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VOLTAGE SAGS IN HV NETWORKS

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ABSTRACT

Power quality is defined in terms of supply voltage. Tripping of equipment due to disturbances in supply voltage is often described as poor power quality. Voltage sag is the main power quality problem that can endanger power system operation. Voltage sag is mainly characterized by magnitude and duration. For sag analysis and mitigation, voltages and currents are usually expressed in RMS values. The emphasis is on sags that occur due to short circuit faults. Many network operators are doing important efforts to collect relevant and precise information about voltage dips in HV networks. This information is however not relevant for the end user, who is connected at a lower voltage level, often behind a Dy transformer and who will not experience the same voltage sags as recorded by the power quality monitors. In most cases the power quality monitors only records rms voltages during sags and the deduction of the characteristics at lower voltage levels is not possible. The voltage phasors are required to derive this kind of information. A new method is proposed here which enables to obtain valuable statistical information for the network users from existing monitors and databases, which only contain information about rms voltages. Estimation of the sag type from the relation between the three rms voltages during the dip is performed. Knowing the dip type the phasors can be calculated. Good results are obtained for faults in transmission networks, especially on overhead lines. Voltage sags occur much more frequently than voltage surges, and that current surges that accompany voltage sag recovery may be the actual culprit causing equipment damage. Event source locating is important to improve the power quality level and to judge the responsibilities of power quality problems. One helpful way to find the location of the power quality event source is to determine the direction of event at each monitor.

Keywords: Event Location, Power Quality, Power Quality Monitoring, Voltage Sags.

I. INTRODUCTION

Voltage sags are huge problems for many industries and it is probably the most pressing power quality problem today. Voltage sags may cause tripping and large torque peaks in electrical machines, which may cause damage to the shaft or equipment connected to the shaft. Some common reasons for voltage sags are lightning strikes in power lines, equipment failures, accidental contact with power lines, electrical machine starts, etc. The definition of voltage sag is a momentary decrease (10% - 90%) in the root mean square (rms) voltage magnitude for duration from a half cycle (10 ms in a grid where $f = 50$ Hz) to 1 min [2]. Voltage interruptions are deeper voltage sags (90% - 100%). Transients are shorter than 10 ms.

Recently many power quality monitors were installed in distribution and transmission networks to obtain statistical information on voltage dips. This statistical information is, in most cases, not relevant for the network user. The equipment of the network user is connected at a different voltage level, often behind a Dy transformer, and as a consequence it does not experience the same dip as recorded by a power-quality monitor. To obtain valuable information for the end user, the voltage dips should be translated to the equipment terminals at the lower voltage level.

1.1 Power Quality

The term “power quality” is the relative frequency and severity of deviations in the incoming power supplied to electrical equipment from the steady 50 Hz, sinusoidal waveform of voltage or current. These deviations may affect the safe or reliable operation of equipment such as computers. Thus terms like “poor power quality” mean that there is ample deviation from norms in the power supply that may cause equipment malfunction or failure.

In certain commercial and industrial electrical applications, it is critical that high quality and uninterrupted power be supplied; for fear that significant economic losses can be incurred. Without good power quality, commercial buildings and industrial facilities can suffer from repeated equipment failures, safety hazards, process interruptions and shutdowns. Even two cycles of a 25% voltage dip can cause unprotected microprocessors to malfunction. Electronic controllers on variable speed motors are even more vulnerable to voltage sags than computers. Surges, transients, noise and sags are the different power quality events. It’s important to be familiar with the most common and disruptive types of power quality events and their typical solutions.

1.2 Power Quality Event

Power quality events are phenomena, which only happen every once in a while. There are many Power Quality events.

1.2.1 Interruption

An “interruption” is a condition in which the voltage at the supply terminals is close to zero.

1.2.2 Under Voltages

Under voltages of various duration are known under different names. Short duration under voltages is called “voltage sags” or “voltage dips”. Long duration under voltage is normally simply referred to as “under voltage”.

1.2.3 Over Voltages

Over voltages of very short duration and high magnitude are called “transient over voltages”, “voltage spikes”, or sometimes “voltage surges”. The latter event is more correctly called “voltage swell”. Longer duration over voltages is simply referred to as “over voltages”.

1.2.4 Transients

Transients can be classified in to two categories known as impulsive transients and oscillatory transients.

