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Assessment of DC Voltages and Currents Ripples Through Waveform Harmonic Factors of Rectified Voltage

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Abstract—**Based on the method of the differential equations algebraization, the assessment method of the DC-circuit analogues for the voltage and current THD values is here applied to the case that the DC source is some rectifier. The analytical description for the zero to four orders' DC-circuit integrated signal harmonics factors of a general multipulse uncontrollably rectified voltage is obtained by infinite series' harmonic synthesis method and analyzed. The core part of a LabVIEW virtual instrument for the assessment of the DC-circuit integrated signal harmonics factors for some simulated or captured exposure signal is offered.**

Keywords—method of differential equations algebraization, DC-circuit THD analogue, DC-circuit n-order integrated signal harmonics factor, uncontrolled AC voltage rectification, infinite series' harmonic synthesis, LabVIEW virtual instrument

I. INTRODUCTION

A differential equations algebraization (ADE) method has been developed by Prof. G.S. Zinoviev (NSTU, Novosibirsk) for direct obtaining expressions of RMS voltages and currents values in a closed analytical form from source differential equations without their solving [1].

The ADE method is asymptotically approximate one. It makes it possible to reach a needed accuracy by adding a few sign-alternating series' terms each of which is carrying information on a power source voltage (current) harmonic content and a load circuit configuration and parameters.

The required exposure (voltage or current) description is provided by a system of weighted exposure total harmonic distortion coefficients, so called differentiated and integrated harmonics factors. These factors make it possible to simulate the action of ideal differentiating and integrating circuits of various orders.

THD cannot be a criterion for some sufficient quality comparative evaluation of power source output voltage (or current for current sources). It shows only a quantity ("weight") of higher harmonics in relation to a fundamental one and does not talk about a distribution of harmonics in a frequency range of a voltage spectrum, in particular, about their proximity to the fundamental component, which is important, for instance, in a voltage source inverter and current source inverter designing process and for taking into account their impact on a load power quality. The criteria that take into account both the "weight" of high-frequency harmonics and their position in the spectrum are the integrated voltage harmonics factors (IHF) of various orders. They reflect the load filtering effect on the investigated exposure signal. They make weighted (by the harmonic order number) summation of harmonics, as a matter of fact, modeling the effect of the action of the amplitude-frequency characteristic of the corresponding order's idealized electric circuit. Such the ideal filter reduces the magnitudes of every harmonic by the number of times equal to the harmonic order number raised to the filter order's power [1].

So, the ADE method and respective IHF coefficients allow designing engineer to predict a harmonic content quality of some voltage or current of any linear circuit of filter and load for a particular input (exposure) voltage or current.

Among other matters, concerning higher harmonics, the developed due ADE method analytically-grounded method for definition of the contributions of customers and AC mains in voltage quality change has been proposed and considered in publications of the NSTU research laboratory of conversion systems' energy-optimisation [1–9].

Since the conducted emission problem of electromagnetic compatibility also takes place in DC power supply, a similar method for finding the quality of electrical energy in a mono-bus DC system by calculating the DC-circuit THD-similar values and for finding the coefficient of participation of a certain individual nonlinear consumer in the overall distortion of DC power quality is also developed [10, 11].

The objectives of this paper are to expand this DC power supply research to the case that the DC source is some rectifier, to provide an analytical description for the zero to four orders' DC-circuit integrated voltage harmonics factors of a general multipulse uncontrollably rectified voltage and to offer a core part of a LabVIEW virtual instrument for the assessment of the DC-circuit integrated signal harmonics factors for some simulated or captured exposure signal.

II. RECTIFIER-BASED DC POWER SUPPLY CIRCUIT

A functional block diagram and an example equivalent circuit of a DC power supply arrangement, based on a rectifier, are shown in Fig. 1 and Fig. 2.

Here an AC power source generates a single- or three-phase sinusoidal voltage, a transformer-rectifier unit transforms it to a multiphase sinusoidal voltage and then to a multipulse rectified voltage, and a passive smoothing DC filter eliminates current and voltage ripples in front of a load.

