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SOFTWARE TOOL FOR VOLTAGE DIP SIGNAL GENERATOR

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This paper presents a software tool for a three-phase voltage dip signal generator, which can be used to generate waveforms similar to those recorded. The voltage dip signal generator is designed to shape the voltage waveforms for the three phases, using random functions for almost all possible parameters. The advantage of using the generated waveforms instead of real data measurements is that the dip parameters are known, and in this way, it can be detected if the specific algorithms used for voltage dips analysis give correct results. Finally the tool was used to generate some voltage dips with different parameters and characteristics.

Keywords: voltage dip, signal generator, random function, software tool

1. Introduction

Voltage dips are considered the main power quality disturbance, due to sensitivity reported in power electronics equipments. This sensitivity has been reflected with interruption in continuous processes, producing high economical losses. According to [1], annual costs due to PQ disturbances in Europe are more than half due to voltage dips and interruptions (< 1 sec). For this reason, in literature are many studies regarding dip detection, parameters computation or estimation, classification according single or three phase events.

In literature, there are many digital signal processing (DSP) technologies employed for voltage dip detection and characterization. Many of them use different types of wavelet transforms or Kalman filters [2]-[6]. Some authors use artificial intelligence to do this [7], [8].

There are a lot of methods and algorithms used in voltage dips detection and classification. A collection of DSP techniques, and a comparison between these techniques used in voltage dip analysis is presented in [9]. In [10] is presented an analysis regarding the accuracy of algorithms adopted in voltage dip measurements.

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All the works listed above, test the performance of the adopted algorithms on real data recorded with different monitoring equipment. To demonstrate the performance of the algorithms, the authors compare the results with other results obtained by well-known algorithms.

This paper aims to present a software tool developed to generate three phase voltage dip waveforms. The paper starts from a previous work [11] where the authors present a mathematical model for a single phase voltage dip generator.

As it follows, Section II presents the algorithm use for software tool development; Section III presents some case studies to demonstrate the correct operation of the tool and the advantage of using it, and finally Section IV present the final conclusions.

2. The Algorithm of Voltage Dip Signal Generator

In this chapter is presented the algorithm and it implementation in C#. First it must to be known the parameters and the characteristics of voltage dips.

The parameters for a single phase voltage dip are: amplitude, duration, phase angle jump (shift). The waveform for a single phase voltage can be affected by harmonic distortion and noise [11].

The mathematical model used for generate a single phase voltage dip is presented in (1).

$$y(t)=\begin{cases} A_1\cdot N(t)\cdot \sin(2\pi f t) & ,t\le t_1 \\ N(t)\cdot j_1(t)\cdot \dfrac{Y_2(t_1+\theta)-Y_1(t_1)}{j_1(t_1+\theta)-j_1(t_1)} & t_1<t\le t_1+\theta \\ A_2\cdot N(t)\cdot \sin(2\pi f t+\varphi) & ,t_1+\theta<t\le t_2 \\ N(t)\cdot j_2(t)\cdot \dfrac{Y_1(t_2+\theta)-Y_2(t_2)}{j_2(t_2+\theta)-j_2(t_2)} & t_2<t\le t_2+\theta \\ A_1\cdot N(t)\cdot \sin(2\pi f t) & ,t_2+\theta<t \end{cases}, \quad (1)$$

$$N(t)=1+\sum_i \frac{A_{in}}{A_1}\cdot \sin(2\pi f_{in}t+\varphi_{in})+\frac{A_n}{A_1}\cdot\prod_i \sin(2\pi f_{jn}t+\varphi_{jn}), \quad (2)$$

The three phase voltage dips are characterized by a variation of amplitude and angle for each phase. For this reason, the three phase voltage dips were classified with a method called ABC Classification [9].

Once the mathematical model and the classification model were selected the software was implemented following the algorithm presented in Fig.1.

