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DEVELOPING A STRUCTURE OF THE GENERATOR OF RANDOM VOLTAGE CHANGES WITHIN ELECTRIC GRIDS OF AN ENTERPRISE

Noisy electric energy within workshop power grids of industrial enterprises results in accelerated physical ageing of electrical facilities as well as in the increased risk of emergency situations. Early evaluation of power quality indices and provision of adequate modes of electric equipment operation under specific conditions is essential research and practice problem.

The problem solution involves a number of experiments under the conditions of different power quality indices, different modes of electric equipment operation, and different means to protect the latter from noisy power. However, such experiments carried out in the context of a real object would result in: significant time consumption because of the necessity to wait for such situations when energy within power grids corresponds to the required quality indices without mentioning losses of electric equipment life; financial expenditures due to the necessity to purchase various high-priced devices to protect the electric facilities and to rehabilitate electric energy within the grids; and accident threat due to the decreased reliability indices of electric facilities operating under the considered conditions.

Computational studies, based upon the development of simulation system as well as upon statistical tests by computers, helps accelerate and simplify considerably the process of the experiments [1]. The method differs from standard experimental ones in the fact that simulation model, implemented by a computer, is analyzed rather than the object itself. In this context, interaction with the former is performed just as it was done with a prototype system and simulation results are processed and tested in such a way as if they were data of full-scale experiments [2].

As for the development of generation of random changes in linear voltage within power grid of a workshop, it is independent problem to be considered separately in this work. It assumes the definition: structures of generator of the random changes; statistical regularities of the latter; and, as a consequence, parameters of the generator being synthesized.

Direct simulation of linear voltage within a grid with noisy electricity is complicated by the fact that all harmonic components have fixed frequencies of their oscillations; only random changes in amplitudes and initial phases are superimposed on them. It follows that it is more expedient to generate amplitudes and initial phases of available harmonics, which statistical regularities of changes should be obtained previously, rather than the random voltage sequences [3].

Fig. 1 represents one of the potential variations of the generator of random changes in linear voltages taking into consideration the mentioned above [4].

In this context, Γ_γ is generator of "white" noise (i.e. values of uniformly distributed uncorrelated random value corresponding to time moments Δt_γ within 0;1 interval); $\Pi_{U_{mABi\gamma}}$, and $\Pi_{U_{mBCi\gamma}}$ are converters of amplitude distribution laws $i=\overline{1,n}$ – harmonics of linear voltages U_{mAB} and U_{mBC} respectively; $\Pi_{\Psi_{ABi\gamma}}$, and $\Pi_{\Psi_{BCi\gamma}}$ are converters of the initial phase distribution laws $i=\overline{1,n}$ – harmonics of the listed voltages U_{AB}, and U_{BC}; $\Phi_{U_{mABi\gamma}}$, and $\Phi_{U_{mBCi\gamma}}$

are filters generating the correlated amplitudes of harmonics of linear voltages U_{AB} , and U_{BC} respectively; $\Phi_{\Psi_{ABi\gamma}}$, and $\Phi_{\Psi_{BCi\gamma}}$ are filters generating the correlated initial phases of harmonics of the same voltages; $\tau_{(U_{mAB}\to U_{mBC})i}$ is amplitude shift of i^{th} harmonic of linear voltage U_{BC} relative to linear voltage U_{AB} along the τ axis being determined on their cross-correlation function; and $\tau_{(\Psi_{AB}\to\Psi_{BC})i}$ is a shift of the initial phase of i^{th} harmonic of linear voltage U_{BC} relative to the initial phase of i^{th} harmonic of linear voltage U_{AB} along the τ axis being determined on their cross-correlation function.

