

**N. ZACHEPA**, assistant, Kremenchuk National University;  
**IU. ZACHEPA**, assoc. prof., Kremenchuk National University.

## VIRTUAL GAGE FOR ANALYSIS OF ENERGY CONVERSION QUALITY IN ELECTROMECHANICAL SYSTEMS

**Problem statement.** Uninterrupted power supply is a very important issue today, especially in cases where technically impossible or economically inefficient use centralized power.

As most universal autonomous power supply using electromechanical generators, which are complex energy system that is characterized by non-linear elements and devices of accumulation.

Emergency situation and disruptions of energy systems can lead to substantial consequences for industrial and municipal enterprises [1]. Refers to the root causes of increasing voltage on the findings of the stator windings, which can lead to breakdown of isolation and the emergence of a multiphase generator short circuits. Dangerous for the isolation voltage increase is a consequence of the disappearance of the magnetic flux of the stator and increased reaction speed of rotation of the unit that occurs when disconnecting the load.

In this regard recently become increasingly popular autonomous diesel generator complex (DGC), in which the non-contact three-phase AC generator. Currently, the most commonly used synchronous generator (SG). Asynchronous generators (AG) compared with synchronous have a simple and reliable design, lower weight and cost in the range of powers to 100 kW [2]. However, the widespread use of DGC AG remain poorly understood issues determining handling capacity of the latter, qualitative and quantitative measures of generated energy.

To the sustainability of AG is necessary to provide two conditions – the presence of controlled sources of reactive mechanical energy [3]. First performed by setting the capacitor, second – implementation AG mechanical connection with a diesel engine internal combustion (DE) or other sources of mechanical energy. When determining the handling capacity of the generator focuses on the choice of regulator capacitive excitation current and the number of degrees capacitor. At the same time to minimize the weight and dimensions values and increased mobility DGC characterized comparability capacity of DE and AG respective excitation systems, which also sets strict conditions on the stability of the prime mover and the quality and energy produced generator.

Electricity for both autonomous and stationary sources characterized by three parameters: frequency, voltage and form of the curve. Frequency of voltage characteristic are active power balance required for normal functioning of the consumer, and active power generated by the electric power source.

If the active power, which is produced sources not less than the required electric power receivers, the frequency of the voltage in electricity the system is 50 Hz. In case of shortage of active power frequency voltage in the system is reduced and reached steady state at reduced frequency. Voltage in DGC with AG is a measure of the balance of reactive power. If the system there is a storage of reactive power, the voltage at consumers is less than nominal, while its excess – voltage higher than the nominal value. Reactive power is conventionally divided into generated and consumed. Reactive power in DGC with AG generated – reactive power capacitors. Consumption of reactive power – reactive power induction motors or synchronous machines excited enough as major consumers connected to the terminals of the generator. In view of the above, are actual research process quality indicators autonomous power generation energy sources at the AG. The purpose is to develop indicators overseer energy modes asynchronous generator based on virtual models in the software environment LabVIEW.

**Experimental part and results obtained.** The most convenient methods of energy processes in different modes autonomous generator complex based on an analysis of the electrical signals, including analysis of the spectra of instantaneous power [2]. The most convenient methods of energy processes independent modes of generator complex based on an analysis of the electrical signals, including analysis of the spectra of instantaneous power [5]. Effective use of this approach should make the equation balance capacity or energy electrical elements of the complex.

The balance of power is the result Telledzhena theorem: The sum of the product of voltage and current of all branches of the circuit which satisfy Kirchhoff's laws equal zero [5]. The product of  $U_i(t) \cdot I_i(t)$  is an instant-power  $P_i(t)$  of  $i$  branch [6] therefore the sum capacity of all branches of the circle is zero. For DGC with AG balance of power are as follows: The amount of power produced AG, is the amount of power consumed by all connected users, which in turn and create branch circuit. In general block diagram of battery power generating units (BPGU) is shown in Fig. 1, comprising: a primary source of mechanical energy (SoME) converter electricity – asynchronous generator (AG) with capacitive excitation system (CES) and power consumers of electricity: single-phase and three-phase alternating current and direct current connectivity through the rectifier. Block control devices contains three groups of sensors.

For analog signals phase voltages and currents at the output of the generator serve as sensors VS1–VS3 and CS1–CS3. Using sensors VS4–VS6, CS4–CS6 and VS7–VS9, CS7–CS9 are needed depending on the time of electrical quantities SoME and at the clamps of consumer. Analog to Digital Converter (ADC) transmits the data from the sensors to formation block power of signal (FBPS) function of FBPS is getting signals of instantaneous power [5÷6] as sum of current input signals and abuse of appropriate sensors, converted to Fourier series [7].