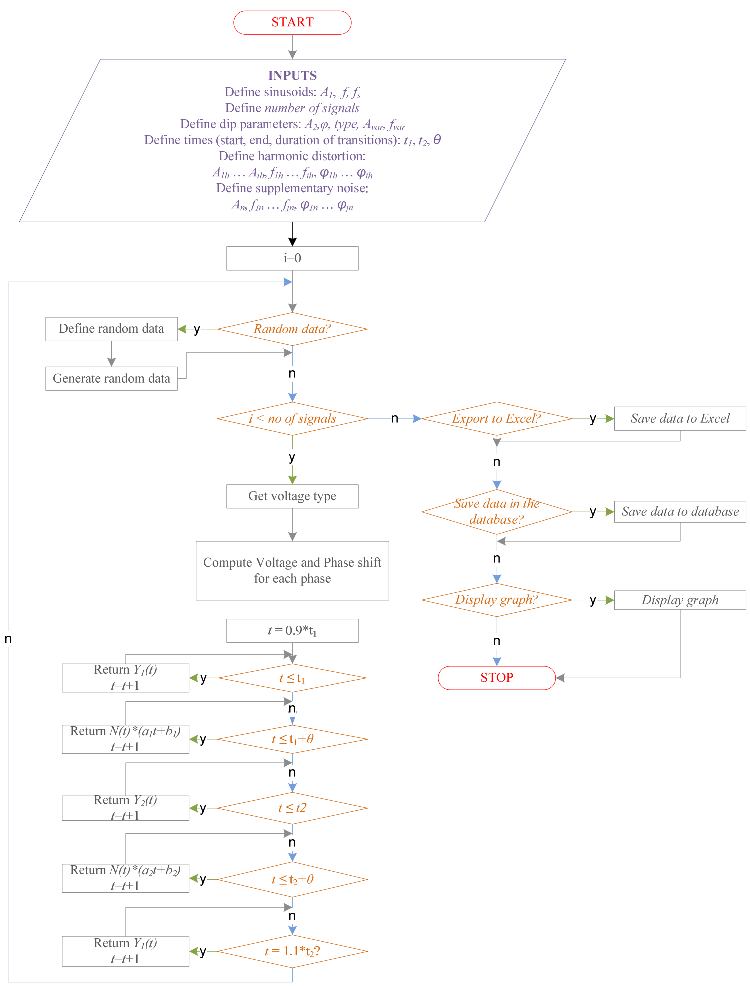

Fig. 1. Flowchart for the algorithm.

The tool offers the possibility to introduce the input parameters or to generate random the needed set of data. Each parameter is generated as a value in a range of possible entries, as described in Table 1.

Table 1

Voltage dip parameters range

Dip Amplitude [pu]	0.6 – 0.8	Harmonics	
φ[º]	-30 – 30	Amplitude [%]	0 – 5
Dip duration [s]	0.01 – 1	φ [º]	0 – 360
Voltage variation [%]	-10 – 10	f [Hz]	150, 250,…, 1250
Frequency variation [%]	-2 – 4	Noisy Frequency	
Dip Type	a, b, c, d, e, f, g	Amplitude	0 – 5
Number of Harmonics	0 – 10	φ [º]	0 – 360
Number of Noisy Frequencies	0 – 10	f [Hz]	0 – 10000

All the parameters and the ranges can be modified, depending of the needs as shown in the Fig.2, where the range for Frequency variation [%] is [-2; 4].

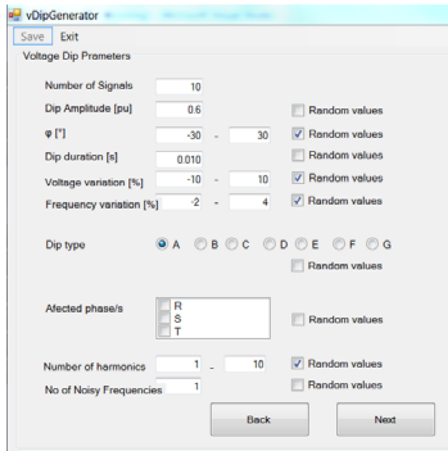

Fig. 2. Parameters window.

After the parameters are defined the application initializes a loop in order to generate the needed signals. In each iteration, the random inputs are calculated and depending of the voltage dip type, for all three phases the dip amplitude and the dip jump angle are defined.

The signal is composed from 5 segments in the following order: normal regime, transition phase, dip regime, transition phase, normal regime, each segment having his interval in time and his parameters, as described in the algorithm.

In the end the list with all signals and parameters are shown (Fig. 3.) and for the selected signal also a graph will be displayed.

Fig. 3. Signals window.

3. Case study

Once the algorithm was implemented into a C# application, three kinds of tests were done. The first test was to generate a single voltage dip signal by entering the numerical values of the input parameters used in the simulation (see Table 2).

Table 2

Voltage dip parameters for dip Type C

Phase-to-phase voltage [kV]	110	Dip Amplitude [pu]	0.5	Harmonics		
		φ[°]	30	f [Hz]	φ[°]	U[V]
f [Hz]	50	Dip duration [s]	0.2	850	6	2300
Real Voltage [kV]	115.5	Dip Type	c	350	245	3500
Real frequency [Hz]	49.5	Number of Harmonics	2	Inter Harmonics		
No of phases	3	Number of Noisy Frequencies	1	f [Hz]	φ [°]	U[V]
				1000	180	6800

The signal can be created as single phase or a three phase signal, using all the parameters given by the user, selecting all parameter to be generated random or selecting which parameter to be random and which to be given by the user. The generated signal in the case where all parameters where given by the user (Table 2) is presented in Fig. 4.

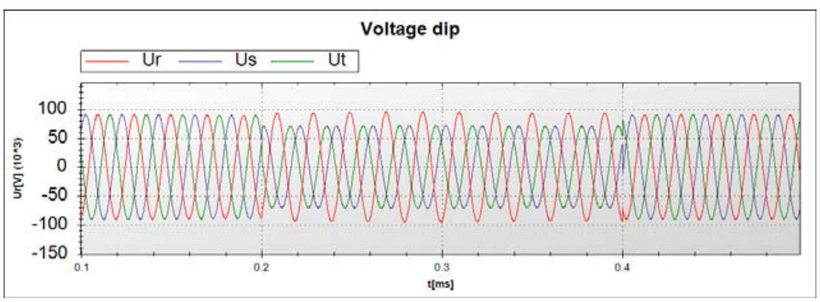

Fig. 4. Waveform during the voltage dip obtained with voltage dip signal generator

In the case it is wanted to generate multiple signals there should be selected which of the parameters to be fix and which to be random.