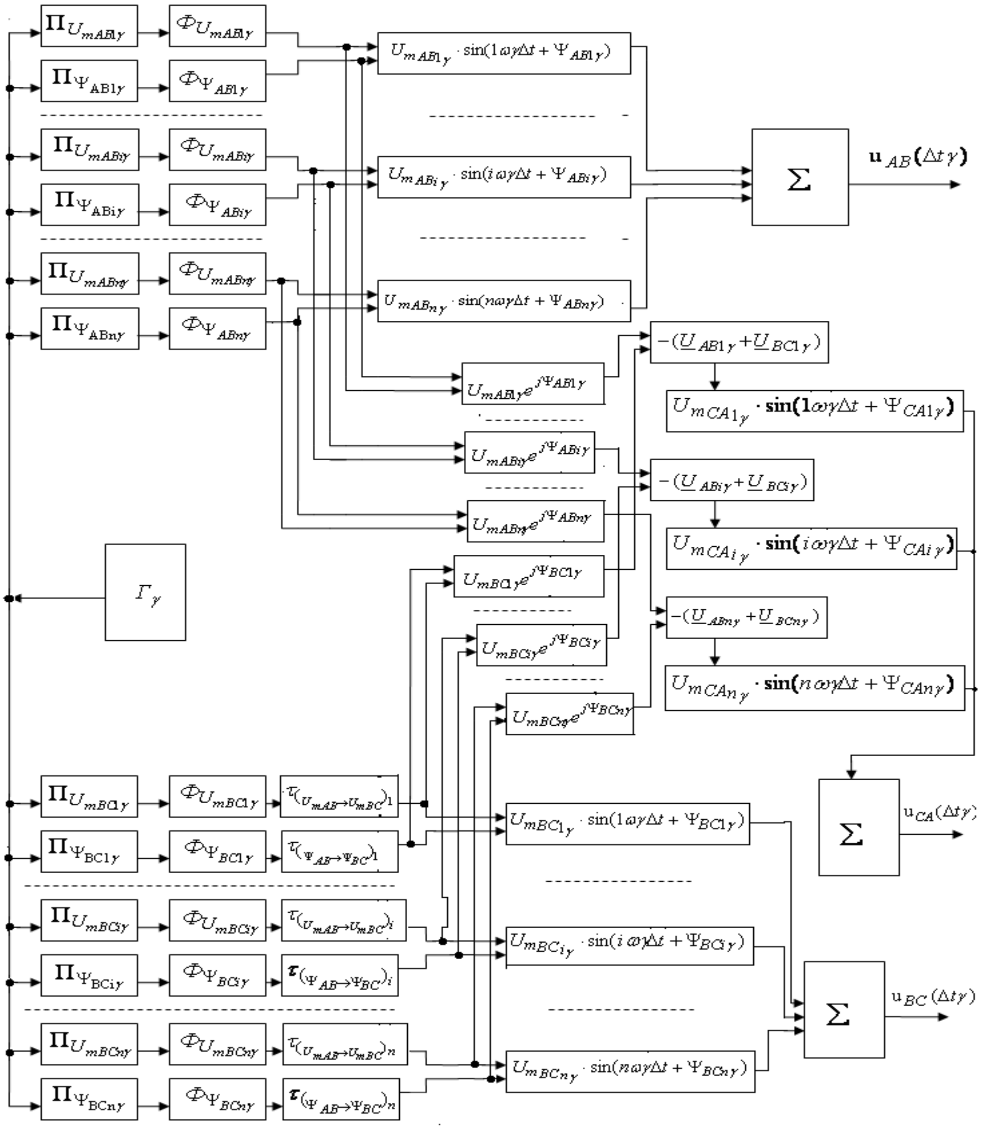

Figure 1 - Generator of linear voltages

According to random changes in amplitudes (U_{mABi}, U_{mBCi}, U_{mCAi}), and initial phases ($\psi_{ABi}, \psi_{BCi}, \psi_{CAi}$) of harmonic components of linear voltages, simulated in such a way, their instantaneous values are determined. Then the latter are added algebraically in summators forming random sequences $u_{AB}(\Delta t\gamma)$, $u_{BC}(\Delta t\gamma)$, and $u_{CA}(\Delta t\gamma)$.

