDM.
3. if **s** is larger than zero and smaller than the threshold, this means that the selected addresses are too few to characterize its original data. A new address should be added into the memory. The addition of a new address into memory in this situation is made possible by a crossover operator. First, two addresses which have the least distance with **p** are mated by the crossover operation. Than an integer is randomly generated as the crossover point and the prefix of one address is joined with the suffix of the other address relative to the crossover point. The generated crossbred address will be appended into the address array.

The reason why GSDM initially empties the addresses of storage locations is that it can prevent loss of the data far from the center of the distribution of the address array. The simplicity of SDM's reading and writing operations is still preserved under GSDM. To implement the memory model of GSDM in pattern recognition, it is clear that the writing operation can be verified as a learning procedure, and that the reading operation is related to the recognition procedure. Process of recognition of armature current is based on GSDM [40], [41].

3. Results of recognition of current

DC motor had following operation parameters: P_N =13 kW, U_N =75 V, I_N =200 A, U_{fN} =220 V, I_{fN} = 4 A, n_N =700 rpm.

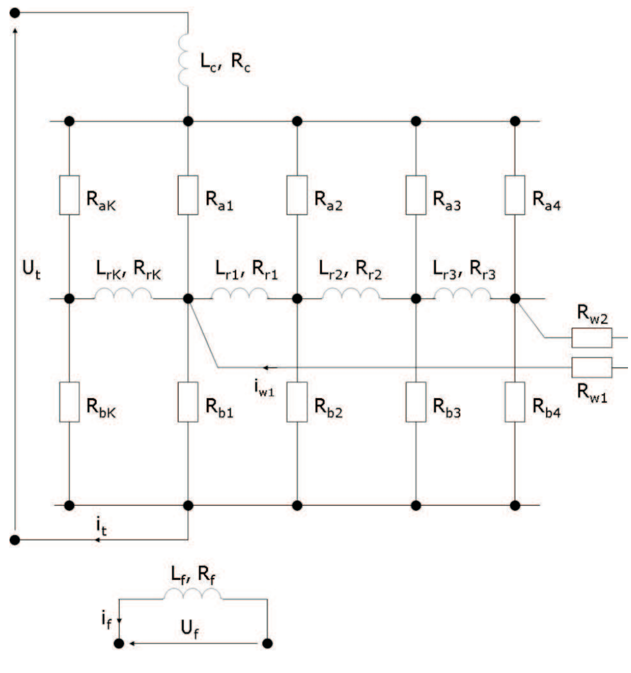

Fig. 6. Diagram of windings for faultless DC motor

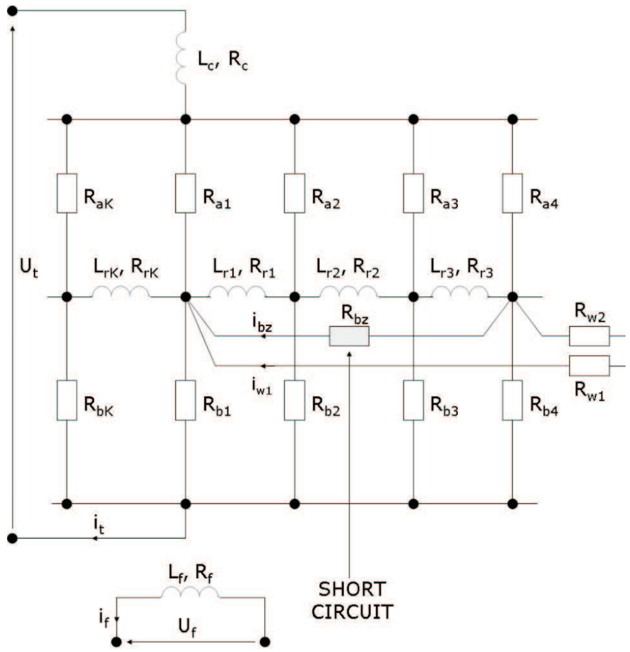

Fig. 7. Diagram of windings for DC motor with shorted rotor coils

It was assumed that each group of three loop rotor coils is shorted through resistance R_{bz} = 7.7 mΩ. The DC motor connected with external resistance produced the load torque. The additional resistance were used in short-circuit to avoid damage of rotor winding. Investigations were carried out for signal of armature current of faultless DC motor and armature current of DC motor with shorted rotor coils (Fig. 6 and Fig. 7). Five half-second samples were used in pattern creation process for each type of signal. There were used 100 samples of armature current of faultless DC motor and 100 samples of armature current of DC motor with shorted rotor coils. These 200 samples were used in identification process.

Efficiency of recognition of armature current is defined as:

$$E = \frac{X_1}{X} \tag{1}$$

where: E – efficiency of recognition of armature current, X_1 – number of correctly identified samples, X – number of all samples.

System should determine the condition of DC motor. Good results for GSDM were obtained for harmonics of frequency range 36-69 Hz. Efficiency of recognition of armature current for faultless DC motor was 100%. Efficiency of recognition of armature current for DC motor with shorted rotor coils was 90%. Parameters of GSDM were chosen as follows: Hamming distance =150, accuracy of the identifying = 0.90, the number of iterations in the genetic algorithm = 100, rate of mutation in genetic algorithm = 0.01, the number of characters of current category = 5, size of GSDM = 500.

4. Conclusions

System of recognition of the armature current was proposed and developed. System worked automatically. Good results were obtained for harmonics of frequency range 36-69 Hz. Efficiency of recognition of armature current for faultless DC motor was 100%. Efficiency of recognition of armature current for DC motor with shorted rotor coils was 90%.

Time of performance of identification process of half-second sample was 0.672 s for Intel Pentium M 730 processor (digital filter, FFT, GSDM). Current recognition system can be useful for protection of motors and metallurgical equipment. System can be useful in inspection of metallurgical products.

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