- Impulsive transients**:** An impulsive transient is a sudden, non-power frequency change in the steady state condition of voltage, current, or both, that is unidirectional in polarity.
- Oscillatory transients**:**

An oscillatory transient is a sudden, non-power frequency change in the steady state condition of voltage, current, or both, that includes both positive and negative polarity values.

1.2.5 Voltage unbalance

Voltage unbalance is sometimes defined as the maximum deviation from the average of the three phase voltages or currents, divided by the average of the three phase voltages or currents, expressed in percent.

1.2.6 Waveform distortion

Waveform distortion is defined as a steady state deviation from an ideal sine wave of power frequency principally characterized by the spectral content of the deviation**.**

1.2.7 Power frequency variations

Power Frequency Variations are defined as the deviation of the power system fundamental frequency from it specified nominal value (e.g. 50 Hz or 60 Hz). The power system frequency is directly related to the rotational speed of the generators supplying the system.

1.3 Voltage fluctuations

Voltage fluctuations are systematic variations of the voltage envelope or a series of random voltage changes, the magnitude of which does not normally exceed the voltage ranges specified by ANSI C84.1 of 0.9 pu to 1.1 pu.

II. UP/DOWN AREA DEFINITION

If a monitor is installed in power system, the monitor can identify the relative location of event source. In other words, the monitor can determine whether the event has come from up area or down area. The relative location of event source is classified into *UP* area and *DOWN* area. Fig. 1 shows the *UP/DOWN* area in the example system.

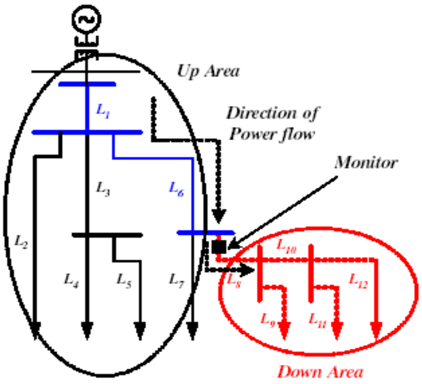


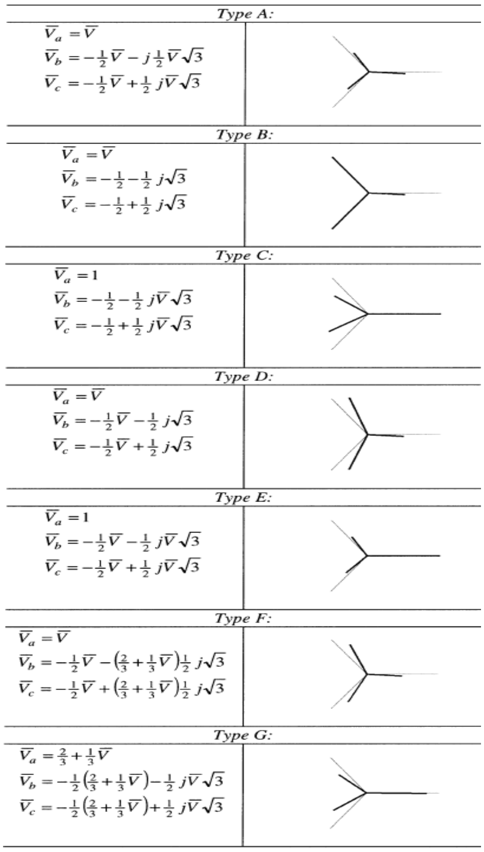
Fig. 1. Definition of UP and DOWN area considering monitor location

III. CLASSIFICATION OF VOLTAGE SAGS

To collect statistics on voltage sags it is important to be able to describe voltage dips through a small number of parameters. Short and long interruptions are described by their duration; voltage sags are typically characterized by duration and a retained voltage. For a three-phase supply it only covers three-phase faults. There are many methods given to characterize the event. The somewhat strange consequence of this is, e.g., that the dip due to a single-phase fault in a high-impedance-grounded system will be quantified the same (or even more severe) as the sag due to a three-phase fault. However a customer behind a Dy-transformer only experiences a severe event in the second case. Some utilities solve this by connecting their monitor's phase-to-phase, but that will limit the amount of information to be obtained from the monitors. To overcome this and similar problems an improved sag characterization has been proposed, which will be summarized below. This characterization is based on the way in which the sags due to different fault types propagate through the system. A generalized magnitude of the event is defined, referred to as “characteristic voltage.” In some papers a method is proposed to extract the type of sag, the characteristic voltage, and other characteristics of three-phase unbalanced voltage sags. This characterization can be used to present dip statistics, for testing of sensitive equipment, but also for extracting additional information about sags. For these methods, the complete waveform information of the voltage is needed, whereas most monitors only store rms voltages to save memory. Even with this limited amount of information it remains possible to extract information about the underlying event but information about the type of sag (and thus the type of fault) could not be extracted from rms voltages only. The method for classification of three-phase unbalanced voltage sags is summarized in Table I.

