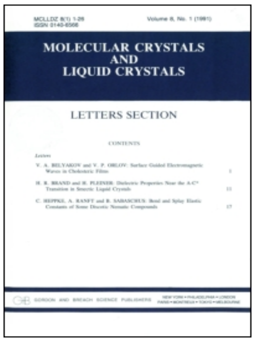

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New method for detection and characterization of voltage dips

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ABSTRACT
The work presented in this paper is dealing with the quality monitoring problem of the electric power. It aims to introduce new technique to treat and to analyze the electrical energy quality related to the voltage dips. It concerns the detection and the classification of voltage dips based on their characterizations. The results of this work are provided using simulation studies under MATLAB / Simulink software.

KEYWORDS
Voltage Dips; Voltage Sags Detection; Classification; Monitoring; Algorithm

I. Introduction

Voltage dips are the most common power disturbance [1–5]. They happen when the rms voltage decreases between 10 and 90 percent of nominal voltage for one-half cycle to one minute [6, 7]. They are usually caused by a short circuit, overload or any others transitory currents which can be required in situation such as [8,9]:

- coupling the transformer,
- Starting high power asynchronous machine.
- operation of a shunt circuit breaker
- coupling capacitors,

View the scale of the problems caused by voltage dips; including malfunction or shutdown of production equipment and tools; producers, retailers and manufacturers are very alert to the imperfections of the electrical energy [8].

We present in this paper a new method to detect, classify and characterize the different types of voltage dips as defined by M. BOLLEN [10]. This method is based on the instantaneous calculation and analysis, of the electrical signal envelop. The shape of the envelop is used in one hand to indicate the presence or not of a voltage dip, and, in the other hand, to determine the voltage

II. Definition and classification of different types of voltage dips

Voltage dips are mainly characterized by their magnitude and phase [10–12]. Thus, they can be represented by so-called vectors phrasemongers. The relationship between them is called signature or type of the dip. Table 1 lists the seven major voltage sag types denoted by the letters A to G [10].

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/gmcl.
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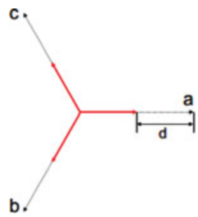
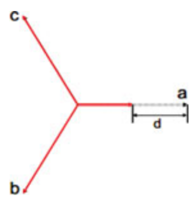
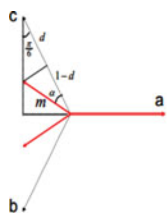
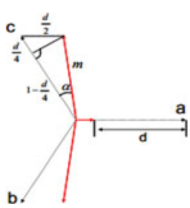
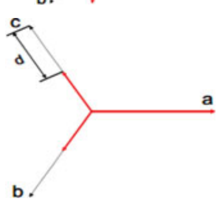
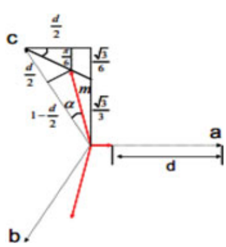
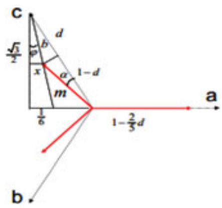
Table 1. The universal classification of voltage dips.

