

# Generation of Different Types of Voltage Sag Using Matlab/Simulink

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**Abstract:-** Voltage sag caused by the short circuit fault in transmission and distribution line. In this paper, voltage sag due to power system faults such as three-phase-to-ground, single-phase-to-ground, phase-to-phase and two-phase-to-ground are created in transmission line model for generation of different types of voltage sag.

This paper describes a methodology for voltage sag generation using Matlab/Simulink. It includes fault simulations for generation of different types of voltage sag using MATLAB Simulink, based on the Sim Power Systems toolbox. This electronic document is a "live" template.

**Keywords—**Introduction, Definitions, Voltage sag types, Line fault Simulink Model, Simulation results (waveforms).

## I. INTRODUCTION

Voltage sags are considered one of the most harmful power quality disturbances, because they adversely affect the satisfactory operation of several types of end-user equipment. This phenomenon is a sort duration reduction in rms value of voltage caused by events such as power system faults, load variations, transformer energization and the start of large induction motors. The most common cause of voltage sags is the flow of fault current through the power system impedance to the fault location. Hence, power system faults in transmission or Distribution can affect respectively a large or small number of customers. A fault in a transmission line affects sensitive equipment up to hundreds of kilometers away from the fault. In this paper, the line fault model is simulated to obtain the different types of voltage sags. In addition, the characteristics of Voltage sag are briefly described.

## II. DEFINITIONS

In this section, the definition of voltage sag [3] and its main characteristics are presented (Figure 1):

- Voltage sag: A decrease in rms voltage from 0.9 pu to 0.1 pu at the power frequency for durations of 0.5 cycle to 1 min .
- Magnitude: The lowest rms value of the voltage during a voltage sag .
- Duration: The time during which the rms value of voltage is under the threshold (0.9 pu).
- Phase-angle jump: The difference between the phase angle of the voltage during an event and the phase angle of the voltage before the event .
- Shape: It defines the behavior of the rms voltage profile during voltage sags. According to their shape, voltage sags are classified as rectangular

(rms voltage value is constant) and non-rectangular (rms voltage value varies) .

- Point-on-wave of sag initiation: The phase-angle of the fundamental voltage wave at the instant of sag initiation.
- Point-on-wave of voltage recovery: The phase-angle of the fundamental voltage wave at the instant of voltage recovery.
- Pre-fault voltage: Voltage value during an interval ending with the inception of a fault.

## III. VOLTAGE SAG TYPES

Voltage sags are currently a matter of great interest because they can pose a number of problems in the supplied equipment depending on their particular sensitivity. Voltage sags can be either symmetrical or unsymmetrical, depending on the causes. If the individual phase voltages are equal and the phase relationship is 120°, the sag is symmetrical. Otherwise, the sag is unsymmetrical. A three-phase short circuit or a large motor starting can produce symmetrical sags. Single line-to-ground, phase-to-phase, or two phase-to-ground faults due to lightning, animals, accidents, and other causes, as well as energizing of large transformers can cause unsymmetrical sags. Load and transformer connections can modify the type of sag experienced by a load. Voltage Sag Types are generally based on the individual voltages (both magnitude and angle) for each of the three phases during sags. Usually, three-phase voltage sags are categorized by either the ABC classification or the symmetrical components classification. However, voltage sag type according to the ABC classification is frequently used due to its simplicity as it is based on a simplified network model. Consequently, the classification is based on incomplete assumptions and cannot be used to obtain the characteristics of measured sags. The symmetrical component classification is more general and gives a direct link with measured voltages but is harder to understand and a translation to the ABC classification may be suitable for many applications. In addition, the ABC classification was developed to analyze the propagation of sag from transmission to distribution levels, when a disturbance propagates through a transformer.