The expressions for the complex phase voltages in Table I are given under the assumption that positive-sequence, negative- sequence, and zero-sequence source impedance are equal. The method for distinguishing between the different sag types based on rms voltages is grounded on this assumption. All voltages in Table I are complex values. The characteristic voltage can be expanded as where is the (characteristic) magnitude and the (characteristic) phase-angle jump. Type B and type E contain a zero-sequence component and can thus only be observed for measurement devices connected in star.

TABLE Complex Voltages and Phasor Diagrams for the different types of three-phase unbalanced dips



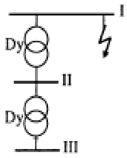
Type A:	
$\overline{V}_a = \overline{V}$ $\overline{V}_b = -\frac{1}{2}\overline{V} - j\frac{1}{2}\overline{V}\sqrt{3}$ $\overline{V}_c = -\frac{1}{2}\overline{V} + \frac{1}{2}j\overline{V}\sqrt{3}$	
Type B:	
$\overline{V}_a = \overline{V}$ $\overline{V}_b = -\frac{1}{2} - \frac{1}{2}j\sqrt{3}$ $\overline{V}_c = -\frac{1}{2} + \frac{1}{2}j\sqrt{3}$	
Type C:	
$\overline{V}_a = 1$ $\overline{V}_b = -\frac{1}{2} - \frac{1}{2}j\overline{V}\sqrt{3}$ $\overline{V}_c = -\frac{1}{2} + \frac{1}{2}j\overline{V}\sqrt{3}$	
Type D:	
$\overline{V}_a = \overline{V}$ $\overline{V}_b = -\frac{1}{2}\overline{V} - \frac{1}{2}j\sqrt{3}$ $\overline{V}_c = -\frac{1}{2}\overline{V} + \frac{1}{2}j\sqrt{3}$	
Type E:	
$\overline{V}_a = 1$ $\overline{V}_b = -\frac{1}{2}\overline{V} - \frac{1}{2}j\overline{V}\sqrt{3}$ $\overline{V}_c = -\frac{1}{2}\overline{V} + \frac{1}{2}j\overline{V}\sqrt{3}$	
Type F:	
$\overline{V}_a = \overline{V}$ $\overline{V}_b = -\frac{1}{2}\overline{V} - \left(\frac{2}{3} + \frac{1}{3}\overline{V}\right)\frac{1}{2}j\sqrt{3}$ $\overline{V}_c = -\frac{1}{2}\overline{V} + \left(\frac{2}{3} + \frac{1}{3}\overline{V}\right)\frac{1}{2}j\sqrt{3}$	
Type G:	
$\overline{V}_a = \frac{2}{3} + \frac{1}{3}\overline{V}$ $\overline{V}_b = -\frac{1}{2}\left(\frac{2}{3} + \frac{1}{3}\overline{V}\right) - \frac{1}{2}j\overline{V}\sqrt{3}$ $\overline{V}_c = -\frac{1}{2}\left(\frac{2}{3} + \frac{1}{3}\overline{V}\right) + \frac{1}{2}j\overline{V}\sqrt{3}$	

IV. ESTIMATING THE DIP TYPE

The main information used in the first step is that the number of possible faults, and thus the number of possible dips is limited. The dip type that best fits with the three measured rms voltages is chosen. A number of approximations are made for this. In the second step, the three rms voltages and the known dip type are used to calculate the characteristic magnitude and phase-angle jump. Expressions like in Table I can be used for this. When the characteristic phase angle jump is neglected, a relation between the large and small voltage drop can be determined for the different types. The characteristic phase angle jump is the result of the difference in X/R ratio of source and feeder impedance. In HV-transmission networks this phase angle jump is in most cases small enough to be neglected.

The seven sag or dip types according to Table I are grouped based on the number of phases with the most severe voltage drop.