Type	Signature	Equation	Origine
A		$\begin{cases} Va = \frac{(1-pc)V}{2}(e^{j\theta}+e^{-J\theta}) \\ Vb = \frac{(1-pc)V}{2}(e^{j(\theta-\frac{2\pi}{3})}+e^{-j(\theta-\frac{2\pi}{3})}) \\ Vc = \frac{(1-pc)V}{2}(e^{j(\theta-\frac{4\pi}{3})}+e^{-j(\theta-\frac{4\pi}{3})}) \end{cases}$	Three phase fault
B		$\begin{cases} Va = \frac{(1-pc)V}{2}(e^{j\theta}+e^{-J\theta}) \\ Vb = \frac{V}{2}(e^{j(\theta-\frac{2\pi}{3})}+e^{-j(\theta-\frac{2\pi}{3})}) \\ Vc = \frac{V}{2}(e^{j(\theta-\frac{4\pi}{3})}+e^{-j(\theta-\frac{4\pi}{3})}) \end{cases}$	Single phase fault
C		$\begin{cases} Va = \frac{V}{2}(e^{j\theta}+e^{-J\theta}) \\ Vb = \frac{mV}{2}(e^{j(\theta-\frac{2\pi}{3}-\alpha)}+e^{-j(\theta-\frac{2\pi}{3}-\alpha)}) \text{ avec} \\ Vc = \frac{mV}{2}(e^{j(\theta-\frac{4\pi}{3}+\alpha)}+e^{-j(\theta-\frac{4\pi}{3}+\alpha)}) \end{cases}$ $cos(\alpha) = \frac{1-pc}{m}$	A fault between two phases
D		$\begin{cases} Va = \frac{(1-pc)V}{2}(e^{j\theta}+e^{-J\theta}) \\ Vb = \frac{mV}{2}(e^{j(\theta-\frac{2\pi}{3}+\alpha)}+e^{-j(\theta-\frac{2\pi}{3}+\alpha)}) \text{ avec} \\ Vc = \frac{mV}{2}(e^{j(\theta-\frac{4\pi}{3}-\alpha)}+e^{-j(\theta-\frac{4\pi}{3}-\alpha)}) \end{cases}$ $cos(\alpha) = \frac{4-pc}{4m}$	Propagation of the voltage dip type C.
E		$\begin{cases} Va = \frac{V}{2}(e^{j\theta}+e^{-J\theta}) \\ Vb = \frac{(1-pc)V}{2}(e^{j(\theta-\frac{2\pi}{3})}+e^{-j(\theta-\frac{2\pi}{3})}) \\ Vc = \frac{(1-pc)V}{2}(e^{j(\theta-\frac{4\pi}{3})}+e^{-j(\theta-\frac{4\pi}{3})}) \end{cases}$	A fault between two phases and the ground
F		$\begin{cases} Va = \frac{(1-pc)V}{2}(e^{j\theta}+e^{-J\theta}) \\ Vb = \frac{mV}{2}(e^{j(\theta-\frac{2\pi}{3}+\alpha)}+e^{-j(\theta-\frac{2\pi}{3}+\alpha)}) \text{ avec} \\ Vc = \frac{mV}{2}(e^{j(\theta-\frac{4\pi}{3}-\alpha)}+e^{-j(\theta-\frac{4\pi}{3}-\alpha)}) \end{cases}$ $cos(\alpha) = \frac{1-pc/2}{m}$	Propagation of the voltage dip type G.

(*Continued on next page*)

Table 1. Continued

Type	Signature	Equation	Origine
G		$\begin{cases} Va = \frac{(1-pc)V}{2}(e^{j\theta}+e^{-J\theta}) \\ Vb = \frac{mV}{2}(e^{j(\theta-\frac{2\pi}{3}+\alpha)}+e^{-j(\theta-\frac{2\pi}{3}+\alpha))}) \text{ avec} \\ Vc = \frac{mV}{2}(e^{j((\theta-\frac{4\pi}{3}-\alpha))}+e^{-j(\theta-\frac{4\pi}{3}-\alpha))}) \end{cases}$ $cos(\alpha) = \frac{1-pc}{m}$	Propagation of the voltage dip type E.

Where,
V is the maximum value of the amplitude of the electrical signal.
pc is the depth of the voltage dip.
m is the value of the voltage drop (type C, D, F and G).
α is the additional phase shift of the voltage that can cause voltage dips.

Mathematical expressions V_k, $k\in$ (a, b, c) concern the three components of each signature. As shown in these various scenarios, voltage dips are generated by an unbalance which can affect the signal magnitude or its phase, so we can classify voltage dip without phase default (A, B, E), and voltage dips with a phase shift affecting one or more phases (C, D, F, G)[4][11].

