Development of battery – driven electromagnetic flow converter

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Introduction

Electromagnetic and ultrasonic fluid flow converters are used for commercial account the most widely. Converters of both types have sufficient conversion accuracy. Therefore other parameters must be evaluated for competitive alternative of these converters. One of the important parameters is energy consumption, necessary for conversion process. This is especially relevant for devices with autonomous supply. There have been made recently only battery-driven ultrasonic fluid flow converters. However, there appear now electromagnetic fluid flow converters with autonomous supply (Siemens, ABB, Idex corporation). Firms, which have announced about creation of such devices, thoroughly conceal means, which were taken for reduce of energy consumption. It is evident that it is the complex of means, which requires accurate theoretical and experimental investigation, using the newest methods of signal processing and the newest element base.

The main problems, which are important for creation of battery-driven electromagnetic flow converters BEMFC, are analyzed. The flow converters with fully filled channel are investigated. We suppose, that fluid has ionic conductivity. Fluid flow is axis-symmetric and parallel to channel axis.
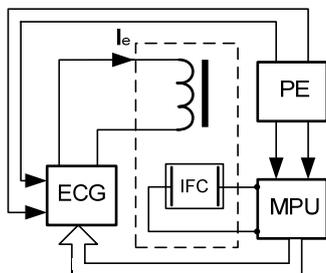

Fig. 1. Structural scheme of BEMFC

Rectangular coordinate system will be superposed with converter channel, supposing that straight line, which connects electrodes centers, coincides with axis *x*, and channel axis coincides with axis *z*.

The structure of battery-driven converter and requirements for its elements

The structure of battery-driven electromagnetic flow converter is shown in Fig. 1.

In this figure IFC is primary flow converter, ECG - excitation current generator, MPU – measurement and processing unity, PE – power element. It is evident that all these units should be constructed, maximally economizing power consumption.

Because the velocity of fluid has only component v_z, electrode signal of IFC e_x can be expressed [1]

$$e_x = \int_\tau (J_x B_y - J_y B_x) v_z \mathrm{d}\tau , \qquad (1)$$

where B_x and B_y are components of magnetic flux density vector B, J_x and J_y – components of virtual current density vector J, τ – volume of active channel zone (in which B is not negligible).

The alternative of channel profile. The channels of round and rectangular cross-sections are used in electromagnetic flow converters. The dotted electrodes are used in round channel, only. The wide electrodes can be used in rectangular channel. The density of virtual current is bigger between wide electrodes rather than between dotted electrodes. Therefore, the stronger signal could be obtained, using rectangular channel with wide electrodes, when the same magnetic field is created in active channel zone. The virtual current is directed along axis *x*, in this case. Seeking maximal economy, magnetic circuit should be constructed in the way, when magnetic current in zone of electrode signal formation is directed towards *y*. Electrode signal of BEMFC with rectangular channel could be expressed [1]

$$e_{xs} = B_y d \overline{v}_z = B_y \frac{d}{S} Q , \qquad (2)$$

where d – is the distance between electrodes, S – area of channel cross- section in electrode plane, $\overline{v}_z$ - average velocity of fluid, Q – volume flow of fluid.

The sensitivity of electrode signal to volume flow Q for concrete sensor channel dimensions is determined by magnetic flux density B_y. In turn, the density of magnetic flux depends on the magnetic flux excitation current I_e. We define the transfer coefficient K_m of magnetic circuit as

$$K_m = \frac{B_y}{I_e}. \qquad (3)$$

The power, which is needed for flow measurement, is proportional to second power of excitation current

$$P_m \approx I_e^2 R_{out}, \qquad (4)$$

where R_{out} – output resistance of excitation current generator ECG. Therefore, the magnetic circuit must be designed in the way that K_m would be as big as possible.

We could dispense energy consumption in this way

$$W = W_m + W_p = qP_m t_\Sigma + (1-q)P_p t_\Sigma, \qquad (5)$$

where W_m is energy consumption during all measurement time, W_p and P_p are, respectively, energy and power consumptions, during all pauses between measurements, q – relative measurement interval of. It is expressed as

$$q = \frac{T_m}{T_c}, \qquad (6)$$

where T_m – the interval of one measurement, T_c – the interval of one measurement cycle together with pause. Relative measurement interval must be chosen according to flow dynamics and the common measurement time.

Energy consumption for measurement W_m composes 95% of total energy consumption W in well designed BEMFC.

The excitation current I_e, needed for measurement, and relative measurement interval q can be reduced using effective filtration of electrode signal.