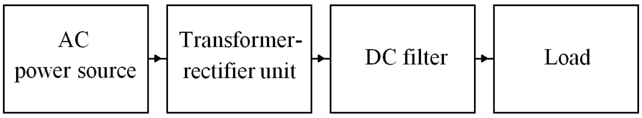

Fig. 1. Functional block diagram of DC power supply arrangement, based on rectifier.

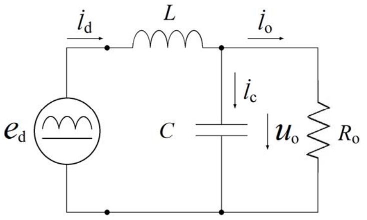

Fig. 2. Equivalent circuit of DC power supply arrangement, based on rectifier, with *LC*-filter.

The equivalent circuit in Fig. 2 is an example of the structure of Fig. 1 with the *LC*-filter as the simple (second-order) variant of the smoothing filter. The differential equations, establishing the relationships between the instantaneous values of the output voltage u_{o} across the output resistor R_{o}, of the input current i_{d} in the filter reactor L, the capacitor C current $\mathrm{i_c}$, the output current $\mathrm{i_o}$ and of the rectified voltage power supply EMF e_{d} are:

$$L\frac{di_{\mathrm{d}}}{dt}+u_{\mathrm{o}}=e_{\mathrm{d}}\,,\ i_{\mathrm{d}}=i_{\mathrm{c}}+i_{\mathrm{o}}\,,\ i_{\mathrm{c}}=C\frac{du_{\mathrm{o}}}{dt}\,,\ i_{\mathrm{o}}=u_{\mathrm{o}}/R_{\mathrm{o}}\,. \quad (1)$$

After substitutions one can obtain equation for the output voltage:

$$LC\frac{d^2u_{\mathrm{o}}}{dt^2}+\frac{L}{R_{\mathrm{o}}}\frac{du_{\mathrm{o}}}{dt}+u_{\mathrm{o}}=e_{\mathrm{d}}\,. \quad (2)$$

Hereinafter, the following designations will be used: X_{DC} to refer to the average value (the DC component) of *x*, X_{AC} to refer to the AC component of *x,* in doing so “o” and “d” (only for e_{d}) in the subscripts will be omitted for the related both AC and DC components. So, from (2) the usefull output voltage component, i.e. DC component, is:

$$U_{\mathrm{DC}}=E_{\mathrm{DC}}\,. \quad (3)$$

After needed two integrations, (2) for AC components is reduced to the form:

$$u_{\mathrm{AC}}+\frac{1}{R_{\mathrm{o}}C}\overline{u}^{(1)}_{\mathrm{AC}}+\frac{1}{LC}\overline{u}^{(2)}_{\mathrm{AC}}=\frac{1}{LC}\overline{e}^{(2)}_{\mathrm{AC}}\,, \quad (4)$$

where $\overline{x}^{(n)}_{\mathrm{AC}}$ is the result of the *n*-fold indefinite integral taking of the instantaneous AC variable x_{AC}.

According to the ADE procedure, applying the squaring and averaging operators, one can obtain the following algebraic equation:

$$U^2_{\mathrm{AC}}+\left(\frac{1}{(R_{\mathrm{o}}C)^2}-\frac{2}{LC}\right)\overline{U}^{(1)\,2}_{\mathrm{AC}}+\frac{1}{(LC)^2}\overline{U}^{(2)2}_{\mathrm{AC}}=\frac{1}{(LC)^2}\overline{E}^{(2)2}_{\mathrm{AC}}\,, \quad (5)$$

where $\overline{X}^{(\mathrm{n})}_{\mathrm{AC}}$ is the RMS value of $\overline{x}^{(\mathrm{n})}_{\mathrm{AC}}$.

