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Comparison of various methods of the control of flux density waveform

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Abstract

In the paper are discussed various methods of control of waveform of the flux density in magnetic circuit. Three methods have been designed and tested: analogue one, digital one using the adaptive filter and second digital using the prerceptron neural network. The digital methods have been designed as the SubVI of the LabVIEW programming platform. The most efficient appeared the application of the neural network.

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1. Introduction

The standards of testing the magnetic materials require to guarantee that the flux density is a sinusoidal waveform. Moreover in special investigations of magnetic materials it is necessary to establish arbitrary waveform of flux density or magnetic field strength (for example square wave, PWM or other).

The oldest method of sinewave control is the analogue feedback method [1]. The advantage of this method is that it is not necessary to use the computer support - only pure electronic circuit is sufficient. But today practically all measuring systems for magnetic materials investigations use the computers.

Analogue method although relatively simple disappoints in more extreme conditions, for example for high flux density or other than sinusoidal systems are currently more frequently used [2–5].

Paper presents the comparison of three relative simple systems for control of the waveform of the excitation of magnetic circuits.

2. The analogue system

Figure 1 presents the block diagram of analogue system. To the input amplifier are connected the source generator and feedback signal. As the feedback signal can be used secondary winding voltage V_B proportional to the dB/dt (sinusoidal flux density waveform) or V_H voltage proportional to the magnetising current (sinusoidal magnetic field strength waveform). To the summing output amplifier there are connected additionally two signals - from differentiating amplifier connected to the V_H voltage (correction of the stray fields) and from the $50Hz$ and $150Hz$ phase shifters (correction of the eventual distorted generator signal).

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Two cases have been tested: with the source generator and with the power net used as the source. The results are presented in Table 1.

Table 1
Distortion of the dB/dt signal and B signal when as the source the power net was used (a) and when as the source signal generator was used (b)

Tested signal	Case	THD [%]
a) input signal	power net	0.4
a) dB/dt	without feedback	22
a) dB/dt	with feedback	3.6
a) B	without feedback	6.4
a) B	with feedback	1.0
b) input signal	signal generator	3.6
b) dB/dt	without feedback	22
b) dB/dt	with feedback	5.3
b) B	without feedback	7.4
b) B	with feedback	1.4

Even when as the source generator was used distorted power net (case a) the flux density waveform was perfectly sinusoidal.

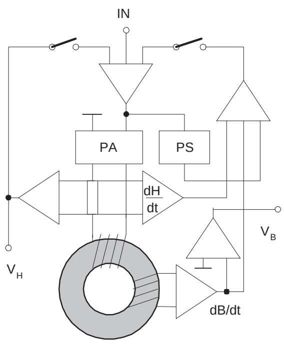

Fig. 1. The magnetic circuit with the neural network used to control the waveform

3. The adaptive filter system

The system with adaptive filter is presented in Fig. 2. The system consist of computer with data acquisition board (including digital to analogue DAC converter and analogue to digital ADC converter) and power amplifier PA. As the source generator is used virtual sine wave generator (subVI of LabVIEW programme). The fixed value (and shape) source signal via filter coefficients units h_n (individual for every sample), DAC unit and power amplifier is connected to primary winding. The secondary voltage via ADC unit is compared (sample by sample) with reference signal. The difference is used to change the filter coefficients h_n according to the LMS (least mean square) method.

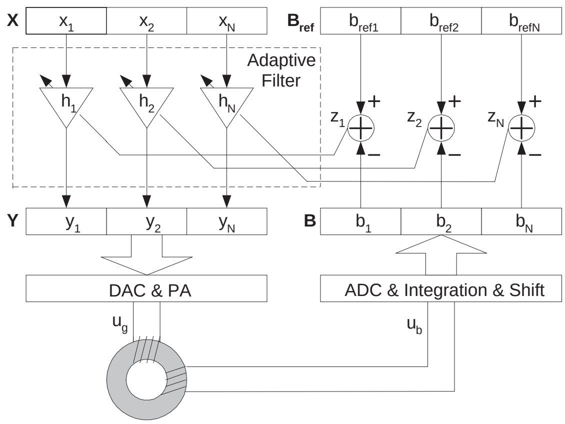

Fig. 2. The magnetic circuit with the adaptive filter used to control the waveform

4. The neural network system

The system with neural perceptron network (Fig. 3) works similarly to described earlier adaptive filter. A virtual source signal is converted by two-layer perceptron net with input number equal to number of samples.