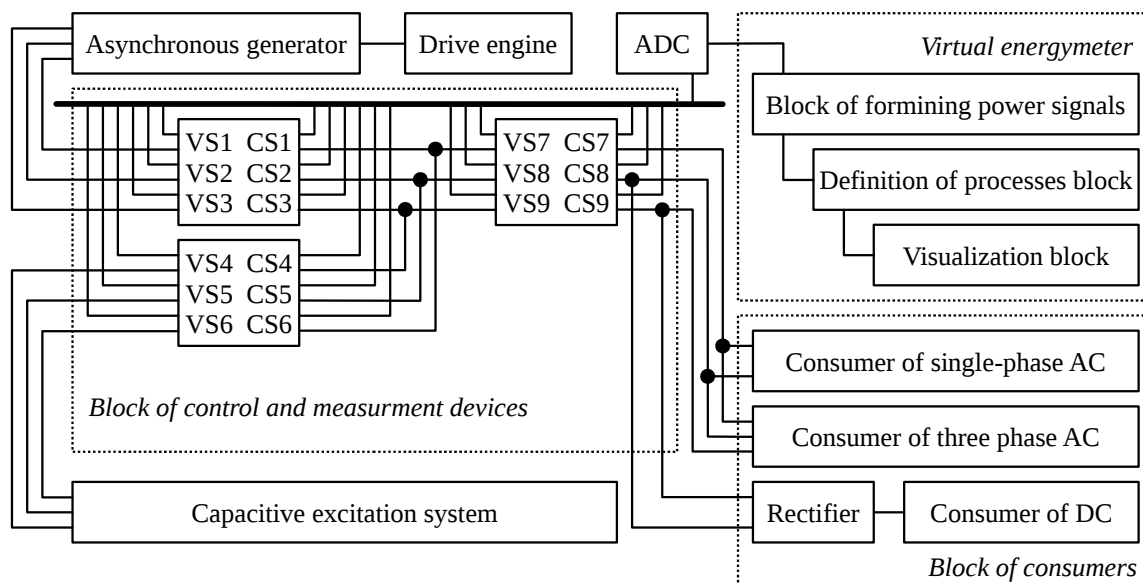


Figure 1 – Block of diagram autonomous energy management plant

Block formation signal power and block identification of indicators energy processes (BIIEP) output for results directly through the power of visualization are part of energy gage which analyzes general quality indicators of electric power at all cell transformation. Definition of indicators of energy processes in AYE performs block DEPB, it enables explore the complex indicators of the voltage  $U(t)$ , current  $I(t)$ , and their multiplication, power  $P(t)$ , namely: Harmonious composition of, effective and average value coefficients distortion signals [8].

Algorithm evaluation processes in an autonomous energy conversion power generating installation is based on the mathematical tools of instantaneous power method, under which the EG is, in general shown in Fig. 2.

Initially performed reading time sensor signals voltage  $u_A(t)$ ,  $u_B(t)$ ,  $u_C(t)$  and currents  $i_A(t)$ ,  $i_B(t)$ ,  $i_C(t)$  and representing time signals in frequency as the sum of orthogonal components [9].

For three-phase system of field harmonic voltage and current signals phase A generator can be represented dependencies form:

$$\begin{aligned}
 u_A(t) &= \sum_{n=1}^N U_n \cos(\Omega_n t - \phi_n) = \sum_{n=1}^N U_{na} \cos(\Omega_n t) + \sum_{n=0}^N U_{nb} \sin(\Omega_n t); \\
 i_A(t) &= \sum_{m=1}^M I_{ma} \cos(\Omega_m t - \psi_m) = \sum_{m=0}^M I_{ma} \cos(\Omega_m t) + \sum_{m=0}^M I_{mb} \sin(\Omega_m t),
 \end{aligned}
 \tag{1}$$

where  $n, m$  – number of harmonic voltage and current;  $N, M$  – number of harmonic components of voltage and current;  $\phi, \psi$  – phase angles of voltage and current signals;  $\Omega_n, \Omega_m$  – angular frequency change of voltage and current signals;  $U_{na} = U_n \cos \phi_n$ ,  $U_{nb} = U_n \sin \phi_n$  orthogonal cosine and sine components of the signal voltage;  $I_{ma} = I_m \cos \psi_m$ ,  $I_{mb} = I_m \sin \psi_m$  – orthogonal cosine and sine components of the signal current.

