ANALYSIS OF ELECTRIC DISTURBANCES IN THE QUALITY OF ELECTRIC ENERGY USING THE ABC METHOD OF CLASSIFICATION FOR THE APPLICATION TO VOLTAGE DIPS AND SHORT INTERRUPTIONS

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Abstract: *In this paper, we try to approach the analysis of voltage sags and short interruptions. In this investigation the voltage sags and short interruptions analysis is carried out for the various circuit types.*
We have used in that network analysis a linear form of the set bars equations which requires a precise network description by set bars voltage and phase or set bars current injection and voltages. By use of equation linearity, the power systems loads are replaced by their equivalent impedance to the equation are then used for analysis and an executable periodic calculation in to computers.
For a complete fault analysis, the system is modeled in MATLAB/Simulink software then the simulation results are compared with a developed method based on the classification of voltage dips. The analysis consists of ABC Classification. Reason for which the equations should be used in order to find out voltages currents in various set bars, or various network branches when the global matrix is calculated either for symmetrical and unsymmetrical short-circuit.

Key words: Imbalance, Power quality, Voltage sags and short interruptions, voltage deviation, voltage oscillation, voltage unsinusoidality, neutral displacement, short interruptions and voltage sags classification.

1. Introduction

The calculation of unsymmetrical in the power system network requires voltage calculation and asymmetrical short-circuits currents. Nevertheless the subscriber must ensure the protection of his installation against fugitive fault or long duration cuts, food safety (continuity of service) and exemplar availability of electrical supply network, which are conditioned by the great reliability of the material provided by manufacturers.

The electric disturbances are an embarrassment for the users without a truly cut of the electrical supply network such as voltage hollows, fast voltage fluctuations, harmonic distortions and voltage imbalances, for that is being studied improvement unsymmetrical index of voltage in the analysis of the electrical networks.

The concept of quality means that the production properties have a good or bad quality. It is always required a good quality, it is the operation purpose of all electric installations. For the electric power, one uses the technical indices of voltage and frequency. For the voltage, the following indices are used, [1,3]:

- Voltage sags and short interruptions
- Voltage asymmetrical
- Voltage Deviation
- Voltage Oscillation
- Voltage Unsinusoidality
- Neutral displacement.

For the frequency, the following indices are used:

- Frequency Deviation
- Frequency Oscillation.

It is necessary to have an improvement of the supply quality of electricity to satisfy the customers and the community's needs, which constitute the electrical network.

Generally, the power absorbed by an installation is higher than the real usage power. This means that certain apparatuses consume in their magnetic circuits and their windings a reactive power which produces any work.

This absorbed parasitic power, overloads unnecessarily the lines and the equipment. Moreover, this power gives place to penalties on behalf of the electricity supplier. It is more benefit to produce it or to compensate, it on its own.

The reactive power is one of the indices evaluating the energy characteristics of an electric network. This is why, it is necessary, not only to give it a more complete physical interpretations, but to establish its relation with the other characteristics of the energy processes and to evaluate quantitatively advantages and disadvantages which result from this. The reactive power characterizes a fundamental property of the electric networks by the fact that it gives possibility to make flexible their mode of operation.

From the economic point of view, the study of the compensation of the reactive power in the electric networks has, generally, two different orientations according to whether it is of a convergence network or a distribution network.

When the grid system is consumed, the required objective is the establishment of the balance of the reactive power to maintain in the nodes of the electric network a voltage level determined such as it would correspond to a maximum transport capacity. In other words, it is about search for a mode of operation of the network, technically and economically optimal.

In the case of the distribution network, the study of the compensation is rather directed towards the resolution of the problems concerning the quality of electric power consumed and consequently, the satisfaction of certain requirements of the consumers, indeed, the distribution networks are characterized by the fact that the consumers are directly connected, to determinate conditions.

For example the maintenance of the voltage in a variation interval equal to 5% of the rated value, the conversion of its symmetry and its configuration within allowable variations.