The weights of perceptron layers are initialised randomly. Next from the difference between reference and output voltage the weight coefficients of the last layers are computed. Next according to the principle back propagation of errors the weight of the next layers are determined. The adaptation of the weights is realised according to the relation $\mathbf{w}(k+1) = \mathbf{w}(k) + \triangle\mathbf{w}$, where $\mathbf{w}(k)$ are the weights in the k-step and $\triangle\mathbf{w} = -\mu\nabla E(\mathbf{w})$. The μ coefficient is the learning rate while objective function $E(\mathbf{w})$ is

$$E(w) = \frac{1}{2}\sum(b_k - b_{refk})^2$$

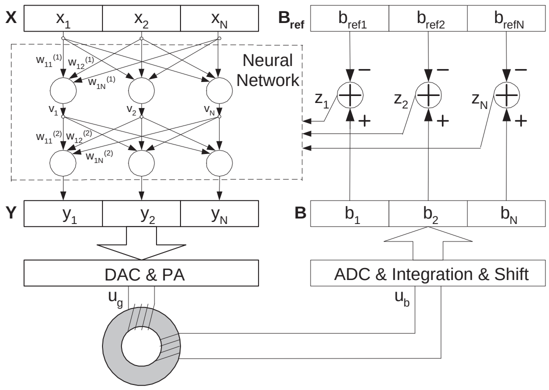

Fig. 3. The magnetic circuit with the neural network used to control the waveform

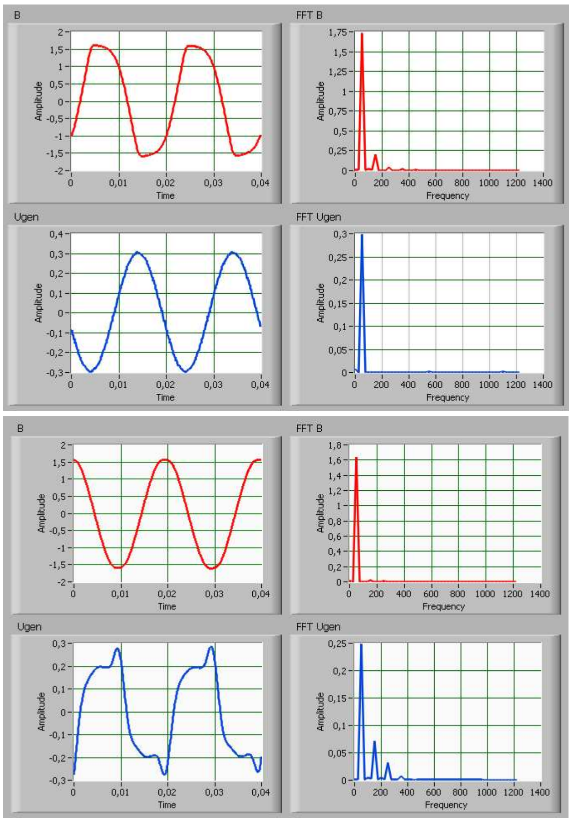

Fig. 4. The output signal of the neural network U_{gen} and the flux density signal B before (up) and after (down) waveform correction

Fig. 4 presents the output signal of the neural network U_{gen} and the flux density signal B with and without waveform correction. Table 2 presents the results of iteration determined for grain oriented steel and assumed flux density value equal to 1.8 T (the algorithm started from zero value).

Table 2
The iteration process of algorithm

Number of iteration	B_{max} [T]	$k = U_{rms}/U_{avg}$ [-]	THD [%]
1	0.018	-	-
5	1.08	1.10248	4.3
10	1.72	1.09828	7.8
15	1.76	1.07466	24.5
18	1.80	1.11079	1.0

The speed of the algorithm can be significantly improved by learning the net to establish initially the weight coefficients to expected values (similarly is it proposed Matsubara [5]) or by appropriate change of the learning coefficient μ.

5. Conclusion

The analogue system depends on the quality of source generator and power amplifier. In extreme cases (high value of the flux density) such system can operate not correctly.

From the comparison of both digital systems the system utilising the neural network seems to be better. For example to obtain the same result the neural network based system required 24 steps of iteration while the system with adaptive filter required more than hundred steps.

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