III. Principle the new method for the voltage dips detection

The method, in a first step, detects and classifies different types of voltage dips, and secondly, determines its depth value, and the affected phases. These can be very useful for a possible correction in real time. The principle of the method is based on the computation and analysis of the envelop of the network voltage on the one hand, and on the other hand on the calculation of the phase shift of each phase, in order to detect if there is any default on the signal phase shift.

The phase calculation can be performed by decomposing signals in the Fourier series [13], and the calculated phase difference of the voltages V_a, V_b and V_c is respectively compared to the values 0 °, −120 °, 120 °.

The method procedure is split into two parts, the first one concerns the detection and the second one is about the classification and the type characterization.of

1. *Detection of the voltage dip*

The envelop of the voltage network, which is used to detect the voltage dip, is determined by locating the signal local maximums. These local maximums are calculated using an algorithm based on the detection of the sign changing of two consecutive samples of the signal difference. Indeed the maximum is obtained if the sign of this difference passes from positive to negative. An interpolation allows to draw the envelop of the signal. Figure 1 shows an example of envelop calculation

However, the method cannot detect a voltage dip starting or ending during negative alternation, in order to remedy this problem, we opted for the rectifying of the voltage (Figure 2),in this case we have access to the negative and positive alternations, and we can detect voltage dip during either negative or positive alternations.

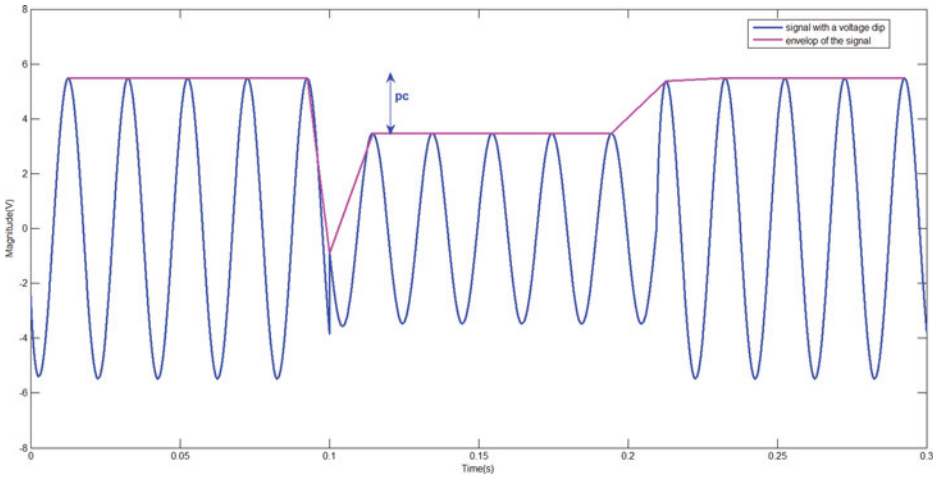


Figure 1. Envelop of a sinusoidal signal.