Electrode signal

Reducing excitation current of magnetic field, we also reduce flow signal e_x, induced in electrodes. The parasitic electrode signals show up in this case. In Fig.2 there is shown equivalent electric scheme of channel. Components of scheme are: e_X – the source of flow signal; e_p – the source of parasitic signals; R_i and C_i - resistance and capacity of twofold electric layer, which is near electrodes, R_{in} – input resistance of measurement and processing unit MPU, R_S - channel wall resistance. Parasitic signals can be divided into quasi-stationary ones E_p and variables Δe_p. Quasi- stationary component E_p of parasitic signals is easily removed remembering its value in pause finish moment. The main reason of parasitic signals Δe_p is noise of electrodes.

The typical signal of electrodes, when the average velocity of fluid flow is equal to 0,05 m/s and excitation current I_e=114mA is shown in Fig. 3. Three major types of noise can be separated in this signal: spikes, 1/f noise and white noise. If we want to reduce excitation current, this signal must be filtered.
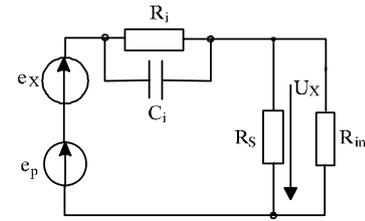

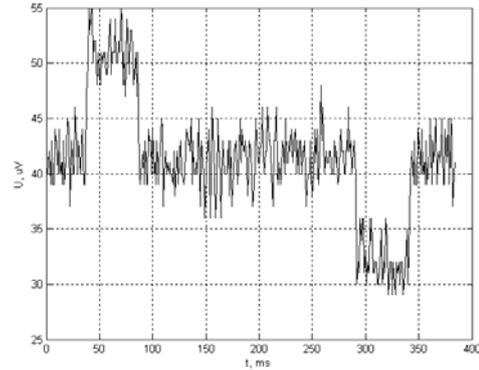**Fig. 2.** Equivalent electric scheme of primary flow converter

Fig. 3. Noised signal

For standard electromagnetic flow converters this signal can be filtered by analog or digital signal integration. However it's enough if the pause and impulse intervals are the same. In battery-driven flow converters relative measurement interval q must be maximal reduced. Therefore, every measured impulse must be maximal filtered i.e. filter must have minimal inertia. Evaluating the components of noise of signal, the best variant is use of Wavelet filters for filtering.

Filtration

When technologies are developing rapidly, and the number of operations, performed by microprocessor, enlarges, digital filters can often be of service to the process of measurement signal exclusion from disturbances. As an example we will show digital filtration of signals with a help of discrete Wavelets transform [2 - 4].

The realization of discrete Wavelet transform with the help of analysis filters

Using filters in Wavelet analysis, the signal is decomposed into components, for which there are used concepts of "approximations", which agree with components of low frequency, and concepts of "details", which correspond with the components of high frequency. Wavelet function ψ corresponds with pulse reaction of high frequency filter, and scale's function ϕ – pulse reaction of low frequency filters.

Discrete Wavelet transform (the process of analysis) could be expressed by the following equation

$$f(t) = \sum_k cA_j(k)\varphi_{i,k}(t) + \sum_k cD_j(k)\psi_{i,k}(t), \qquad (7)$$

where

$$\varphi_{i,k} = \sum_n h_0(n-2k)\varphi_{i+1,n}(t) \qquad (8)$$

$$\psi_{i,k}(t) = \sum_n h_1(n-2k)\varphi_{i+1,n}(t) \qquad (9)$$

In the Fig. 4 there is shown three - leveled filters set of "tree chart" structure [4].
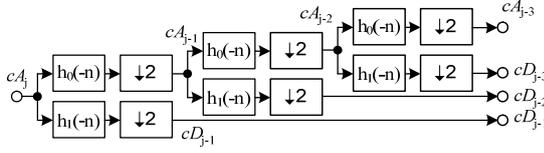

Fig. 4. The set of three - leveled analysis filters

For this set of three- leveled analysis filters, signal cA_j is equal to

$$cA_j = cA_{j-3} + cD_{j-1} + cD_{j-2} + cD_{j-3}. \qquad (10)$$

Inverse discrete Wavelet transform with the help of synthesis filters

Using inverse discrete Wavelet transform IDWT the initial signal $f(t)$ can be synthesized

$$cA_j = \sum_k h_0(n-2k)cA_{j-1}(k) + \sum_k h_1(n-2k)cD_{j-1}(k). \qquad (11)$$

The realization of IDWT corresponds with the set of synthesis filters, shown in Fig. 5. Here $h_0(n)$ and $h_1(n)$ – pulse reactions of filters.