In fact the quality of the low voltage depends essentially on the quality of the high voltage.

So the indices of the electric power quality with condition the operation of the electric components and with define the discounted economic effect, [9,10].

2. Relation of Electric power quality indices

2.1. Quality in normal mode

In a normal mode for which is elaborated an electric network with a balance of power corresponds to the following parameters:

- Voltage
- Frequency

Any derivation of these parameters due to an unspecified disturbance can be expressed by the variation of these parameters. In addition, this variation may have non desirable consequences. For this reason, the quality of the electric power is subjected to consumers' requirements and in particular on the:

- Behaviour of the voltage and frequency
- Continuity of service and quality of the supplying.

The improvement of the electric supply of quality consists in reducing the number of the faults and their cut durations, whatever the component (Dividing network and transforms post, switched network) and for a care of voltage quality, [10,11],[4].

A. Voltage behavior

The tolerated voltage variations result from the application of the schedule conditions. They are especially originated by the voltage drop on the electric network and depend primarily of the transport of the reactive energy. in high voltage

$$U = 5\% \quad (5kV < U_N < 33kV)$$

The tariff conditions incite the customers as much as possible to limit the reactive energy drawn from the electric supply networks.

B. Maintenance of frequency to its rated value

The quality of the frequency depends in theory on permanent balance between the power provided by the stations of production and the power constantly variable called by the customers. From where the constant worries of the distributor to chop peak demand and to spread it on out the load diagram, by proposing to customers off peak time and seasonal tariffs.

$$F = 50Hz \quad 0{,}05\ Hz$$

3. Mathematical model for the analysis of voltage sags and short interruptions

One often calculates the mode of voltage sags and short interruptions using the symmetrical component method, in an element of the symmetrical three-phase network one can replace a non-linear voltage system and current by the sum of three independent balanced systems, for each one of them the relations between voltages and currents are reduced to quadruple balances, [5].

This system can be represented (as shown in Fig .1) using the following symmetrical components:

- Direct omponent
- Opposite omponent
- Homopolar Component

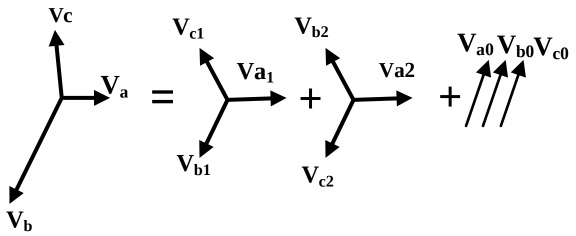

Fig. 1 Decomposition of an asymmetrical system into three symmetrical systems (direct, opposite and homopolar)

3.1. Direct Component (positive sequence)

It is formed of three of the same components respectively shifted of 120° and 240°. whose sequence is ABCA (where in time the phases of this system follow one another in the normal order that one can call direct).

3.2. Opposite Component (negative sequence)

It is also formed of three of the same components but respectively shifted of 240° and 120° (Where in time the phases of three vectors follow one another in the opposite order of the precedent)

3.3. Homopolar Component

It is formed of three of the same components of same phase.

Let us start from a circuit whose voltages form a direct system normally, we characterize its unsymmetrical in voltage by the following formula and one measures his value in %,[1].

$$K_2\% = \frac{V_2}{V_{Phasenom}}.100 \qquad (1)$$

U_2: Voltage of the opposite component of essential frequency, [4].

$$K_2\% = \frac{\left|V_a + a^2 V_b + a V_c\right|}{\sqrt{3}.V_{nom}}.100 \qquad (2)$$

a: Characterize the transformation of the non symmetrical system into three symmetrical systems of symmetrical component.

V_a, V_b, V_c, are the voltages of the symmetrical system. Naturally, one would substitute the opposite component for the direct component for a circuit whose voltages form normally an opposite system. In a three-phase circuit non symmetry, only one of the components is significant, for example the direct component V_D, the other components opposite V_I and homopolar V_0 are low, if on the contrary, the circuit is strongly unbalanced the two last components take significant values.In fault analysis, value of this current is calculated for the different types of faults at various locations in the system. There is a simple worked to measure a fault [9,10].

