I J R B A T, Issue (Special-16), Vol. II, July 2020: 71-79 e-ISSN 2347 – 517X

A Double-Blind Peer Reviewed & Refereed Journal Original Article

INTERNATIONAL JOURNAL OF RESEARCHES IN BIOSCIENCES, AGRICULTURE AND TECHNOLOGY

POWER QUALITY ISSUES & DETECTION METHODS FOR VOLTAGE SAG AND SWELL

Vijay G Neve[1], Pallavi V. Pullawar[2], Chetan H. Kidile[3]

[1]*HOD of Electrical Engineering Department, Jagadambha College Of Engineering & Technology, Yavatmal, Maharashtra*

[2,3]*Asstt.Prof. of Electrical Engineering Department, Jagadambha College Of Engineering & Technology, Yavatmal, Maharashtra*

ABSTRACT

Power quality may be defined as the measure analysis and improvement of the bus voltage usually load bus voltage to be pure sinusoid at rated magnitude and frequency. Due to increase use of non-linear and electronic based equipment's the load bus voltage and current waveforms will not be a pure sinusoid in rated magnitude and frequency. This creates the disturbances in the system. In power system there are various kinds of power quality disturbances such as voltage sags (dips), swells, transients, flickers, harmonics etc. Among these voltage dips (sag) particularly troublesome, since sags in modern power system leads to tripping or misoperation of customer equipment and reduced life of the equipment. This paper presents the various power quality issues and various detection methods for determining the voltage sag and voltage swell. The prediction of voltage sag and swell in a power system is necessary for the analysis of supply reliability.

KEY WORDS: Power quality, voltage dips, voltage sag, voltage swell, Harmonics, Auto signal, Fourier Transform, Wavelet Transform.

INTRODUCTION:

Electric power quality is a very important issue as far as the power supply utilization is concerned. It is the measure of how well electric power supply reach to the customer end for their specific utilization. Voltage sag, swell harmonics, flickering, distortion of wave are the key parameters which decides the power quality. The importance of power quality issues has increased due to various reasons. First of all, there have been changes in the nature of electrical loads. The characteristics of load have become more complex due to the increased use of power electronic equipment, which results in a deviation of voltage and current from its sinusoidal waveform. On another hand, equipments have become more sensitive to power quality due to its electronic nature. The Voltage and current in the power systems are rarely fixed at their nominal values. Voltages and currents usually have variations and each of these variations can create problems for customers depending on how severe the level of variations may be and the vulnerability of the loads. Such fluctuation phenomena are called "power quality disturbances" Power quality disturbances are caused by many events, such as starting a motor, switching equipment in the system, lightning, and balanced, unbalanced faults. In order to solve power quality problems, the effects of the disturbances need to be understood clearly. According to IEEE Standard

1159-1995, a voltage dip is a momentary voltage drop from 0.1 to 0.9 per unit in rms with duration of 0.5 cycles to one minute. In order to assess the total financial losses to the customer it is therefore necessary to assess as accurately as possible the number of voltage dips. Hence it is necessary to predetermine (as per standards) the voltage sag and swell by using various detection methods.

POWER QUALITY ISSUES

Poor power quality is caused by electrical disturbances such as transients, surges, sags, blackouts and harmonics. The power quality signature, or characteristic, of the disturbance identifies the type of power quality problem. The nature of the variation in the basic components of the sine wave, i.e., voltage, current, and frequency, identifies the type of power quality problem. The power quality issues include:

Transients

The term *transient* has long been used in the analysis of power system variations to denote an event that is undesirable but momentary in nature. Transients can be classified into two categories, **impulsive and oscillatory.** These terms reflect the wave shape of a current or voltage transient.

Impulsive *Transient:*

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 (primarily either positive or negative). Impulsive transients are normally characterized by their rise and decay times which can also be revealed by their spectral content. For example, a 1.2 x 50-µsec 2000-V impulsive transient nominally rises from zero to its peak value of 2000 V in 1.2 µsec, then decays to half its peak value in 50 µsec. The most common cause of impulsive transients is lightning. Figure 1 illustrates a typical current impulsive transient caused by lightning.