The filtration of electromagnetic converters of fluid's flow, using sets of different Wavelets filters

Because the biggest influence of parasitic noises occurs near little flows, we chose the velocity of flow v=0,05m/s for experiment. In the Fig. 3 there is shown noised signal [4].
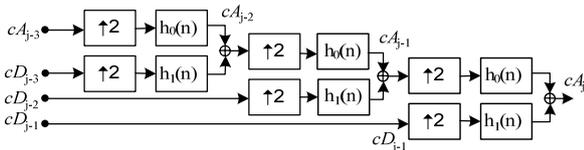

Fig. 5. The set of three- leveled synthesis' filters

Using filters' sets of the simplest Haar Wavelet, we performed the filtration of 1-4 levels, which are respectively shown in Fig. 6-9.

As it is seen from Fig. 3, 6-9, significant neutralization of noises occurs till using 4 - leveled Haar filters.
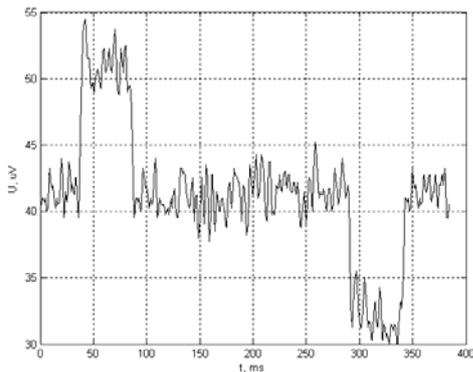

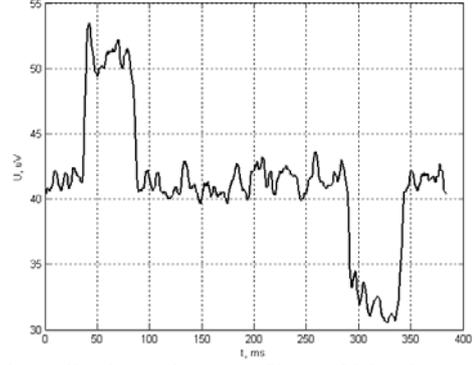**Fig. 6**. The realization, using Haar filters of 1 level

Fig. 7. The realization, using Haar filters of 2 level
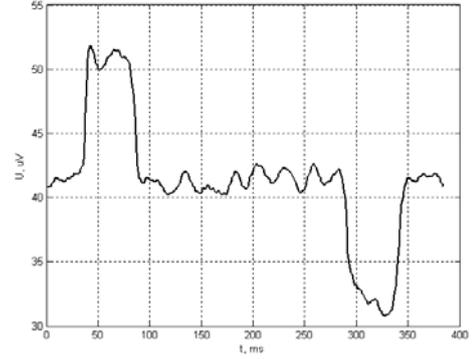

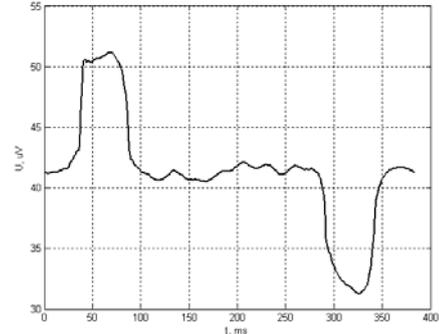**Fig. 8.** The realization, using Haar filters of 3 level

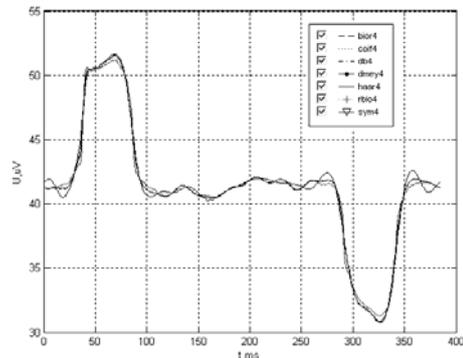**Fig. 9.** The realization, using Haar filters of 4 level

Fig. 10. The realization, using 4- leveled different filters

The filtration of higher level is inappropriate. Supposing that in our case optimal realization of discrete Wavelet transform, using filters sets, is 4- leveled, we accomplished 4- leveled filtration, which is shown in Fig. 3, using Wavelets of different types [4]. Results are shown in Fig. 10.
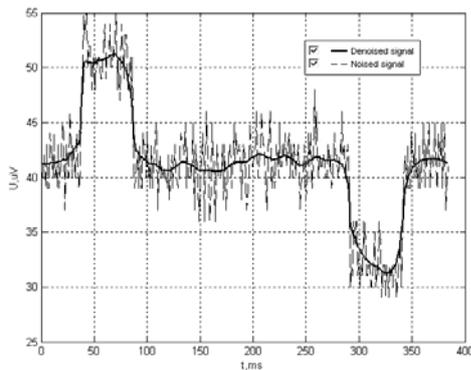
Fig. 11. The comparison of noised signal with filtrated signal

As it is seen, there is no significant difference, choosing different types of Wavelets.