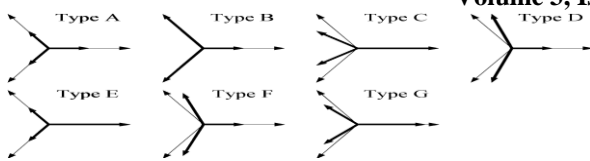


Fig.1 Types of Voltage Sag [1]

#### IV. FACTORS THAT AFFECT VOLTAGE SAG TYPE

Specifically, at the equipment terminals, these factors affect the voltage sag type: [1]

##### A. Fault type

Voltage sags are primarily caused by system faults. Each fault type has a different effect to the voltages at the fault point, which subsequently defined the voltage sag types.

- Single-Line-to-Ground (SLG) Fault
- Line-to-Line (LL) Fault
- Double-Line-to-Ground (LLG) Fault
- Three Phase (3P) Fault

##### B. Transformer Winding Connection

Transformer winding connections are classified into three types to explain the transfer of three-phase unbalanced voltage sags, as well as the change in voltage sag type, from one voltage level to another.

- Type 1 – Transformers that do not change anything to the voltages. The primary voltages (per unit) are equal to the secondary per unit voltages. The only transformer configuration that falls under this type is the Wye Grounded-Wye grounded (Yg Yg).
- Type 2 – Transformers that remove the zero-sequence voltage. Basically, the secondary voltage (pu) is equal to the primary voltage (pu) minus the zero-sequence component. The Delta-delta (Dd), Delta-zigzag (Dz) and the Wye-wye (with both windings ungrounded or with only one star point grounded) belong to this type.
- Type 3 – Transformers that changes line and phase voltages. Delta-wye (Dy), Wye-delta (Yd) and the Wye-zigzag (Yz) fit under this type.

##### C. Load Connection

- Wye-connected load
- Delta-connected load

The classification is derived based on the combination of the three factors discussed above.

#### V. LINE FAULT SIMULINK MODEL

The Line Fault Model consists of 11 KV 50 Hz three phase source block feeding through a 11KV/415 1 MVA delta/wye transformer to a 500KVA resistive inductive load. There is a fault block located at the source feeder line to simulate various types of line faults and a multistage fault block to simulate multistage fault. This line fault model is capable of simulating various line faults including L-G , L-L-G , L-L ,three phase and multistage faults.[5]

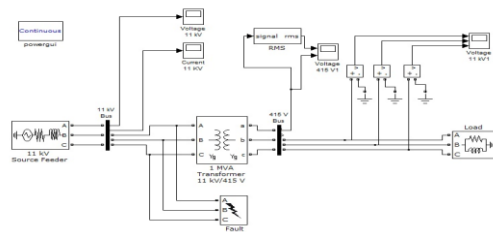


Fig.2 Line Fault Model

Using the Signal rms block the rms value of voltage can be obtained and the scope is used to observe the simulation results.

#### VI. SIMULATION RESULTS

Conditions as below:

##### CASE I

- Fault Type: Three phase to ground
- Transformer Configuration :  $\Delta/Yg$
- Load Connection : Yg

Post-Sag Voltage Waveforms:

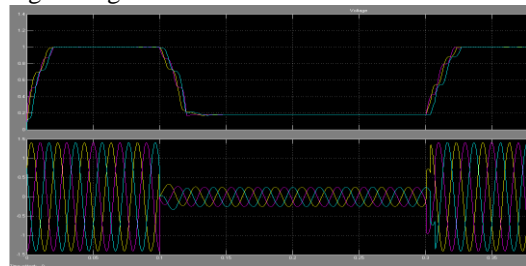


Fig.3 (a): Voltage (rms) waveform & Fig.3 (b): Phase to ground Voltage waveform of all the three phases R, Y & B

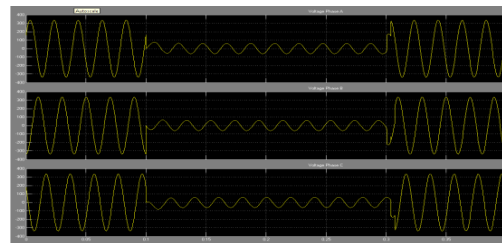


Fig.4 (a) Phase to ground Voltage waveform of phase Y  
Fig.4 (b) Phase to ground Voltage waveform of phase R  
Fig.4 (c) Phase to ground Voltage waveform of phase B

Now from Fig.1 we can refer that the sag type is- **Sag A** where there is equal drop in phases Y, R & B and the phase displacement between the phases are  $120^\circ$  due to symmetrical fault i.e. 3 phase to ground fault.