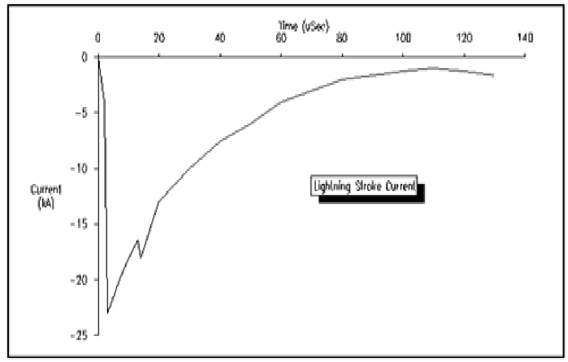

Fig. 1 Lightning stroke current impulsive transient

Oscillatory *Transient*:

An oscillatory transient consists of a voltage or current whose instantaneous value changes polarity rapidly. It is described by its spectral content (predominant frequency), duration, and magnitude. The spectral content subclasses are high, medium, and low frequency.

Oscillatory transients with a primary frequency component greater than 500 kHz and a typical duration measured in microseconds (or several cycles of the principal frequency) are considered *high-frequency oscillatory transients.* These transients are almost always due to some type of switching event. High-frequency oscillatory transients are often the result of a local system response to an impulsive transient. Power electronic devices produce oscillatory voltage transients as a result of commutation and RLC snubber circuits.

A transient with a primary frequency component between 5 and 500 kHz with duration measured in the tens of microseconds (or several cycles of the principal frequency) is termed a medium-frequency transient. Medium frequency transient caused by back to back capacitor bank energization, cable switching etc.

A transient with a primary frequency component less than 5 kHz, and duration from 0.3 to 50 ms, is considered. This category of phenomena is frequently encountered on sub-transmission and distribution systems and is caused by many types of events, primarily capacitor bank energization.

Short-duration variations

Each type of variation can be designated as **instantaneous, momentary, or temporary, depending on its duration**. Short-duration voltage variations are almost always caused by fault conditions, the energization of large loads that require high starting currents, or intermittent loose connections in power wiring. Depending on the fault location and the system conditions, the fault can cause either temporary voltage rises (swells) or voltage drops (sags), or a complete loss of voltage (interruptions).

Interruption

An interruption occurs when the supply voltage decreases to less than 0.1 pu for a period of time not exceeding 1 min. Interruptions can be the result of power system faults, equipment failures, and control malfunctions. The interruptions are measured by their duration since the voltage magnitude is always less than 10% of nominal. Some interruptions may be preceded by voltage sag when these interruptions are due to faults on the source system. The voltage sag occurs between the time a fault initiates and the protective device operates. Figure 2 shows a momentary interruption

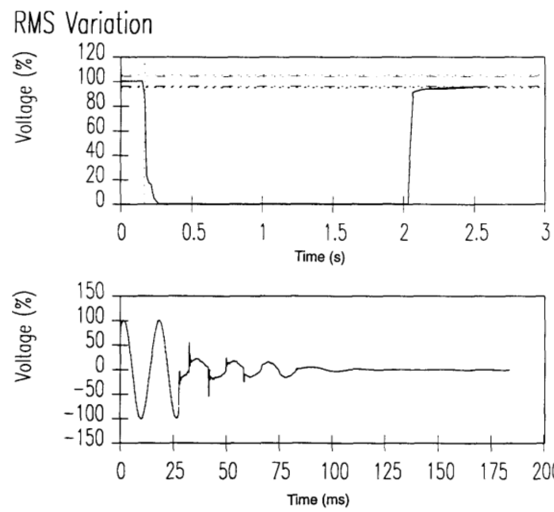

Fig. 2 Momentary interruption due to a fault and subsequent recloser operation.

Voltage Sag

Voltage sag as defined by IEEE Standard 1159-1995, IEEE recommended practice for monitoring electric power quality, is a decrease in root mean square (RMS) voltage at the power frequency for durations **from 0.5 cycles to 1 minute** .Typical magnitudes are between 0.1 and 0.9 pu.. Voltage sags are usually caused by:

- Operation of Reclosers and Circuit breakers.
- Inrush Currents.
- Fault Currents.
- Switching on of large loads.
- Switching off of capacitor bank.

An induction motor will draw six to ten times its full load current during starting. This lagging current causes a voltage drop across the impedance of the system. If the current magnitude is large relative to the system available fault current, the resulting voltage sag can be significant.

The effect of voltage sag mainly affects on to sensitive electronic equipment than the conventional electrical equipment. Sensitive equipment such as computers, adjustable speed drive, microprocessor and the micro-controller etc.

The three important characteristics of voltage sags are:

- ✓ Magnitude (depth).
- ✓ Duration.
- ✓ Phase Angle Jump.