4- Techniques Approach

A. The ABC Classification

The ABC classification distinguishes between seven types of three phase unbalanced voltage sag. Expressions for the complex voltages for these seven types are given in Table I.

The complex prefault voltage in phase a is indicated by E_1. The voltage in the faulted phase or between the faulted phases is indicated by $\boldsymbol{V}$ while V_a, V_b, V_c are the phase voltage.

Table I:

Seven types of three phase unbalanced voltage sag according to ABC classification, [6],[13].

Type A: $V_a = V$, $V_b = -\frac{1}{2}V - \frac{\sqrt{3}}{2}JV$, $V_c = -\frac{1}{2}V + \frac{\sqrt{3}}{2}JV$
Type B: $V_a = V$, $V_b = -\frac{1}{2}E - \frac{\sqrt{3}}{2}JE$, $V_c = -\frac{1}{2}E + \frac{\sqrt{3}}{2}JE$
Type C: $V_a = E$, $V_b = -\frac{1}{2}E - \frac{\sqrt{3}}{2}JV$, $V_c = -\frac{1}{2}E + \frac{\sqrt{3}}{2}JV$
Type D: $V_a = V$, $V_b = -\frac{1}{2}V - \frac{\sqrt{3}}{2}JE$, $V_c = -\frac{1}{2}V + \frac{\sqrt{3}}{2}JE$
Type E: $V_a = E$, $V_b = -\frac{1}{2}V - \frac{\sqrt{3}}{2}JV$, $V_c = -\frac{1}{2}V + \frac{\sqrt{3}}{2}JV$
Type F: $V_a = V$, $V_b = -\frac{1}{2}V - \frac{\sqrt{3}}{2}JV$, $V_c = -\frac{1}{2}V + \frac{\sqrt{3}}{2}JV$
Type G: $V_a = \frac{1}{2}E + \frac{1}{3}$, $V_b = -\frac{1}{3}E - \frac{1}{6}V - \frac{\sqrt{3}}{2}JV$, $V_c = -\frac{1}{3}E - \frac{1}{6}V + \frac{\sqrt{3}}{2}JV$

Figs 2 to 8 shows the graph for each type indicates by the Table 1, [5].