Since, in accordance with the ADE method assumption, $\overline{U}^{(\mathrm{n}\geq\mathrm{N})}_{\mathrm{AC}}\equiv 0$, the resulting equations for the RMS value of the output voltage AC component at the various values of the approximation level N are

$$U_{\mathrm{AC}}=\frac{1}{LC}\overline{E}^{(2)}_{\mathrm{AC}}=a_0^2E_{\mathrm{DC}}\overline{K}^{(2)}_{\mathrm{heDC}} \quad (6)$$

for the case of N=1 (the roughest level of approximation),

$$U_{\mathrm{AC}}=\frac{1}{LC}\left[\overline{E}^{(2)2}_{\mathrm{AC}}-\left(\frac{1}{(R_{\mathrm{o}}C)^2}-\frac{2}{LC}\right)\overline{E}^{(3)2}_{\mathrm{AC}}\right]^{1/2}=$$

$$=a_0^2E_{\mathrm{DC}}\sqrt{\overline{K}^{(2)\,2}_{\mathrm{heDC}}-a_1\overline{K}^{(3)\,2}_{\mathrm{heDC}}} \quad (7)$$

for the case of N=2 and

$$U_{\mathrm{AC}}=\frac{1}{LC}\left[\overline{E}^{(2)2}_{\mathrm{AC}}-\left(\frac{1}{(R_{\mathrm{o}}C)^2}-\frac{2}{LC}\right)\overline{E}^{(3)2}_{\mathrm{AC}}+\right.$$

$$\left.+\left[\left(\frac{1}{(R_{\mathrm{o}}C)^2}-\frac{2}{LC}\right)^2-\frac{1}{(LC)^2}\right]\overline{E}^{(4)2}_{\mathrm{AC}}\right]^{1/2}=$$

$$=a_0^2E_{\mathrm{DC}}\sqrt{\overline{K}^{(2)\,2}_{\mathrm{heDC}}-a_1\overline{K}^{(3)\,2}_{\mathrm{heDC}}+a_2\overline{K}^{(4)\,2}_{\mathrm{heDC}}} \quad (8)$$

for the case of N=3 etc, where

$a_0=\dfrac{1}{\omega_{\mathrm{p}}\sqrt{LC}}$, $a_1=\dfrac{1}{(\omega_{\mathrm{p}}R_{\mathrm{o}}C)^2}-2a_0^2$, $a_2=a_1^2-a_0^4$, ω_{p} is a fundamental angular frequency of e_{d} pulses, and $\overline{K}^{(\mathrm{n})}_{\mathrm{heDC}}$ is the above mentioned DC-circuit integrated voltage harmonics factor (DCIHF) of order n,

$$\overline{K}^{(\mathrm{n})}_{\mathrm{heDC}}=\frac{\overline{E}^{(\mathrm{n})}_{\mathrm{AC}}\cdot\omega_{\mathrm{p}}^{\mathrm{n}}}{E_{\mathrm{DC}}}=\frac{1}{E_{\mathrm{DC}}}\sqrt{\sum_{\mathrm{k}=1}^{\infty}\left(\frac{E_{(\mathrm{k})}}{k^{\mathrm{n}}}\right)^2}\,, \quad (9)$$

here $E_{(\mathrm{k})}$ is the RMS value of k-order harmonic of e_{d}.

As can be seen from (6)-(8), a further rising of level N will leads to appearance of additional terms with alternating signs in radicand in (8), which will become less and less due to a low values of a_1, a_2, etc. As a rule, engineering practice precision allows to confine the calculations to N=1.

Now we are ready to write the equation for the DC-circuit voltage THD analogue,

$$K_{\mathrm{huDC}}=\frac{U_{\mathrm{AC}}}{U_{\mathrm{DC}}}\,, \quad (10)$$

namely, for N=3 we have

$$K_{\mathrm{huDC}}=a_0^2\sqrt{\overline{K}^{(2)\,2}_{\mathrm{heDC}}-a_1\overline{K}^{(3)\,2}_{\mathrm{heDC}}+a_2\overline{K}^{(4)\,2}_{\mathrm{heDC}}}\,. \quad (11)$$

Similar way we might process the equations for any required variables, in particular, the equation for the input current i_{d},

$$i_{\mathrm{dAC}}+\frac{1}{R_{\mathrm{o}}C}\overline{i}^{(1)}_{\mathrm{dAC}}+\frac{1}{LC}\overline{i}^{(2)}_{\mathrm{dAC}}=\frac{1}{L}\overline{e}^{(1)}_{\mathrm{AC}}+\frac{1}{R_{\mathrm{o}}LC}\overline{e}^{(2)}_{\mathrm{AC}}\,, \quad (12)$$