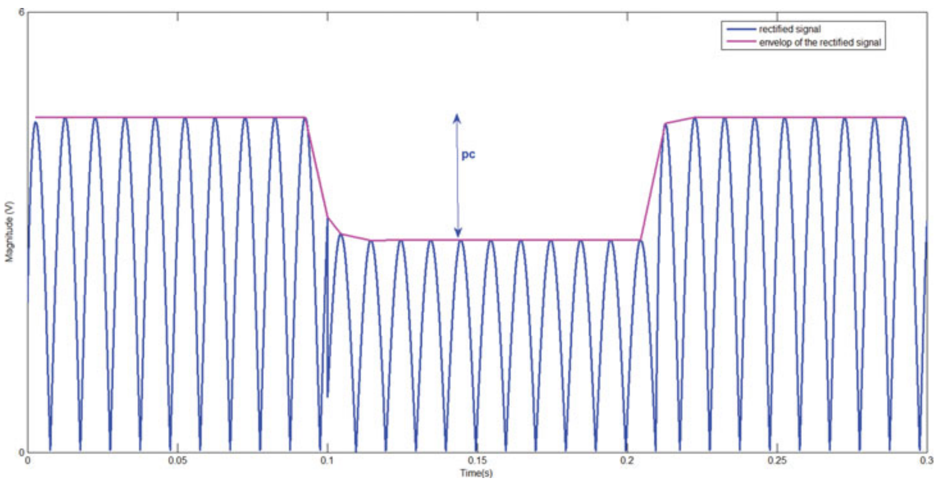


Figure 2. Envelop of a rectified signal.

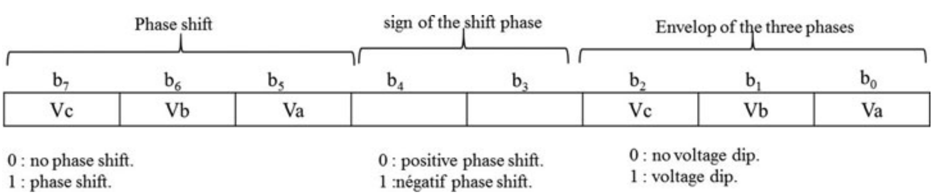


Figure 3. Binary word representing the state of three phases.

The rectifier receives the voltage from a step-down three-phase transformer type $Y_n y_n$, which does not modify the signature and the type of the voltage dip [11, 14].

2. *Voltage dips classification*

The difference between the maximum and the minimum of the signal envelop informs about the presence or the absence of the voltage dip, this difference can be, in one hand, translated by a Boolean signal, which will be equal to zero in the case of the voltage dip absence and

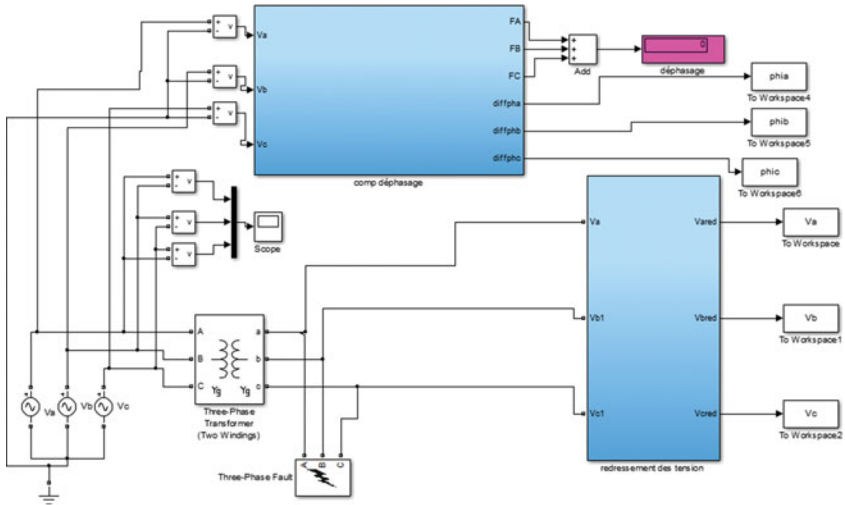


Figure 4. Platform of simulation.