Presentation time function of power phase A with (1) as a harmonic orthogonal components according to  $p_A(t) = u_A(t) \cdot i_A(t)$  will look:

$$p_A(t) = \sum_{k=1}^K P_{k0} + \sum_{k=1}^K P_{ka} \cos(\Omega_k t) + \sum_{k=1}^K P_{kb} \sin(\Omega_k t) ;
 \tag{2}$$

where  $\sum_{k=1}^K P_{k0}$  – total permanent component power;  $\sum_{k=1}^K P_{ka}$  – cosine component of total capacity;  $\sum_{k=1}^K P_{kb}$  – the total sinus component of power;  $\Omega_k$  – circular frequency of  $k$  harmonic power ( $\Omega_k = |\Omega_n \pm \Omega_m|$ );  $k$  – number of harmonic components of power.

The total capacity of the three-phase system supplied to the stator winding of the generator capacity is the sum of individual phases:

$$p(t) = p_A(t) + p_B(t) + p_C(t) ,
 \tag{3}$$

where  $p_B, p_C$  – time function facilities phases B and C.

Analysis of energy processes executed on the virtual laboratory complex (VLC) [10, 11]. Research autonomous power sources based on asynchronous generator with capacitive excitation, that developed in LabVIEW graphical programming environment [12÷16].