to obtain its DC-circuit current THD analogue,

$$K_{\mathrm{hidDC}}=\frac{I_{\mathrm{dAC}}}{I_{\mathrm{dDC}}}\,. \quad (13)$$

III. DC-CIRCUIT INTEGRATED VOLTAGE HARMONICS FACTORS OF GENERAL MULTIPULSE UNCONTROLLABLY RECTIFIED VOLTAGE

Both discrete uncontrolled switching devices, i.e. semiconductor diodes, and uncontrolled rectifiers are often used within the transformer-rectifier unit (TRU) to obtain multipulse DC voltage, see, for example, both classical solutions of one of the inventors of 1980s [12] and some publications of NSTU scientific school authors [13-25].

Let's here define by p a pulse multiplicity of the rectified voltage power supply EMF e_{d}, which is corresponding to the number of repeating segments of the rectified voltage waveform curve on a period of a feeding sinusoidal voltage (voltages).

Some troubles in practical implementation of multipulse TRU, such as the needs in performing's accuracy of multiwinding transformers' turns ratios in addition to requirement for enough high energy-efficiency of the windings, have been appeared starting with the rather low p values, like $p = 12$ (see, for example [26]). However, despite these challenges, a general possibility for obtaining the pulse multiplicity integer values not only of 2…6, but also of 8, 10, 12, 15, 16, 20, 24, 30, 48 and so forth, is shown and proved by simulations [16, 17, 24, 25].

It is further assumed that no capacitance is present directly across the TRU output. Some reasonable level of the rectifier loading maintains symmetry of the pulses with respect to the vertical axis passing through the top of the pulse. Each of such identical pulses is the waveform upper part of some TRU sinusoidal EMF e_{TRU} with an amplitude value E_{m} and an initial angular frequency ω. This sinusoidal EMF is a linear combination of initial sinusoidal EMFs of some transformers' windings, and it can be presented as the cosine function if the zero point of time corresponds to the top of the pulse. The resulting ripples' fundamental angular frequency ω_{d} of EMF e_{d} is p times more than the initial angular frequency ω of windings' EMF:

$$\omega_{\mathrm{d}} = p\omega . \qquad (14)$$

So, for an arbitrary pulse multiplicity p the rectified voltage power supply EMF e_{d} can be presented as it is shown in Fig. 3.

The rectified voltage power supply EMF e_{d} within the interval $-\pi \le \omega_{\mathrm{d}} t \le \pi$, i.e. $-\pi/p \le \omega t \le \pi/p$, can be described as follows:

$$e_{\mathrm{d}}(t) = e_{\mathrm{TRU}}(t) = E_{\mathrm{m}} \cos \omega t = E_{\mathrm{m}} \cos \frac{\omega_{\mathrm{d}} t}{p} . \qquad (15)$$

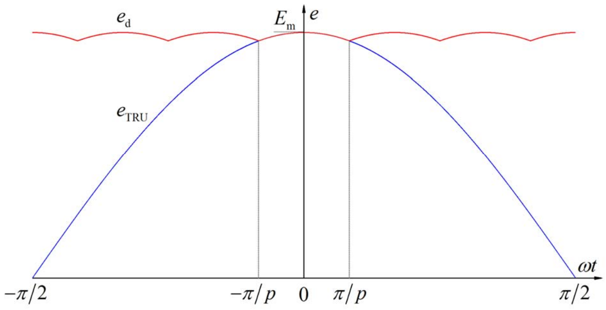

Fig. 3. Waveform diagram of EMF of rectified voltage (here $p = 12$).

Due to the even signal symmetry, EMF e_{d} can take a form of cosine Fourier series for the specified interval:

$$e_{\mathrm{d}}(t) = \frac{E_{\mathrm{m}}}{\pi/p} \sin(\pi/p) +$$

$$+ \frac{E_{\mathrm{m}}}{\pi/p} \sum_{k=1}^{\infty} \left(\left[\frac{\sin\left(\left(k - \frac{1}{p}\right)\pi\right)}{kp-1} + \frac{\sin\left(\left(k + \frac{1}{p}\right)\pi\right)}{kp+1} \right] \cos(kp\omega t) \right) =$$

$$= \frac{E_{\mathrm{m}} \sin(\pi/p)}{\pi/p} \left(1 + 2\sum_{k=1}^{\infty} \left(\frac{(-1)^{k-1} \cos(kp\omega t)}{(kp)^2 - 1} \right) \right) . \qquad (16)$$