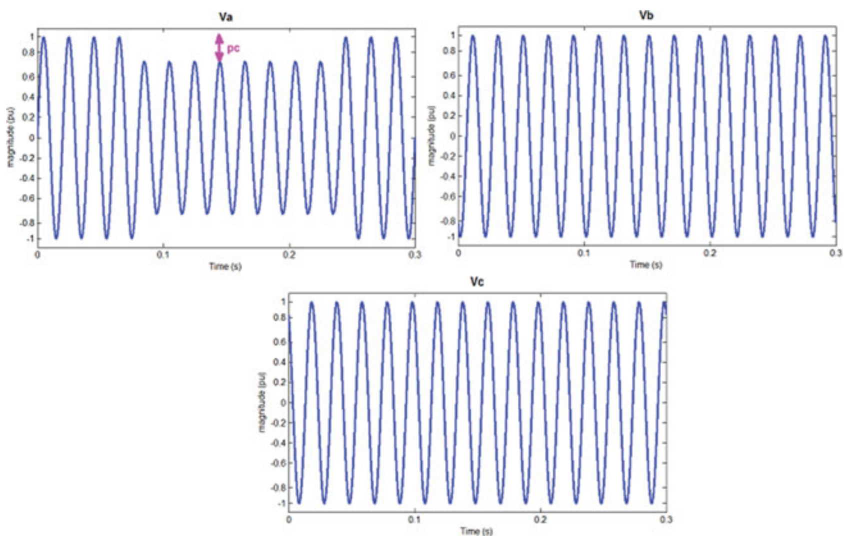


Figure 5. The three tensions V_a, V_b, and V_c.

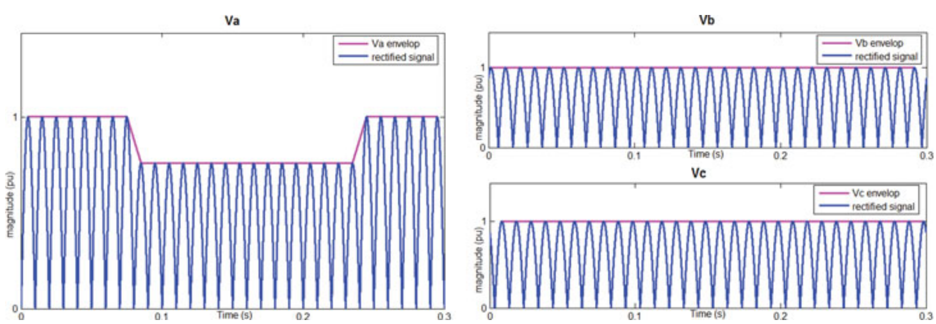


Figure 6. Envelop of the rectified signals V_a, V_b, and V_c.

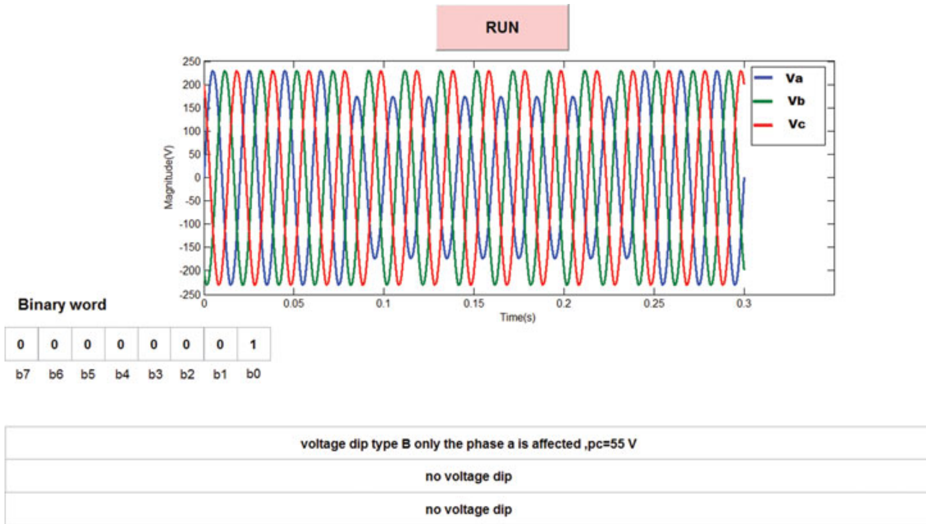


Figure 7. Results of the classification.

equal to one in the opposite case, and on the other hand, used to compute the depth of the voltage dip.