##### CASE II

- Fault Type: Single phase to ground
- Transformer Configuration : Y/Y
- Load Connection : Yg

Post-Sag Voltage Waveforms:



Fig.5 (a) : Voltage(rms) waveform & Fig.5 (b) :Phase to ground Voltage waveform of all the three phases R,Y & B

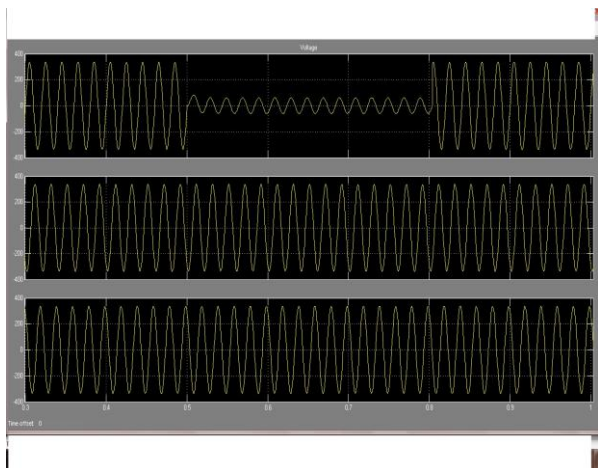


Fig.6 (a) Phase to ground Voltage waveform of phase Y  
Fig.6 (b) Phase to ground Voltage waveform of phase R  
Fig.6 (c) Phase to ground Voltage waveform of phase B

Now from Fig.1 we can refer that the sag type is- **Sag B** where there is no drop in phase Y and B, drop in Phase R only and the phase displacement is  $120^\circ$ .

**CASE III**

- a. Fault Type: Single phase to ground
- b. Transformer Configuration :  $\Delta/Y$
- c. Load Connection : Yg

Post-Sag Voltage Waveforms :

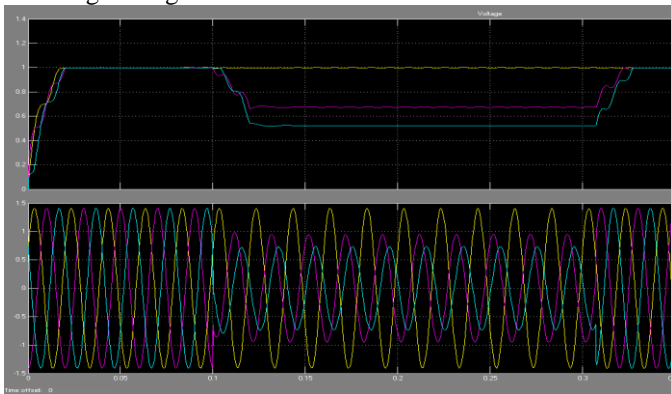


Fig.7 (a) : Voltage(rms) waveform & Fig.7 (b) :Phase to ground Voltage waveform of all the three phases R,Y & B