In accordance with (9), now we are able to write expression for the DC-circuit integrated voltage harmonics factor of order n of the rectified voltage waveform curve with an arbitrary pulse multiplicity value:

$$\overline{K}^{(\mathrm{n})}_{\mathrm{heDC}} = \sqrt{2\sum_{\mathrm{k}=1}^{\infty} \frac{1}{\left((kp)^2 - 1\right)^2 k^{2\mathrm{n}}}} . \qquad (17)$$

As a result of applying of infinite series harmonic synthesis formulae [27, 28], the zero to four orders' DCIHF factors can be presented in the form

$$\overline{K}^{(\mathrm{n})}_{\mathrm{heDC}} = \sqrt{P_{\mathrm{n}}} ,$$

$$P_0 = -1 + \frac{\pi}{2} \cot(\pi/p) \frac{1}{p} + \pi^2 \frac{1}{2\sin^2(\pi/p)} \frac{1}{p^2} ,$$

$$P_1 = -2p^2 + \frac{3\pi}{2} \cot(\pi/p)\, p + \pi^2 \left(\frac{1}{2\sin^2(\pi/p)} + \frac{1}{3} \right) ,$$

$$P_2 = -3p^4 + \frac{5\pi}{2} \cot(\pi/p)\, p^3 + \pi^2 \left(\frac{1}{2\sin^2(\pi/p)} + \frac{2}{3} \right) p^2 + \frac{\pi^4}{45} ,$$

$$P_3 = -4p^6 + \frac{7\pi}{2} \cot(\pi/p)\, p^5 + \pi^2 \left(\frac{1}{2\sin^2(\pi/p)} + 1 \right) p^4 +$$

$$+ \frac{2\pi^4}{45} p^2 + \frac{2\pi^6}{945} ,$$

$$P_4 = -5p^8 + \frac{9\pi}{2} \cot(\pi/p)\, p^7 + \pi^2 \left(\frac{1}{2\sin^2(\pi/p)} + \frac{4}{3} \right) p^6 +$$

$$+ \frac{\pi^4}{15} p^4 + \frac{4\pi^6}{945} p^2 + \frac{\pi^8}{4725} . \qquad (18)$$

Unfortunately, these polynomial expressions, as shows their comparison to the related series expressions in Mathcad, are needed to be limited up to $p = 29$ for n = 3 and up to $p = 16$ for n = 4. Also the real importance of the multiple expressions P_0 … P_4 is low due to the related DCIHF factors $\overline{K}^{(0)}_{\mathrm{heDC}}$ … $\overline{K}^{(4)}_{\mathrm{heDC}}$ have curves of dependences on p which practically coincide with each other.

The dependences of the DC-circuit integrated voltage harmonics factors on the pulse multiplicity *p* (in the range 2…48) are shown in Fig. 4 for the three various factors value ranges. To present the full range of p (18) have been used for n = 0…2 and (17) have been used for n = 3, 4, and in the latter case the number of the summed up terms of the series has not had an identified impact on the results.

The zero-order DC-circuit integrated voltage harmonics factor $\overline{K}^{(0)}_{\text{heDC}}$ should be treated as the DC-circuit voltage THD analogue of the EMF e_{d} itself:

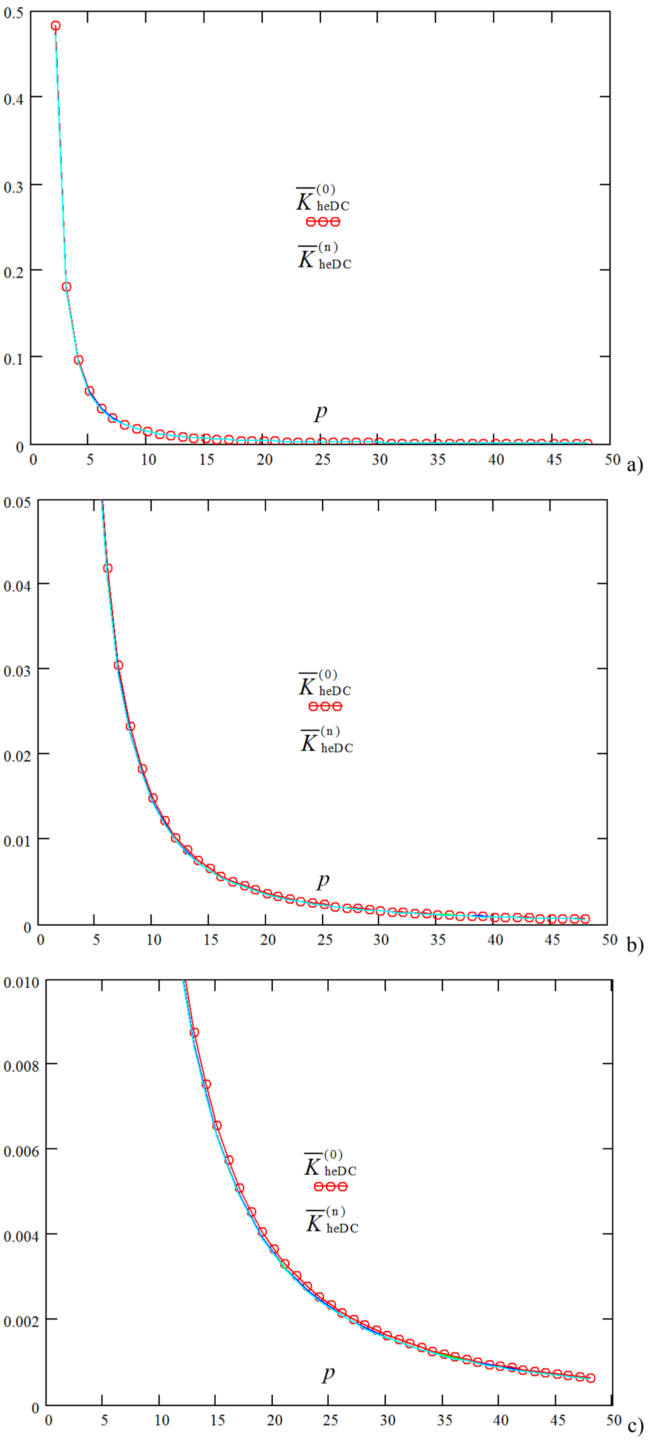

Fig. 4. Dependences of the DC-circuit integrated voltage harmonics factors of various orders on the pulse multiplicity: a) in the range up to 0.5; b) in the range up to 0.05; c) in the range up to 0.01.

$$\overline{K}^{(0)}_{\text{heDC}} = K_{\text{heDC}} = \frac{E_{\text{AC}}}{E_{\text{DC}}}. \tag{19}$$

To assess the proximity degree of $\overline{K}^{(0)}_{\text{heDC}}$ … $\overline{K}^{(4)}_{\text{heDC}}$ functions of *p* to each other the function $MaxD\%\_0(p)$ has been considered,

$$MaxD\%\_0(p) = \frac{MaxD(p)}{\overline{K}^{(0)}_{\text{heDC}}(p)} \cdot 100, \tag{20}$$

where $MaxD(p)$ is the function of a maximum deviation of the functions $\overline{K}^{(n)}_{\text{heDC}}(p)$ from each other at a particular *p*,

$$MaxD(p) = \left| \max\left(\overline{K}^{(i)}_{\text{heDC}}(p)\right) - \min\left(\overline{K}^{(i)}_{\text{heDC}}(p)\right) \right|,$$

$\text{i} \in \{0, 1, \ldots, 4\}$.

Since the function $MaxD\%\_0(p)$ has the peak value less than 3.87% (see Fig. 5), for evaluative computations, like in section II, the factor $\overline{K}^{(0)}_{\text{heDC}}$ might be used as the only factor K:

$$K = K_{\text{heDC}} = \overline{K}^{(0)}_{\text{heDC}} \approx \overline{K}^{(1)}_{\text{heDC}} \approx \ldots \approx \overline{K}^{(4)}_{\text{heDC}}. \tag{21}$$

So, (11) for the DC-circuit voltage THD analogue of the output voltage in Fig. 2 can be rewritten as approximate expression:

$$K_{\text{huDC}} \approx K a_0^2 \sqrt{1 - a_1 + a_2}. \tag{22}$$

IV. LABVIEW VIRTUAL INSTRUMENT FOR ASSESSMENT OF DC-CIRCUIT INTEGRATED SIGNAL HARMONICS FACTORS

The National Instruments LabVIEW software environment (Laboratory Virtual Instrument Engineering Workbench) is a widespread powerful monitoring and analysis tool, which can provide processing of both simulated and captured signals including a real time data acquisition and measurement due to the numerous specially developed and compatible hardware products.