The Boolean signal, is used to determine the typology of the voltage dip according to a code based on the storage of the three phases' state in a binary word, having 8 bits (byte). The three first bits, b_0, b_1, b_2 inform, respectively, about the absence or the presence of the voltage dip on the signals V_a, V_b and V_c, the last three bits b_5, b_6, b_7 inform, respectively, about the presence or not of a phase shift default on the voltages V_a, V_b and V_c. Both bits b_4 and b_3 are reserved for the sign of the shift phase, this information is useful to classify the voltage dip type G. Figure 3 illustrate the principle of this binary word.

Table 2. Codes of seven types of the volatge dip.

Type of the voltage dip		Binary word								Decimal value
No voltage dip		0	0	0	0	0	0	0	0	0
Type B	a	0	0	0	0	0	0	0	1	1
	b	0	0	0	0	0	0	1	0	2
	c	0	0	0	0	0	1	0	0	4
Type E	a,b	0	0	0	0	0	0	1	1	3
	a,c	0	0	0	0	0	1	0	1	5
	b,c	0	0	0	0	0	1	1	0	6
Type C	a,b	0	1	1	0	0	0	1	1	99
	a,c	1	0	1	0	0	1	0	1	165
	b,c	1	1	0	0	0	1	1	0	198
Type A	a,b,c	0	0	0	0	0	1	1	1	7
Type G	a,b,c	0	1	1	0	0	1	1	1	103
	a,b,c	1	0	1	0	0	1	1	1	167
	a,b,c	1	1	0	0	0	1	1	1	199
Type F	a,b,c	0	1	1	0	1	1	1	1	111
	a,b,c	1	0	1	0	1	1	1	1	175
	a,b,c	1	1	0	0	1	1	1	1	207
Type D	a,b,c	0	1	1	1	1	1	1	1	127
	a,b,c	1	0	1	1	1	1	1	1	191
	a,b,c	1	1	0	1	1	1	1	1	223

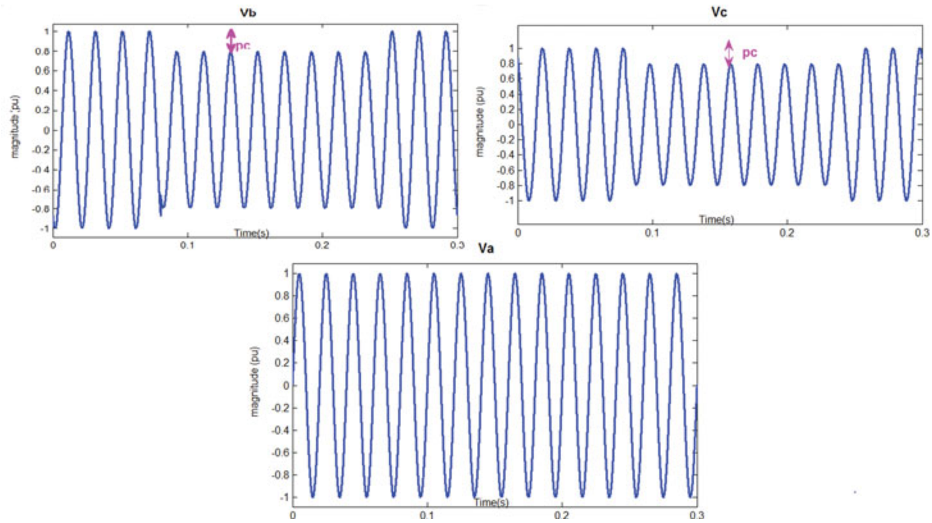


Figure 8. Voltage dip type C.

For every binary word, we correspond a type of the voltage dip as shown in table 2, to simplify the processing of the information, we realized a coding BCD.

Our method is applied to examples simulated under the MATLAB / SIMULINK environment.

IV. Simulation

For our simulation, we generated at first a three-phase system 380/230 V of 50 Hz, to simulate a low-voltage network, then we created two types of a voltage dip:

- Type B in the phase B
- Type C in the phases A and B.

The voltage dip is created by a block programmed under Simulink and called “fault breaker”, which can introduce single-phase, two-phase and three-phase fault (Figure 4).