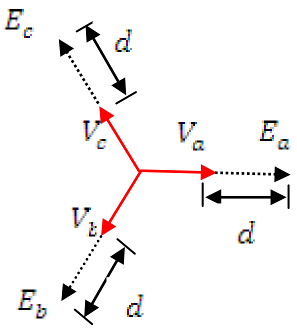

Fig. 2: Voltage sag type A

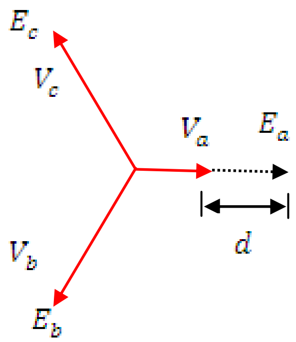

Fig. 3: Voltage sag type B

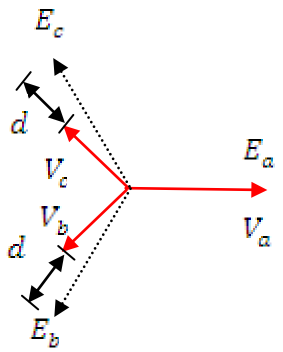

Fig. 4: Voltage sag type C

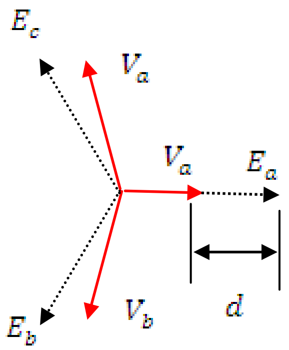

Fig. 5: Voltage sag type D

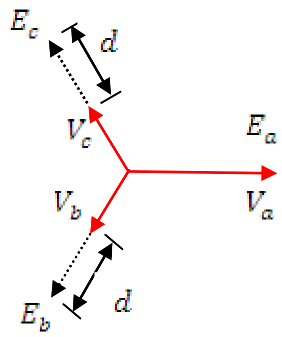

Fig. 6: Voltage sag type E

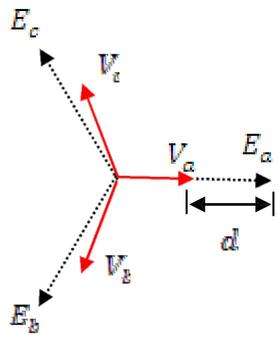

Fig. 7 . Voltage sag type F.

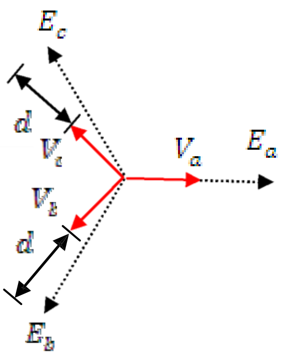

Fig. 8: Voltage sag type G

B. The Symmetrical Component classification

The symmetrical-component classification does not Suffer from the same limitation as the ABC Classification. The symmetrical-component classification distinguishes between dips with the main voltage drop in one phase and dips with the main voltage drop between two phases.

Fig. 9 shows the voltage divider model for three-phase unbalanced voltage sag, [7].

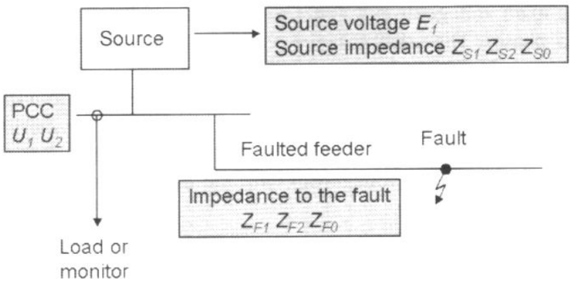

Fig.9: Voltage divider model for three-phase unbalanced voltage sag

5. Programming and simulation.

The programs carried out by the computer with broad range, incorporate many automatic characteristics, to facilitate their uses in the studies of operations.

These programs consist in integrating a series of subroutine in the computer to carry out various existing calculations and different data of the problem.

The principal flow chart is shown in Fig .10.

5.1. Principal subroutines for the asymmetrical short-circuit and the voltage sag

A. Data acquisition

The data are introduced starting from various separate files. Parameters of the networks system given by the number of: Bus, lines, loads, generators, motors and transformers, etc.

- Initial voltage

This factor allows the voltage reading the level of each bus of network bars, before the fault.

These voltages are given directly in symmetrical components, by respecting the order of classification of the sets of bars; only one component which exists and equalizes with 1p.u (direct component), on the other hand the two other components are null (opposite component and hompolar).

- Impedance elements of the network (line, generators, motors, transformers and loads)

This file comprises all the elements of the network and their impedances; These impedances are given in symmetrical components (direct, opposite and homopolar) corresponding to the three superimposed modes of the short-circuit,[2].

The ground is taken as reference, one thus allots the number " 0 ".

The impedances are given in the form of a table with:

Z_{s1} direct impedance
Z_{s2} opposite impedance
Z_{s0} homopolar impedance

- Matrix impedance of network **Z**

After having formed the three matrix admittance Y(+), Y(-) and Y(0), corresponding respectively to the direct, opposite and homopolar modes, [6].

One calculates the matrix Z(+), Z(-) and Z(0) by using the matrix reverse by the algorithm of " GAUSS-JORDAN ",[7].