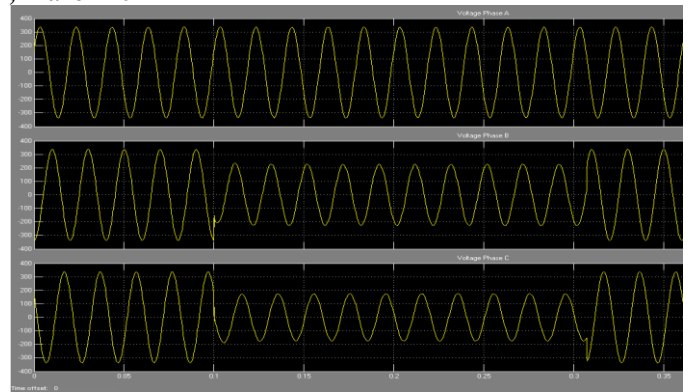


Fig.8 (a) Phase to ground Voltage waveform of phase Y  
Fig.8 (b) Phase to ground Voltage waveform of phase R  
Fig.8 (c) Phase to ground Voltage waveform of phase B  
Now from Fig.1 we can refer that the sag type is- **Sag C** where there is no drop in phase Y and drop in Phases R & B and the phase displacement is no longer  $120^\circ$  due to unsymmetrical fault i.e. phase to ground fault.

**CASE IV**

- a. Fault Type: phase to phase
- b. Transformer Configuration :  $\Delta/Y$
- c. Load Connection : Yg

Post-Sag Voltage Waveforms:

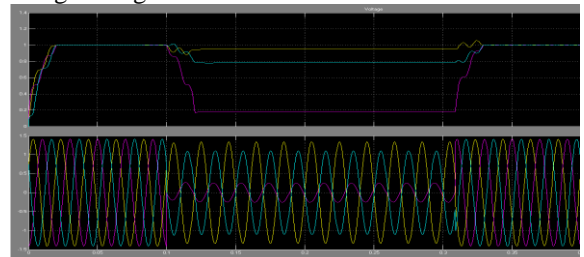


Fig.9 (a) : Voltage(rms) waveform & Fig.9 (b) :Phase to ground Voltage waveform of all the three phases R,Y & B

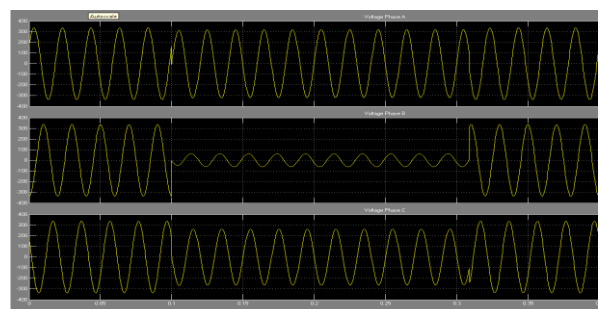


Fig.10 (a) Phase to ground Voltage waveform of phase Y  
Fig.10 (b) Phase to ground Voltage waveform of phase R  
Fig.10 (c) Phase to ground Voltage waveform of phase B

Now from Fig.1 we can refer that the sag type is- **Sag D** where there is more drop in phase R than Phases Y & B and the phase displacement is no longer  $120^\circ$  due to unsymmetrical fault i.e. phase to phase fault.

**CASE V**

- a. Fault Type: Two phase to ground
- b. Transformer Configuration : Y/Y
- c. Load Connection : Yg

Post-Sag Voltage Waveforms :

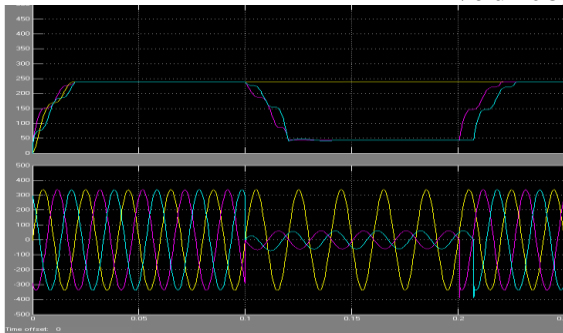


Fig.11 (a) : Voltage(rms) waveform & Fig.11 (b) :Phase to ground Voltage waveform of all the three phases R,Y & B