Voltage Swell

Voltage swell as defined by IEEE Standard 1159-1995, IEEE Recommended Practice for Monitoring Electric Power Quality, is an increase in root mean square (RMS) voltage at the power frequency for durations **from 0.5 cycles to 1 minute. Magnitudes are between 1.1 and 1.8 pu**.

A swell can occur due to a single line-to-ground fault on the system resulting in a temporary voltage rise on the unfaulted phases. Swells can also be caused by:

- switching off a large load
- switching on a large capacitor bank

Figure 3 illustrates a voltage swell caused by a SLG fault. Swells are characterized by their magnitude (RMS value) and duration. The severity of a voltage swell during a fault condition is a function of the fault location, system impedance, and grounding. On an ungrounded system, the line-to-ground voltages on the ungrounded phases will be 1.73 pu during a line-to-ground fault condition. Close to the substation on a grounded system, there will be no voltage rise on the unfaulted phases because the substation transformer is usually connected delta-wye, providing a low impedance zero-sequence.

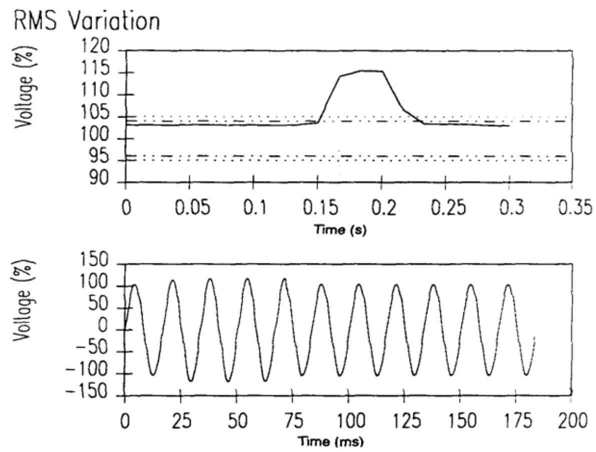

Fig. 3 Instantaneous voltage swell caused by a SLG fault

Long Duration Variation

Long-duration variations encompass root-mean-square **(rms) deviations at power frequencies for longer than 1 min.** Long-duration variations can be either *overvoltages* or *undervoltages*. Overvoltages and Undervoltages generally are not the result of system faults, but are caused by load variations on the system and system switching operations. Such variations are typically displayed as plots of rms voltage versus time.

Interruption Sustained

When the supply voltage has been zero for a period of time in excess of 1 min, the long-duration variations is considered a sustained interruption.

Undervoltage

If the voltage sag is persist for time duration more than 1 minute then it is called as

Undervoltage. An Undervoltage is decreases in rms ac voltage to less than 90 percent at the power frequency for duration longer than 1min. A load switching on, or a capacitor bank switching off, can cause an undervoltage until voltage regulation equipment on the system can bring the voltage back to within tolerances. Overloaded circuits can result in under-voltages also.

Under-voltages generally are not the result of system faults. They are caused by load variations on the system and system switching operations.

Overvoltage

If the voltage swell is persist for time duration more than 1 minute then it is called as Overvoltage. An Overvoltage is an increase in the rms ac voltage greater than 110 percent at the power frequency for duration longer than 1 min. Overvoltages are usually the result of load switching (e.g. switching off a large load or energizing a capacitor bank). The Overvoltages result because either the system is too weak for the desired voltage regulation or voltage controls are inadequate. Incorrect tap settings on transformers can also result in system Overvoltages.

Voltage unbalance

Voltage unbalance (also called Voltage imbalance) 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. Voltage unbalance can also be the result of blown fuses in one phase of a three-phase capacitor bank. Severe voltage unbalance (greater than 5 percent) can result from single-phasing conditions.

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.

DC offset

The presence of a dc voltage or current in an ac power system is termed *dc offset*. This can occur as the result of a geomagnetic disturbance or asymmetry of electronic power converters, and also half wave rectification.

Harmonics

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to operate (termed the *fundamental frequency*; usually 50 or 60 Hz)**.** Periodically distorted waveforms can be decomposed into a sum of the fundamental frequency and the harmonics. Harmonics are originating from many sources, in which typically power electronics are involved, but may also be produced by the nonlinear characteristics of devices and loads on the power system.

Harmonic distortion levels are described by the complete harmonic spectrum with magnitudes and phase angles of each individual harmonic component. It is also common to use a single quantity, the *total harmonic distortion* (THD), as a measure of the effective value of harmonic distortion.