After the formation of the total matrix of the network Z which corresponds to the balanced system, starting from the three preceding matrix (Z(+), Z(-) and Z(0)).

Each element of Z is under matrix whose diagonal elements corresponding respectively to the elements of the matrix impedances (of the three modes), of the same row on the other hand the other elements are null,[1].

Example:

$$Z = \begin{bmatrix} Z(+) & 0 & 0 \\ 0 & Z(-) & 0 \\ 0 & 0 & Z(0) \end{bmatrix} \qquad (3)$$

B. Resolution of the short-circuit equations

It is the part where one determines the various sizes related to the short circuit.

Choice of the fault type:

One must choose the type of short-circuit which one wishes to simulate to calculate non symmetry.

- Type "1" corresponds to the two-phase short-circuit "with the ground ".
- Type "2": corresponds to the "two-phase " short-circuit.
- Type "3": corresponds to the "single-phase" short-circuit, [1].

- Formation of the fault matrix Yf: According to the type of fault one directly chooses the matrix corresponding fault admittance.

Choice of the bus at fault: One gives the number of the bus at fault, then the computer carries out a series of arithmetic operations to determine the current and the voltages fault, as well as the lines currents, this by using various subroutines relating to matrix calculations.

C. Results print out

The results are printed in the various separate files. These files are used to check the impedances matrix Z(+), Z(-), Z(0) and Z (total matrix of the network).

- Voltage fault print:

This file gives the values of the three-phase voltages to the various bar sets (the ground is taken as reference).

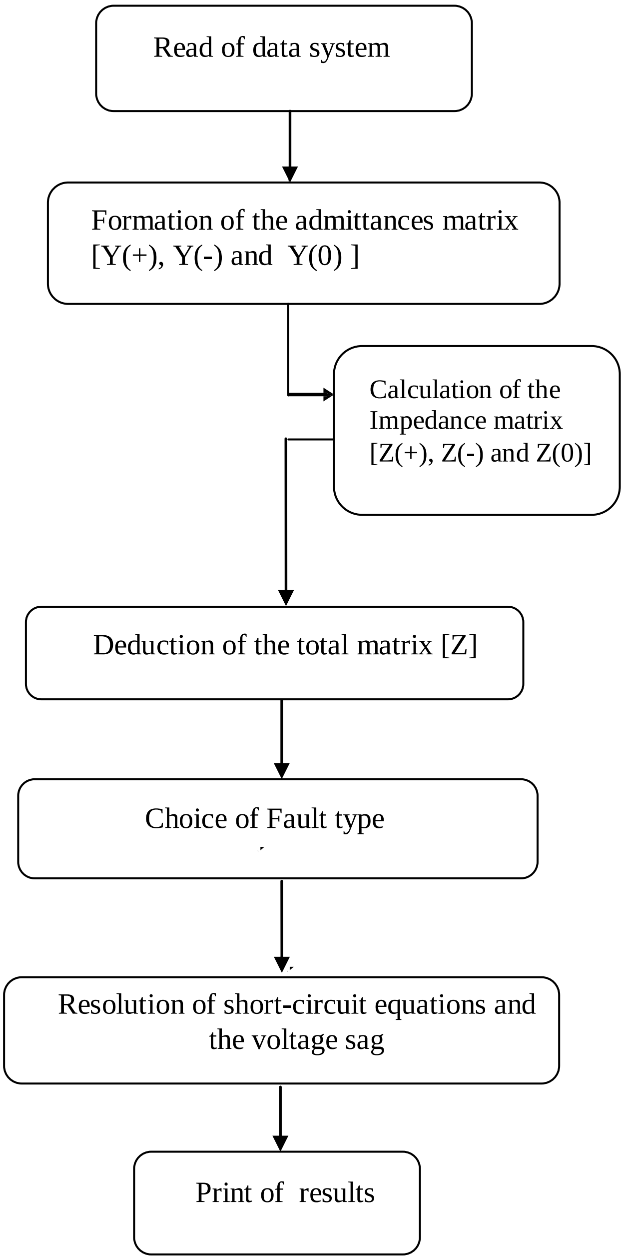

Fig. 10. Synoptic of the flow chart.