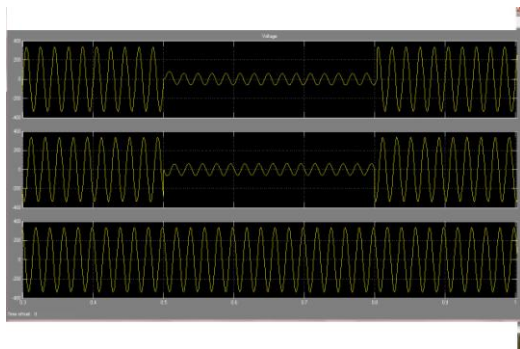


Fig.12 (a) Phase to ground Voltage waveform of phase Y  
Fig.12 (b) Phase to ground Voltage waveform of phase R  
Fig.12 (c) Phase to ground Voltage waveform of phase B

Now from Fig.1 we can refer that the sag type is- **Sag E** where there is drop in phase R and phase Y i.e in faulty phases, no drop in phase B and the phase displacement is 120°.

**CASE VI**

- a. Fault Type: Two phase to ground
- b. Transformer Configuration :  $\Delta/Y$
- c. Load Connection : Yg

Post-Sag Voltage Waveforms:

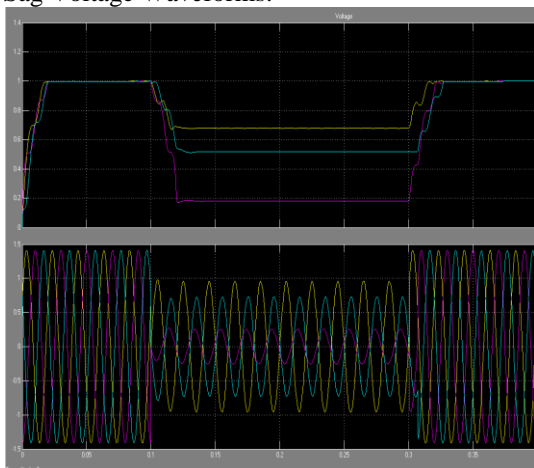


Fig.13 (a) : Voltage(rms) waveform & Fig.13 (b) :Phase to ground Voltage waveform of all the three phases R,Y & B

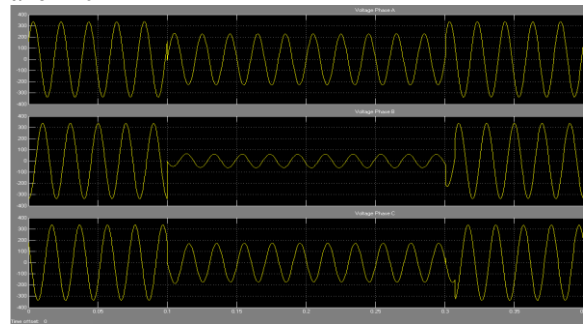


Fig.14 (a) Phase to ground Voltage waveform of phase Y  
Fig.14 (b) Phase to ground Voltage waveform of phase R  
Fig.14 (c) Phase to ground Voltage waveform of phase B

Now from Fig.1 we can refer that the sag type is- **Sag F** where there is greater drop in phases non-faulted phase R as compared to faulted phases Y & B and the phase displacement between the phases are not 120° due to unsymmetrical fault i.e. phase to phase ground fault.

**CASE VII**

- a. Fault Type: Two phase to phase ground
- b. Transformer Configuration :  $\Delta/\Delta$
- c. Load Connection : Yg

Post-Sag Voltage Waveforms:

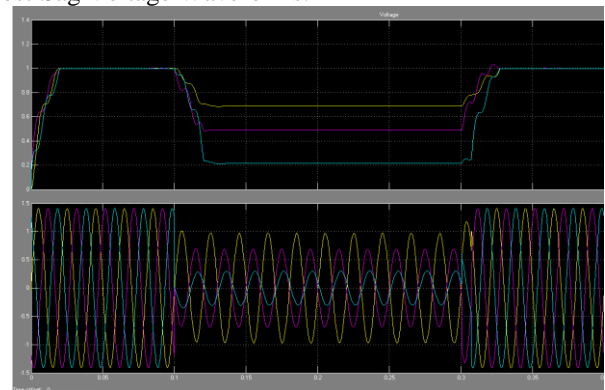


Fig.15 (a) : Voltage(rms) waveform & Fig.15 (b) :Phase to ground Voltage waveform of all the three phases R,Y & B

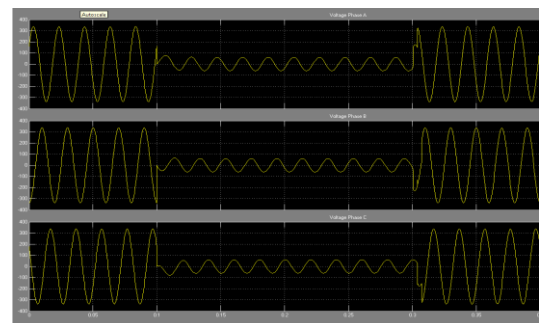


Fig.16 (a) Phase to ground Voltage waveform of phase Y  
Fig.16 (b) Phase to ground Voltage waveform of phase R  
Fig.16 (c) Phase to ground Voltage waveform of phase B

Now from Fig.1 we can refer that the sag type is- **Sag G** where there is greater drop in phases non-faulted phase R as compared to faulted phases Y & B and the phase displacement between the phases are not 120° due to



unsymmetrical fault i.e. phase to phase ground fault. In a similar manner as above cases, by changing the fault type in the fault block, Transformer connection and load connection we can obtain different types of sag for different conditions of these factors. Now for conditions as below the table below summarizes the combination and the resulting voltage sag type.

Voltage Sag Type	Fault Type	Transformer Type			Load Connection	
		Type 1	Type 2	Type 3	Wye	Delta
Sag A	3Φ	Not Depend			Not Depend	
Sag B	LG	Yes	----	----	Yes	----
Sag C	LG	Yes	----	----	----	Yes
		----	Yes	----	----	Yes
		----	----	Yes	Yes	----
	LL	Yes	----	----	Yes	----
		----	Yes	----	Yes	----
		----	----	Yes	----	Yes
Sag D	LG	----	Yes	----	Yes	----
		----	----	Yes	----	Yes
	LL	Yes	----	----	----	Yes
		----	Yes	----	----	Yes
		----	----	Yes	Yes	----
		----	----	Yes	Yes	----
Sag E	LLG	Yes	----	----	Yes	----
Sag F	LLG	Yes	----	----	----	Yes
		----	----	Yes	Yes	----
Sag G	LLG	----	Yes	----	Yes	----
		----	----	Yes	----	Yes

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[6] Voltage Sag Characterization with Matlab/Simulink Joaquín Caicedo, Felipe Navarro, Edwin Rivas and Francisco Santamaría Electromagnetic Compatibility and Interference Group (GCEM) Universidad Distrital Francisco José de Caldas Bogotá, Colombia.

### VII. CONCLUSION

From the figures above, the following can be observed:

- Voltage Sag Type A results to all three voltages down by the same amount.
- Type B has the faulted phase voltage reduced.
- Type C sag causes the two affected phase voltages to change along the imaginary axis only (both in magnitude and angle).
- For type D, the two affected phase voltages change in the real axis only with an accompanying drop in magnitude in the remaining phase.
- Type E results to reduced voltage magnitude in the two affected phases.
- Type F is similar to Type D, except that the voltage change is along both real and imaginary axes.
- Voltage sag type G is similar to Type C but with the voltage change in both axes. In addition, the remaining phase also experiences a decrease in voltage.

### REFERENCES

[1] M. H. J. Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions. New York: IEEE Press, 2000.