To demonstrate this functionality the second type of testing was done by generating 10 three phase signal having type “E” voltage dip and using a set of numerical input values obtained using the random function for all the other parameters. The signals were generated starting from a voltage level of 110 kV at 50 Hz frequency. The sampling rate used is 10 kHz. The generated values are presented in Table 3.

Table 3

Three phase "E" type Voltage dip - random parameters

No	Real Voltage [kV]	Real frequency [Hz]	Dip Amplitude [pu]	φ[º]	Dip duration [s]	Number of Harmonics	Number of Noisy Frequencies
0	112.2	50.256	0.657	24.064	0.503	9	1
1	102.3	49.754	0.634	2.977	0.665	9	3
2	113.3	49.252	0.611	-18.111	0.828	9	5
3	113.3	50.423	0.669	-27.099	0.107	6	1
4	106.7	50.814	0.688	9.905	0.197	5	1
5	114.4	50.249	0.766	-0.285	0.162	8	7
6	117.7	50.312	0.665	-11.182	0.360	4	9
7	118.8	50.138	0.762	15.632	0.415	6	6
8	103.4	50.918	0.601	29.640	0.595	4	3
9	101.2	50.026	0.759	-28.451	0.667	5	3

The last type of testing was done by generating a set of 100 input parameters using random function for all parameters. Regarding the results, in Fig. 5., it is shown the distribution of the dip types over the 100 generated signals.

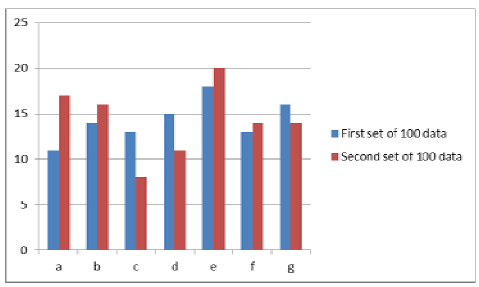

Fig. 5. Number of dips for each type

In the same is presented also the distribution of the jump angle in different intervals segments.

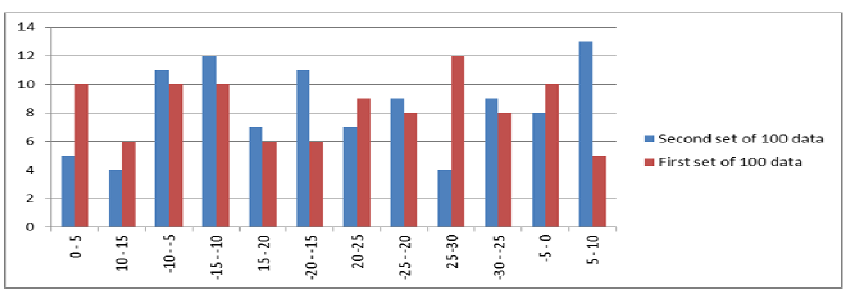

Fig. 6. Number of dips for jump angle ranges

The last graph represents the distribution of the pairs dip amplitude - dip duration.

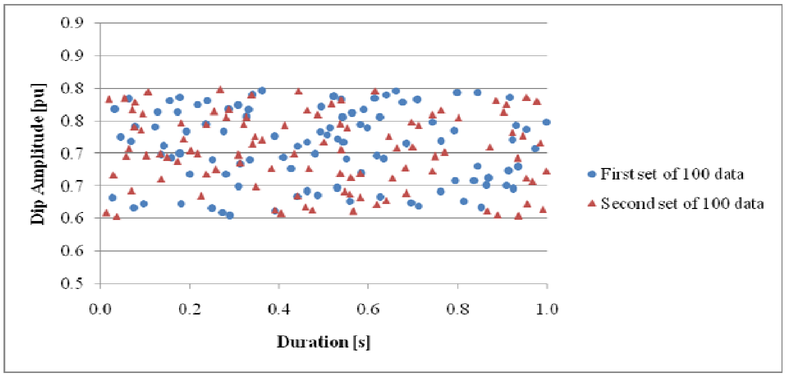

Fig. 7. Generated dip amplitude - dip duration pairs

4. Conclusions

In this paper was presented a software tool developed to generate three phase voltage dip waveforms. The voltage dip signal generator is designed to shape the voltage waveforms for the three phases, using random functions for almost all possible parameters. The advantage of using the generated waveforms instead of real data measurements is that the dip parameters are known, and in this way, it can be detected if the specific algorithms used for voltage dips analysis give correct results.

Finally, in order to demonstrate the correctness of the algorithm, the tool was used to generate some voltage dips with different parameters and characteristics. The results obtained were graphically presented.

The implemented software will be available online at the webpage of Power Engineering Department from University Politehnica Timisoara, and we suggest that the generated signals that are used for testing different algorithms used in voltage dip analyses to be available on internet so that comparative testing, between two methods, to be done using the same data.

Acknowledgement

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