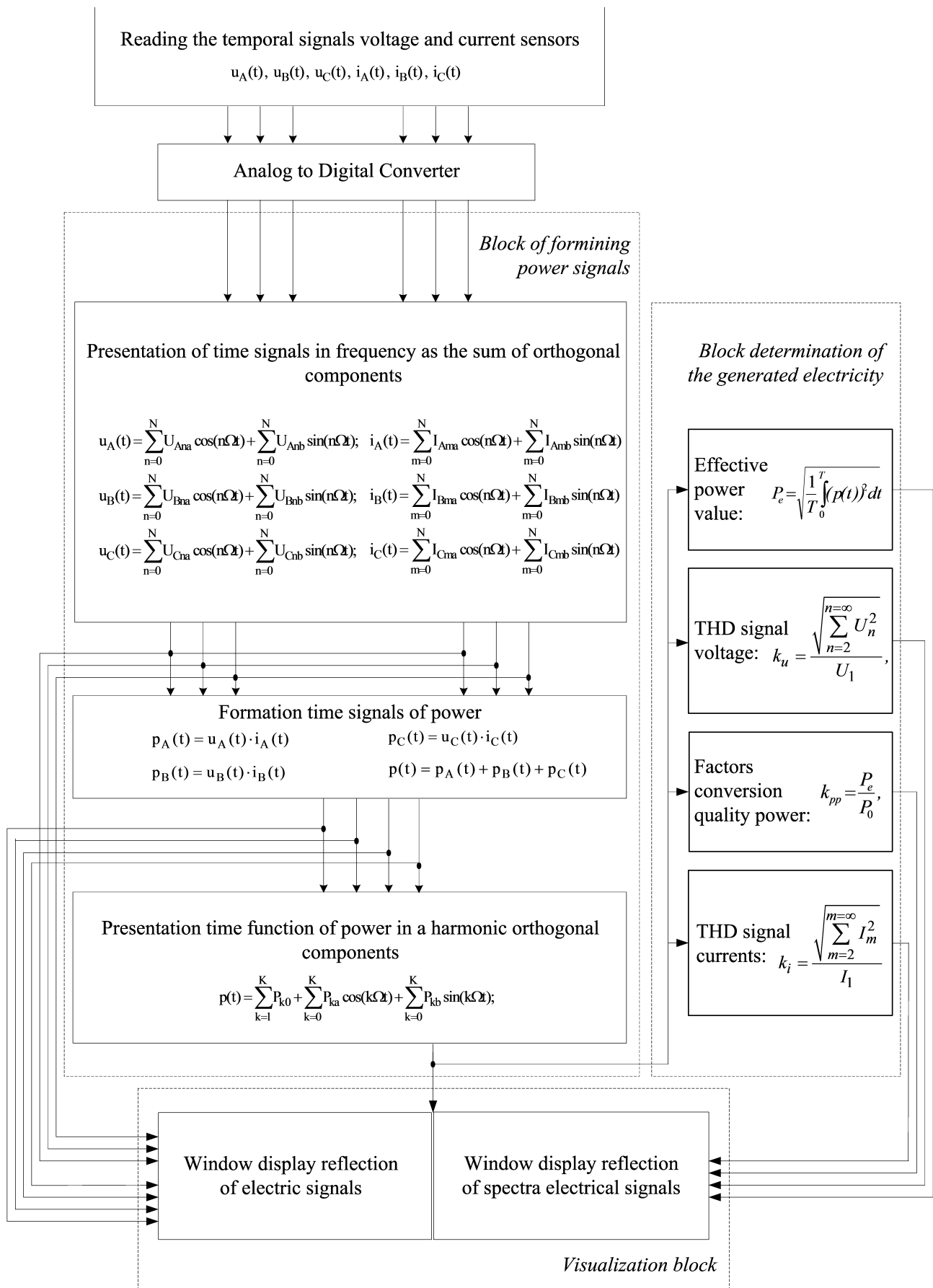


Figure 2 – Algorithm evaluation process energy conversion in the autonomous power generation complex

On the top are displayed in real time depending on changes in signal phase voltages  $u_A(t)$ ,  $u_B(t)$ ,  $u_C(t)$ , currents  $i_A(t)$ ,  $i_B(t)$ ,  $i_C(t)$ , powers  $p_A(t)$ ,  $p_B(t)$ ,  $p_C(t)$ , and the curve of the total electric power  $p(t)$  that is supplied to the generator stator (fig. 3).

Also on the panel displays numeric coefficients of nonlinear distortion signal current and voltage, and for the power displayed: effective power value, utilization of active and reactive power, nonlinear coefficient of signal power.

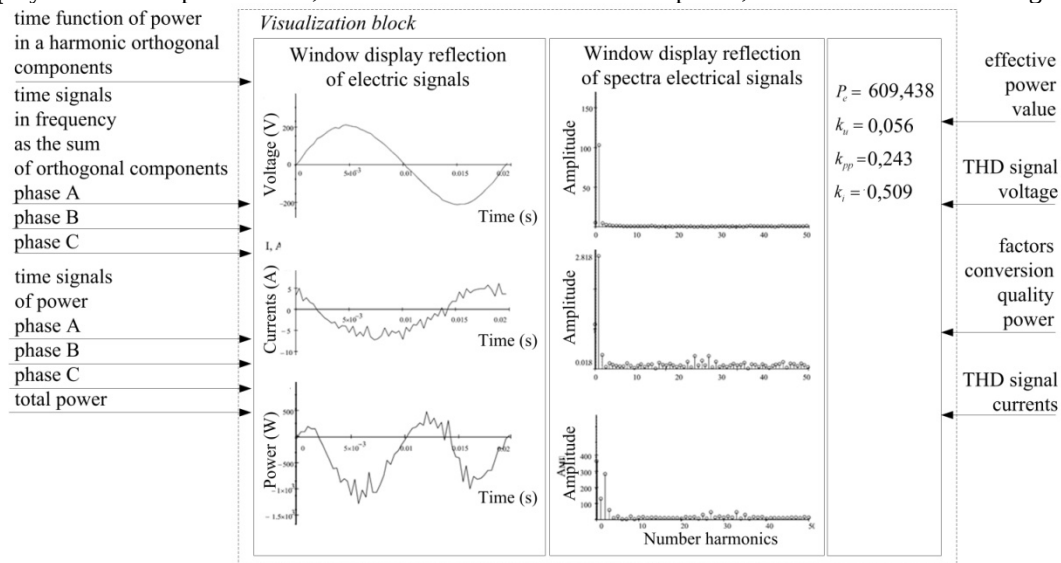


Figure 3 – Display of electrical signals and their spectrum

Designed power warden is a software block whose functionality is the analysis of energy processes in different modes autonomous generator complex.

As mathematical tools used method of instantaneous power, allowing maximum display processes of generation and energy recovery between the power source and the consumer. Defining performance energy conversion processes electrical signals is to obtain dependence of voltage and current and their product – instantaneous power, and the definition of permanent and alternating sinus and cosine components of power effective values of instantaneous power. Research energy processes arising in the power system, allows assessing the quality of energy conversion.