6. Numerical example

This part is devoted to the test implementation; in order to give a precise idea on the various stages of calculations carried out by the computer for the determination of voltage sag for the various types of short-circuits (three-phase, single-phase, two-phase and two-phase-ground).

The simulation of the network in fault condition was conducted based on balanced and unbalanced faults where the simulink model network system of the three bus bars is shown in Fig 15. The data used in the simulation shown in Table II. In single line ground fault analysis, phase A is the faulted phase shown in Fig 11, three phase fault at Fig 12, two phase fault at Fig 13 and two phase-to- ground fault at Fig 14, [7].

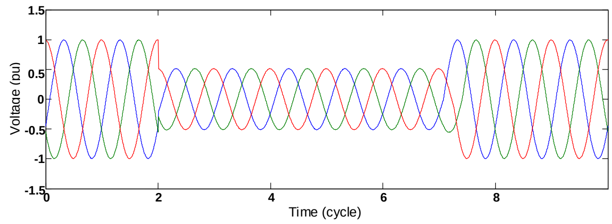

Fig.11: Balanced three phase fault, [7].

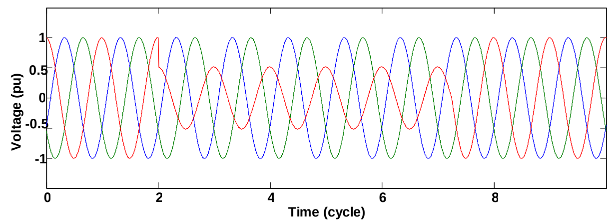

Fig.12: Single-line-to -ground fault, [7].

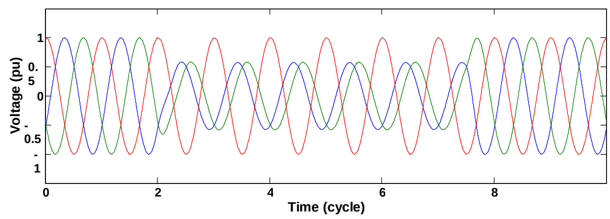

Fig.13: Two-phase Fault [7]

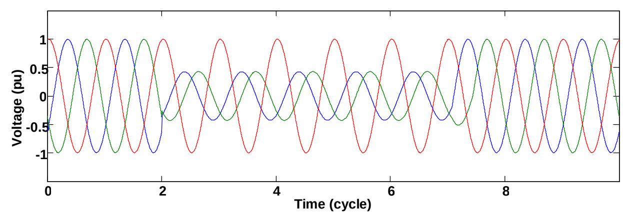

Fig.14: Two-phase -to-ground Fault [7]

Initial Data:

Fault is on the bus bar " 1 "
Number of generators = 1
Number of bus bars = 3
Number of lines = 2

Table II:
System Data, [7].

System Quantities	Values
Source Voltage	11 KV
System frequency	50 HZ
Source impedance	1+8 J
Load power	666.5 KW+1154 KVarj
Fault impedance	1000+0.1JΩ
Fault time	0.5 s
Rated transformer	11 /33 KV
Transmission Lines	L= 0.766Ω/km; R= 0.5613Ω/km