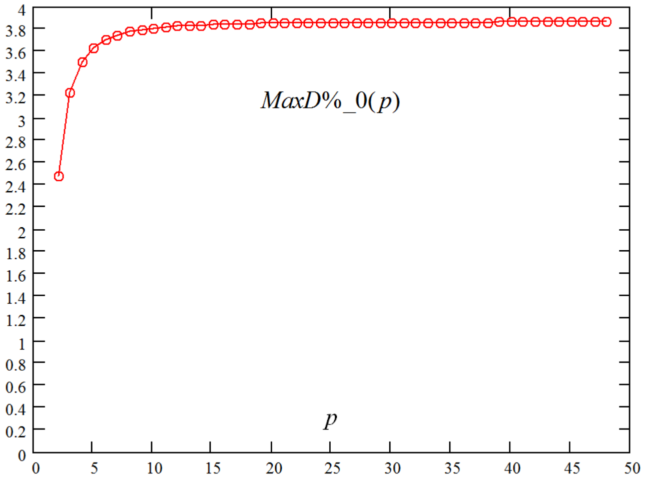

Fig. 5. Function of maximum deviation of DC-circuit integrated voltage harmonics factors' functions from each other as a percentage of the zero-order factor.

The LabVIEW has the enough wide range of means for the harmonic contents monitoring and evaluating, see, for instance, an IEEE conference paper [29] and references in it. Based on before provided virtual instruments (VIs), user-defined VIs with seemingly limitless level of complexity can be implemented.

The VIs for estimation of the various-orders IHF of some imposed to a filter and load unit AC signal are presented and discussed in [30, 31]. The very high accuracy has been demonstrated for simulations with enough high sampling rate of the input exposure signal. These virtual instruments were many times further applied for the advanced investigation of space vector pulse width modulated signals' waveforms.

Also there are various opportunities to use some advanced LabVIEW models to process signals, obtained outside of LabVIEW. For instance, the LabVIEW virtual instrument for the assessment of simulated signal alternative current IHF, equipped with the input module for waveform data points import from PSIM output text file, "Table data converter", is offered and proved to be effective [32].

Here the above mentioned techniques are applied to DC circuit signals. The core part block diagram of the LabVIEW virtual instrument for the DCIHF factors evaluation is presented in Fig. 6. It is directly implementing the first equation of (9).

It is obvious that the signal can be some voltage or current signal and can be both simulated and acquired from some ADC of real metering system. The using of this virtual instrument only makes sense if the investigated signal is unipolar one.

The zero- to third-order DCIHF factors values, obtained for few p values (up to $p = 18$) as results both of the computations according to (18) and of the VI measurements of imported PSIM-simulated signals, are shown in Table I below. The measured waveform signals correspond to the PSIM time step value of 0.1 μs. This is consistent with the VI input signal sampling rate value of 10 MHz. The values of the exact mathematical expression (18) have been used as the references while the relative error values calculating (which has been performed before the values rounding).

The intentionally redundant sampling rate was expected to serve as ensuring proximity of metering results to the theoretical values. As can be seen from the table, the accuracy of the results from the application of the offered VI has exceeded all expectations even at lowered level of harmonic distortions.

All the ratio error values are positive, indicating that all the metering estimates are greater than the related theoretical values, i.e. the VI would inflate DCIHF factors values a priori due to sampling. Thus, some adequate sampling rate can be chosen to obtain some desired or acceptable level of the ratio errors from the point of view of industrial designing.

V. CONCLUSIONS

The assessment method of the DC-circuit analogues for the voltage and current THD values has been applied to the case that the distorted DC voltage source is some rectifier.