**Bibliography (transliterated):** 1. Toroptsev, N. F. Asinhronnye generatory dlya avtonomnykh elektroenergeticheskikh ustanovok. Moscow: Energoproggress, 2004. Print. 2. Zubkov Yu. D. Asinhronnye generatory s kondensatornym vzbuzhdeniyem. Kazakhstan: Alma-Ata, 2004. Print. 3. Grigorash, O. V. "Modern condition and prospects of application of asynchronous generators in the autonomous power." Promyshlennaya energetika, No. 3. 1995. 29–32. Print. 4. Lukutin, B. V. and Sipaylov, G. A. Ispol'zovaniye mekhanicheskoy energii vobnovlyayemykh prirodnykh istochnikov dlya elektrosnabzheniya avtonomnykh potrebitel'ey. Frunze: Izd. «Ilim», 1987. Print. 5. Rodkin D.I. "Sostavlyayushchiye mgnovennoy moshchnosti poligarmonicheskikh signalov." Elektrotehnika, No. 3. 2003. 39–44. Print. 6. Rodkin D.I. "Osobennosti primeneniya energeticheskogo metoda identifikatsii dvigateley peremennogo toka pri psevdopoligarmonicheskikh signalakh." Elektromekhanichni i enerhozberihayuchi systemy, Kremehchuk, KrNU, No. 5. 2009. 7–20. Print. 7. Rodkin D.I. "Energo Protssesy v trekhfaznoy dvigatel'noy nagruzke s nesinusoidal'nyim napryazheniyem pitaniya." Problemy stvorenniya novykh mashyn i tekhnolohiy: naukovy pratsi KDPU, No. 1. 1998. 23–35. Print. 8. Korenkova T.V., Kravec A.M., Serdyuk A.A., Boyko M.B., Mokryy A.Yu. "Struktura energonablyudatelya v sostave fizicheskoy modeli elektrogidravlicheskogo kompleksa." Elektromekhanichni ta enerhetychni systemy, metody modelyuvannya ta optymizatsiyi. Zbirnyk naukovykh prats' XII Mizhnarodnoyi naukovo-tekhnichnoyi konferentsiyi molodykh uchenykh i spetsialistiv, Kremenchuk, April 10–11. 2014. 77–78. Print. 9. Zagirnyak M.V., Rodkin D.I., Korenkova T.V. "Otsenka protsessov energo preobrazovaniya s ispol'zovaniyem sostavlyayushchikh mgnovennoy moshchnosti." Elektromekhanichni i enerhozberihayuchi systemy, Kremehchuk, KrNU, No. 4. 2013. 152–167. Print. 10. Zacheпа Yu.V., Zacheпа N.V. and Sergiyenko, S.A. "Software and logical complex for research of diesel generator sets with asynchronous generators." Visnik Natsionalnoho tekhnichnoho univ'sitetu «Kharkivskiy politekhnichniy institut», No. 12.1121. 2015. 330–333. Print. 11. Zacheпа, Yu.V. "Mathematical model of autonomous power supplies generated on the basis of diesel generator." Elektromekhanichni i energozberigayuchi systemy: shchokvartalnyi naukovo-virobnichiy zhurnal, No. 1.29. 2015. 26–37. Print. 12. Trevis, Dzh. LabView dlya vseh. Moscow: DMK Press; PriborKomplekt, 2005. Print. 13. Yevdokimov, Yu.K. and Kirsanov, A.Yu. "Organization of a typical remote automated laboratory using LabVIEW-technology in a technical college." Obrazovatelnyye, nauchnyye i inzhenernyye prilozheniya v srede LabVIEW i tekhnologii National Instruments: Sb. trudov Mezhdunarodnoy konferentsii, Moscow. November 14–15 (2006): Available at: [http://www.ict.edu.rux/lib/index.php?id\\_res=3630](http://www.ict.edu.rux/lib/index.php?id_res=3630). 14. Batovrin, V.K. and Bessonov, A.S. LabView: praktikum po osnovam izmeritelnykh tekhnologiy: uchebnoye posobiye dlya vuzov. Moscow: DMK Press, 2005. Print. 15. Batovrin, V.K., Bessonov, A.S. and Moshkin, V.V. "Experience in the development of open educational resources based on virtual instrumentation." Otkrytoye obrazovaniye, No. 5. 2009. 117–124. Print. 16. Petrov M.N. and Belehkov M.N. "Building a virtual interface meter Postroyeniye interfeysa virtualnogo izmeritelnogo pribora." Vestnik Novgorodskogo gosudarstvennogo universiteta. No. 23. 2003. 96–99. Print.

Received 19.06.2017