Finally these signals were lowered and rectified in order to be analyzed by our approach.

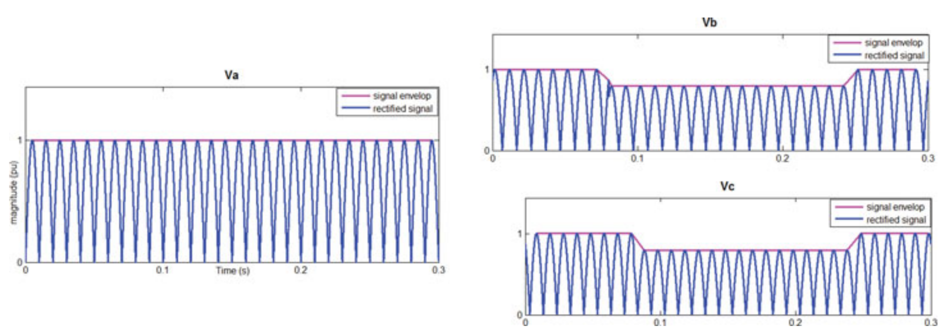


Figure 9. Envelops of the network of the voltage dips.

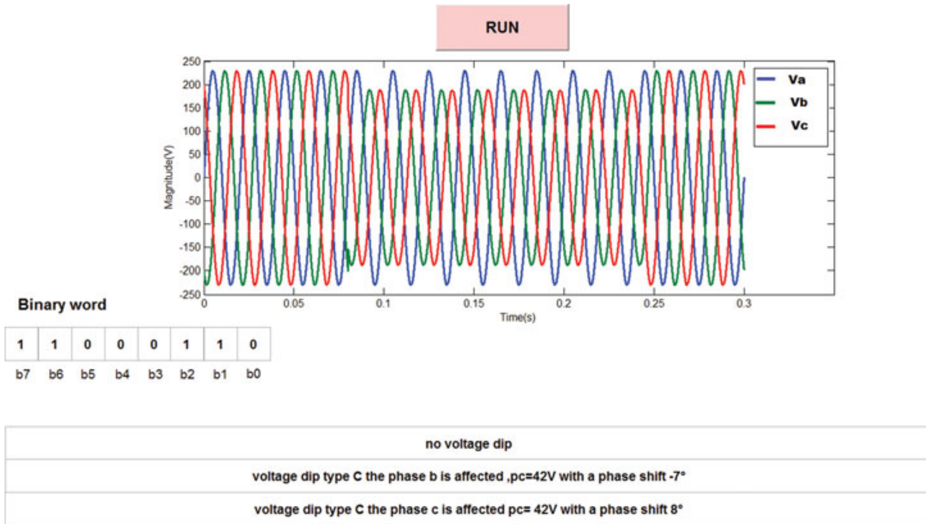


Figure 10. results of simulation of this type of voltage dip.

V. Results and discussion

Example 1: voltage dip type B

The Three phase voltage of the simulated network, with a fault on the phase A, are illustrated on Figure 5. These signals are, then, handled using our voltage dip analyzer, developed above. The Figure 6 presents the envelop of the three voltages. The result of the voltage dip analyzer is shown, thanks to the graphical interface designed using Matlab software.

According to Figure 7, we notice that our method identifies, classifies and characterizes the voltage dip in the phase B, it represents a depth of 55 V.

Example 2: voltage dip type C

In the same way, we create a fault between the phase B and C. Figure 8 shows the three phase voltages with their voltage dips. Their envelops are presented on Figure 9. And the output of our voltage dip analyzer is shown on Figure 10.

VI. Conclusion

We develop a new approach to identify and analyze the voltage dip, Using Matlab / SIMULINK software, the method is tested and confronted, the obtained result are encouraging and can be exploited to develop identification's sensor in the real time. The next step of our work is to apply our approach to identify and study the voltage dips related the wind turbine.

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