As it is seen from Fig. 1, initial random process, being a random uncorrelated value, distributed on uniform laws within [0;1] interval, is simulated by corresponding generator. There are different techniques to obtain it; however, to all practical purposes, program method to generate pseudorandom sequences (PRS) is the most convenient in this context. In their software, the current computers have built-in function to generate PRSs helping them solve the majority of problems of signal simulation.

$\Pi_{U_{mABi\gamma}}$, $\Pi_{U_{mBCi\gamma}}$, and $\Pi_{\Psi_{ABi\gamma}}$, $\Pi_{\Psi_{BCi\gamma}}$ units transform initial random signal to those uncorrelated ones predetermined distribution laws. Selection of the most efficient signal depends upon the type of the laws. Nonlinear transformation methods (i.e. inverse function), piecewise-linear approximation of distribution law, and a method of elimination (by Neumann) are mostly used to perform the operation [5].

Generating filters $\Phi_{U_{mABi\gamma}}$, $\Phi_{U_{mBCi\gamma}}$, $\Phi_{\Psi_{ABi\gamma}}$, and $\Phi_{\Psi_{BCi\gamma}}$ transform uncorrelated random sequences with the predetermined distribution laws into the correlated ones according to autocorrelation functions of the considered values. Nonrecursive filtration of input sequence is one of the most popular transformation techniques [4,5]:

$$y_n = \sum_{k=0}^{N} S_k x_{n-k}, \quad (1)$$

where $\mathrm{M}[y_n] = 0$, and

$$\mathrm{M}[y_n y_k] = \begin{cases} \mathrm{K}_{n-k,} |n-k| \le \mathrm{N}; \\ 0, |n-k| > \mathrm{N}, \end{cases}$$

where y_n is output correlated sequence, x_n is input uncorrelated sequence, S_k are coefficients, K_{n-k} is a value of correlation function within $(n-k)\Delta$ point, and M is expectation symbol.

Random change in linear voltage U_{BC} results from its cross-correlation function with U_{AB} voltage. The simplest technique to solve the problem is in PRS generation with the prescribed type of a correlation function, and its corresponding time interval delay. The fact can explain availability of $\tau_{(U_{mAB} \to U_{mBC})i}$ and $\tau_{(\Psi_{AB} \to \Psi_{BC})i}$ units within the structural circuit [4]. Instantaneous value of linear voltage $u_{CA}(t)$ is determined according to the known ratio:

$$\underline{U}_{CA} = -(\underline{U}_{AB} + \underline{U}_{BC}). \quad (2)$$

It is clear that (2) dependence use will result in the formation of systematic error since values of linear voltage $\underline{U}_{CA}$ will not correspond to a distribution law being typical for it. It is possible to eliminate the error while implementing randomly selected sequence (i.e. randomization) of linear voltage generation.

References

1. Borky , J., Bradley, Th.: Effective Model-Based Systems Engineering. 1st ed. 779 p. Springer International Publishing AG. Cham, Switzerland (2019).

2. Dori, D. Model-Based Systems Engineering with OPM and SysML. 1st ed. 411 p. Springer-Verlag New York Inc. New York, United States (2016).

3. M. Tryputen, V. Kuznetsov, A. Kuznetsova, K. Maksim and M. Tryputen, "Developing Stochastic Model of a Workshop Power Grid," 2020 IEEE Problems of Automated Electrodrive. Theory and Practice (PAEP), Kremenchuk, Ukraine, 2020, pp. 1-6, doi: 10.1109/PAEP49887.2020.9240898.

4. Kawano, S., Yoshizawa, S. and Hayashi, Y.:Centralized voltage control method using voltage forecasting by JIT modeling in distribution networks 2016 IEEE/PES Transmission and Distribution Conference and Exposition (T&D), Dallas, TX, 2016, pp. 1–5.

5. Udagawa, T., Yasuhiro, H., Takahashi, N., Matsuura, Y., Morita, T. & Minami, M.) Evaluation of Voltage Control Effect for Data Acquisition Period Length from SCADA with IT Switches, Journal of International Council on Electrical Engineering. Vol. 3, No. 2, 146 – 152(2013)