In Fig. 11 for comparison are shown original (noised), and signal filtered by 4- leveled Haar filters.

Conclusions

1. Creating the battery-driven electromagnetic flow converters, the main attention must be paid on reduction of excitation current of magnetic field.

2. The same response with smaller excitation current could be reached, using channel with rectangular cross-section.

3. For the filtration of the signal it is recommended to use discrete Wavelet transform.

4. The best is to use 4- leveled sets of filters for filtration of electromagnetic flow converter electrode signal.

References

1. **Padegimas R., Vaikasas R., Virbalis J.A.** Selection of the Magnetic Circuit Design for Electromagnetic Fluid Flow Converter with Rectangular Channel // Electronics ir Electrical Engineering. – Kaunas: Technologija, 2006. – Nr.3(67). –P.41–46.
2. **Marvasti S., Gillies D.** Novel Intelligent Wavelet Filtering of Embolic Signals from TCD Ultrasound // http://www.doc.ic.ac.uk/research/technicalreports/2004/DTR 04-7.pdf
3. **Gandhi, P., Pappu R., Rao S.** Wavelets for Baseband Coding of Waveforms. – IEEE Globecom, 1994. – P. 363–367.
4. **Wavelet Toolbox 4.0 home page.** http://www.mathworks.com/products/wavelet/

R.Katutis, J.A. Virbalis. **Development of Battery – Driven Electromagnetic Flow Converter // Electronics and Electrical Engineering. – Kaunas: Technologija, 2007. – No. 4(76). – P. 79–82.**

The mean parameter of battery-driven electromagnetic flow converter s is power consumption. Stronger signal, when magnetic field is the same, could be obtained, using channel of rectangular cross-section with wide electrodes. Magnetic circuit should be designed in the way that transmission coefficient would be as big as possible. Power consumption can be reduced, decreasing relative measurement interval and excitation current, but the parasitic signals shows up. Effectiveness of filtration of every pulse of electrode signal must be maximal. To heave a mean the composition of noise of signal, for filtering the best variant is Wavelet filters. During the examination, there was determined that the best is to use 4-leveled sets of filters. Ill. 11, bibl. 4 (in English; summaries in English, Russian and Lithuanian).

Р.Катутис, Ю.А. Вирбалис. Предпосылки создания электромагнитного преобразователя расхода с автономным питанием // Электроника и электротехника. – Каунас: Технология, 2007. – № 4(76). – C. 79–82.

Важнейший параметр электромагнитного преобразователя расхода – потребление энергии. Более сильный сигнал при том же магнитном поле может быть получен, используя прямоугольный канал и широкие электроды. Для уменьшения затрат энергии магнитная цепь должна конструироваться с максимальным коэффициентом передачи. Уменьшая относительный интервал измерения, также можно уменьшить и потребление энергии, но в при этом следует повысить эффективность фильтрации сигнала электродов. Зная состав шума электродов лучше всего использовать Wavelet фильтры. Экспериментально установлено, что оптимальным является чступенный набор Wavelet фильтров. Ил. 11, библ. 4 (на английском языке; рефераты на английском, русском и литовском яз.).

R.Katutis, J.A. Virbalis. **Elektromagnetinio skysčio srauto keitiklio su autonominiu maitinimo šaltiniu sukūrimo prielaidos // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 4(76). – P. 79–82.**

Elektromagnetinio skysčio srauto keitiklio su autonominiu maitinimo šaltiniu pagrindinis parametras yra energijos sąnaudos, reikalingos keitimo procesui. Stipresnis signalas, esant tokiam pat magnetiniam laukui gaunamas naudojant stačiakampį kanalą su plačiais elektrodais. Magnetinė grandinė turi būti konstruojama taip, kad magnetinės grandinės perdavimo koeficientas būtų kuo didesnis, nes žadinimo srovės dydis tiesioiai nusako energiją jutiklyje. Mažinant matavimo impulso santykinę trukmę, mažėja ir energijos sąnaudos, tačiau reikia efektyviau filtruoti. Kiekvienas matavimo impulsas turi būti maksimaliai nufiltruotas, t.y. filtras turi turėti minimalią inerciją. Tam geriausiai tinka vilnelių filtrai. Patogiausia naudoti keturių pakopų vilnelių filtrų rinkinius. Il. 11, bibl. 4 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).