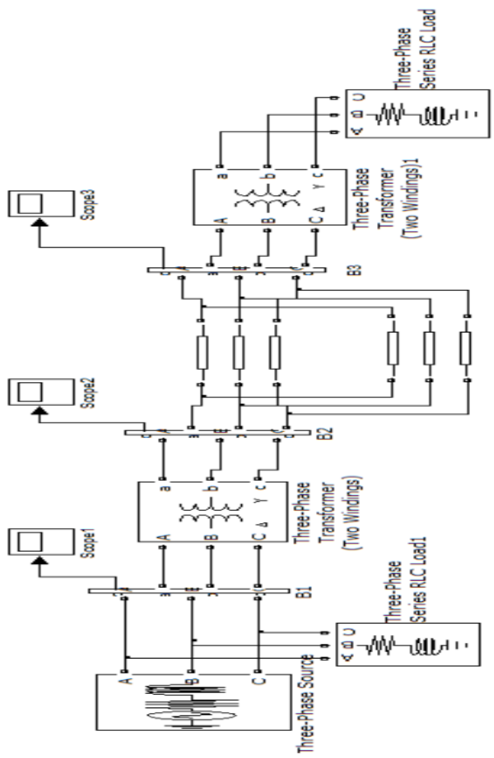

Fig.15: The Simulink model of network

system with three bus bars

7. Results

- A. Balanced Three Phase Fault

ABC Classification

In order to analyze by using ABC classification method, the value of voltage in the faulted phase at the PCC (point of common coupling between the customer and the user) must be calculated.

Voltage sags for each of phases of balanced three phase fault is found and compared with Fig.11

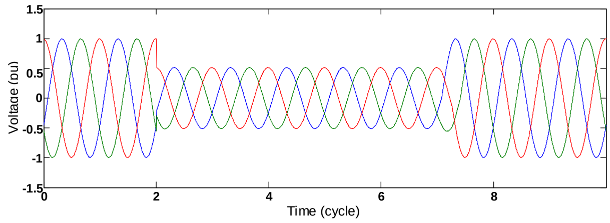

Fig.16: Voltage at bus bar 1

- B. Single Line-to-ground Fault

ABC Classification

Voltage sags for phase A, phase B and phase C of single phase-to-ground fault in this technique is compared with Fig.12

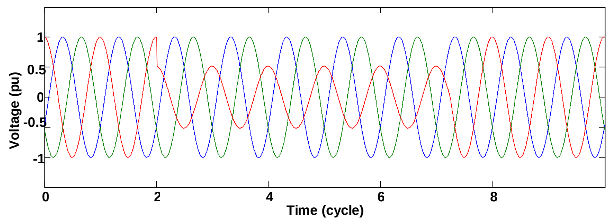

Fig.17: Voltage at bus bar 1

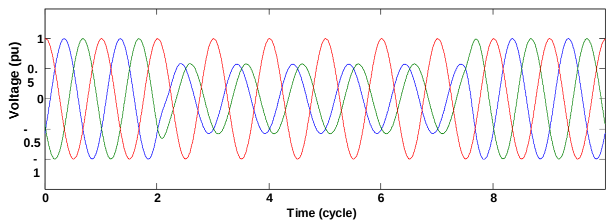

Fig.18: Voltage at bus bar 2

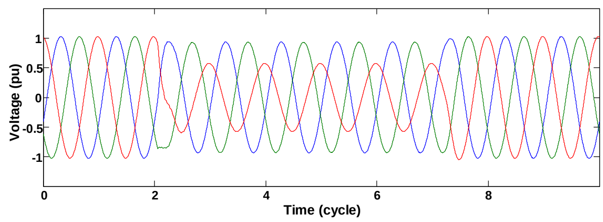

Fig.19: Voltage at bus bar 3

- C. Two-phase Fault

ABC Classification

Voltage sags for phase B and phase C of Two-phase Fault in this technique is compared with Fig.13