TABLE II
FAULT TYPE AND DIP LOCATION THREE-PHASE UNBALANCED DIPS



Fault Type	*Dip Location*		
	I	*II*	*III*
3-phase	A	A	A
3-phase-to-ground	A	A	A
2-phase-to-ground	E	F	G
2-phase	C	D	C
1-phase-to-ground	B	C	D

- *Type A*: the three voltages drop the same amount. These events will be referred to below as three-phase drops.
- *Type C, E and G:* two retained voltages are much smaller than the third one, these voltage dips are referred to as two-phase drops.
- *Type B, D and F:* one voltage drops much more than the two other voltages (single-phase drops).

V. PHASE ANGLE JUMP

A short circuit in a power system not only causes a drop in voltage magnitude but also a change in the phase angle of the voltage. In a 50 Hz or 60 Hz systems, voltage is a complex quantity, which has magnitude and phase angle. A change in the system, like a short circuit, causes a change in voltage. This change is not limited to the magnitude of the phasor but includes a change in phase angle as well. We will refer to the latter as the phase angle jump associated with the voltage sag. The phase angle jump manifests itself as a shift in zero crossing of the instantaneous voltage. Phase angle jumps are not of concern for most equipment. But power electronic converters using phase angle information for their firing instants may be affected.

Phase angle jumps during three phase faults are due to the difference in X/R ratio of source and the feeder. A second cause of phase angle jumps is the transformation of sags to lower voltage values. To obtain the phase angle jump of measured sag, the phase angle of the voltage during the sag must be compared with the phase angle of the voltage before the sag. The phase angle of the voltage can be obtained from the voltage zero crossing or from the phase of the fundamental component of the voltage. The complex fundamental voltage can be obtained by doing a Fourier transform on the signal

VI. ORIGIN OF PHASE ANGLE JUMPS

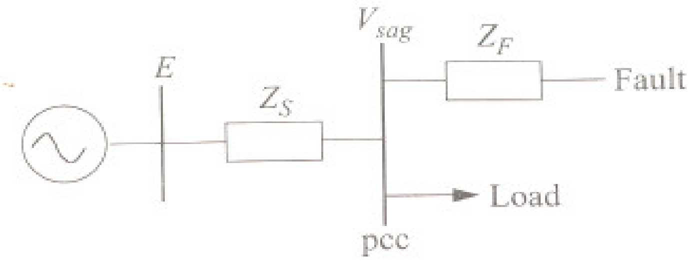


Fig. 2 Voltage divider for voltage sag

To understand the origin of phase angle jumps associated with voltage sags, the single-phase voltage divider model of Fig. 2 can be used again, with the difference that Z_s and Z_f are complex quantities. Like before we neglect all load currents and assume E=1. This gives for the voltage at the point of common coupling (pcc) as

$$V_{\mathbf{sag}} = Z_f /(Z_s+ Z_f)$$

Let $Zs = R_s + jX_s$ and $Z_f = R_f + jX_f$. The argument of V_{sag} , thus the phase angle jump in the voltage can be obtained by the following expression.

$$\Delta\Phi=\tan^{-1}(X_f /R_f) - \tan^{-1}(X_s+X_f / R_s+ R_f) \qquad \ldots(1)$$

If , $(X_s /R_s)(X_f /R_f)$

Then equation (1) is zero and there is no phase angle jump. The phase angle jump will thus be present if the X/R ratios of the source and feeder are different.

VII. CONCLUSION

This paper given the sag type & determined the relative location of voltage sag source according to its cause. Rules to determine the relative location are proposed. For the sag due to line fault, the ratio of the current magnitude during fault to that before fault is used to determine the relative location. If a cause of the sag is the starting of an induction motor, increase in active power at the monitor is utilized to detect the *DOWN* event. Finally, in case of the sag due to the transformer saturation, the cause is identified by the dominance of the second harmonic in the current. And the current ratio with an adapted threshold is utilized to determine the relative location. Most power quality monitors only store the rms voltages during a sag. The information concerning the sag type and the characteristic voltage is summarized here.

REFERENCES

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

[2] P.M. Anderson, Analysis of Faulted Power Systems, New York: IEEE Press, 1995.

[3] J.C. Das, Effects of Momentary voltage dips on the operation of induction motors and synchronous motors, IEEE Transactions on Industrial Applications, vol.26, No. 4, July 1990, pp. 711-718.

[4] F.J Maginnis and N.R.Schultz, Transient performance of induction motors, AIEE Trans., vol.63, pp.641-646, Sep 1944.