The theoretical polynomial expressions for the various-orders' DC-circuit integrated voltage harmonics factors of a general uncontrollably rectified multipulse voltage have been obtained for the arbitrary value of voltage pulse multiplicity.

The LabVIEW virtual instrument for the assessment of the DC-circuit integrated signal harmonics factors for some simulated or captured exposure (imposed) signal is offered and tested within the context of low level of harmonic distortion. It should be noted that the area of application of the virtual instrument is much wider than quality estimation of some rectified voltage.

Both the calculated and measured values of DC-circuit integrated signal harmonics factors would allow for engineering design of DC power supply systems with specified voltage quality.

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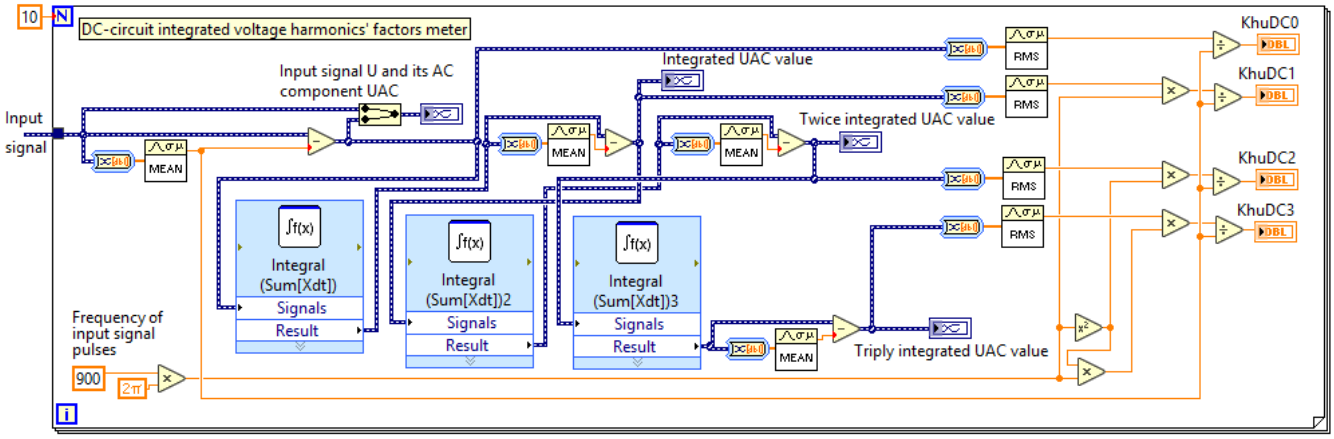

Fig. 6. Core part of LabVIEW virtual metering instrument for zero to third orders DC-circuit integrated signal harmonics factors evaluation.

TABLE I. ASSESSMENT OF UNCONTROLLABLY RECTIFIED VOLTAGE AS EXAMPLE OF USE OF VIRTUAL METER FOR DC-CIRCUIT INTEGRATED SIGNAL HARMONICS' FACTORS

Order of Factor, *n*	**Pulse multiplicity, *p***	**DC-Circuit Integrated Voltage Harmonics Factor Value**		
		Origin of value		***Ratio error,%***
		Calculating	***Metering***	
0	2	0.483426	0.483475	0.010
	3	0.182707	0.182716	0.005
	4	0.097721	0.097753	0.033
	6	0.041967	0.041977	0.024
	12	0.010284	0.010294	0.094
	18	0.004554	0.004564	0.206
1	2	0.473994	0.474041	0.010
	3	0.178049	0.178058	0.005
	4	0.095018	0.095043	0.026
	6	0.040740	0.040748	0.018
	12	0.009974	0.009981	0.069
	18	0.004416	0.004422	0.147
2	2	0.472017	0.472068	0.011
	3	0.177077	0.177087	0.005
	4	0.094455	0.094480	0.026
	6	0.040485	0.040492	0.018
	12	0.009910	0.009916	0.068
	18	0.004387	0.004394	0.148
3	2	0.471554	0.471609	0.012
	3	0.176850	0.176862	0.007
	4	0.094323	0.094349	0.027
	6	0.040425	0.040433	0.020
	12	0.009895	0.009917	0.231
	18	0.004380	0.004427	1.085

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