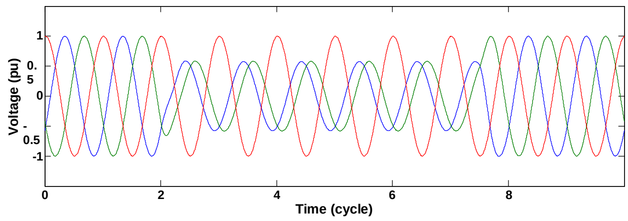

Fig.20: Voltage at bus bar 1

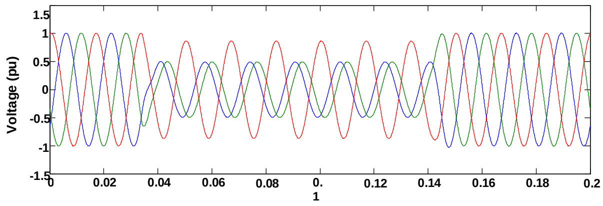

Fig.25: Voltage at bus bar 3

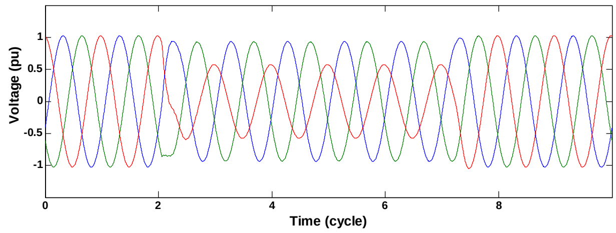

Fig.21: Voltage at bus bar 2

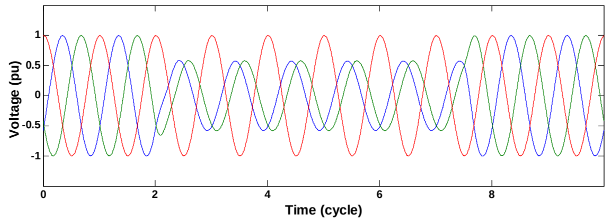

Fig.22: Voltage at bus bar 3

- D. Two-phase -to-ground Fault

ABC Classification

Voltage sags for phase B and phase C of *Two-phase -to-Ground Fault* in this technique is compared with Fig.14

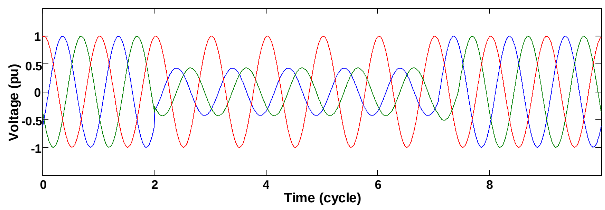

Fig.23: Voltage at bus bar 1

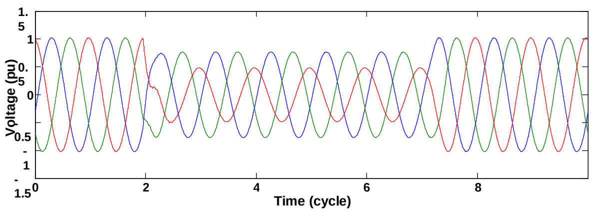

Fig.24: Voltage at bus bar 2

8. Conclusion

The results obtained in this paper are to identify the major problems affecting the quality of electrical energy, and analyse voltage sags in a power grid. In the case of voltage dips, a method based on the classification of voltage dips has been developed. This method determines the types of voltage dips, and estimates their severity. It is easily set up and performs well in the automatic analysis of voltage dip. The results obtained are very satisfactory and comparable with the work presented by the papers [6], [8] and [12].

The classification of voltage dips in three-phase systems remains a point of discussion. It is based on the different types of defects that can occur in a three phase system.

The analytical method applied for classification of voltage dips is very useful when analyzing the spread of hollow through the transformers.

This methodology allows extracting the characteristics of voltage sags and determining its type and severity. In addition, ABC classification was developed when the perturbation propagates through a transformer. The method of analysis that we applied shows that voltage dips are caused mainly by defects in the system. Each type of defect has a different effect on the voltages at the fault, which then defined the types of voltage drop.

There are seven basic types of voltage dips, according to ABC classification. A balanced three-phase voltage dips will result in a type A. A phase to ground fault will result in the type B, and the two-phase fault will result in the type C. Sags of type E, F and G are due to a defect in two phases to ground. In general, the methods developed and presented in this article shall be applied to a larger number of actual cases to better estimate their limitations and assess more accurately their performance.

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