Interharmonics

Voltages or currents having frequency components that are not integer multiples of the frequency at which the supply system is designed to operate (e.g., 50 or 60 Hz) are called *interharmonics.* They can appear as discrete frequencies or as a wideband spectrum.

Interharmonics can be found in network of all voltage classes. The main sources of interharmonic waveform distortion are static frequency converters, cycloconverters, induction furnaces, and arcing devices. Power line carrier signals can also be considered as interharmonics**.**

Notching

Notching is a periodic voltage disturbance caused by the normal operation of power electronic devices when current is commutated from one phase to another. Notching could be regarded as harmonics with high orders, but is typically considered as special case.

Noise

Noise is defined as unwanted electrical signals with broadband spectral content lower than 200kHz superimposed upon the power system voltage or current in phase conductors, or found on neutral conductors or signal lines. Noise in the power systems can be caused by power electronic devices, control circuits, arcing equipments, loads with solid state rectifiers & switching power supplies

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 of 0.9 to 1.1 p.u.. Loads that can exhibit continuous, rapid variations in the load current magnitude can cause voltage variations. Certain voltage fluctuations are often referred to as a Flicker, as shown in Figure 4, because of the visible effect to incandescent lamp. To be technically correct, Voltage Fluctuation is an undesirable of voltage fluctuation in some loads.

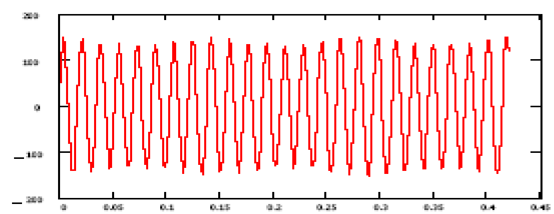

Fig. 4. Voltage fluctuation (flicker)

Power frequency variations

Power frequency variations are defined as the deviation of power system fundamental frequency from it specified nominal value (e.g., 50 or 60 Hz). The power system frequency is directly related to the rotational speed of the generators supplying the system. There are slight variations in frequency as the dynamic balance between load and generation changes. The size of the frequency shift and its duration depend on the load characteristics and the response of the generation control system to load changes. On modern interconnected power systems, significant frequency variations are very rare.

Lastly, focuses on voltage dips, of which surveys (Hunter, 2001; Whisenant, 2001) indicate that they comprise the single or second most important Power Quality phenomenon when the number of process interruptions is considered as shown in the Fig. 5.

Dips cause even more damage than complete electricity outages, since they have a higher frequency of occurrence many solutions to reduce damage caused by voltage dips exist, all having their own technical and economic characteristics.

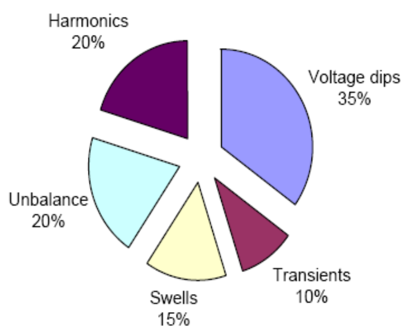

Fig. 5 Percentage of Various Issues

DETECTION METHODS FOR VOLATGE SAG AND SWELL

The various detection methods such as RMS, Peak, Fourier and Missing voltage methods are as under-

A) RMS METHOD:

$$V^{RMS}(i) = \sqrt{\frac{1}{N}\sum_{j=1}^{i+N-1} V^2(j)}$$

Where,

N is Number of the samples per cycle

V (j) is j^{th} sample of the recorded voltage waveform

$V^{RMS}(i)$ is i^{th} sample of the calculated RMS voltage.

B) PEAK VALUE METHOD

The peak voltage as a function of time can be obtained by using the following expression

$$Vpeak = \max_{0<\tau<T}(|V(t-\tau)|)$$

Where,

V_{peak} = peak value of voltage signal.

V (t) = the sampled voltage waveform.

T= is an integer multiple of one half cycle or Full cycle.

FOURIER METHOD.

$$Vfund = \frac{2}{N}\sum_{n=-\infty}^{\infty} V(n)e^{(-jw_0 n)}$$

Where,

W_0= 2π (f/Fs).

f=frequency of supply.

Fs=sampling frequency.

V (n) = sampled voltage waveform;

N=Number of sample in one cycle;

V_{fund}= complex fundamental component of the voltage signal;

MISSING VOLTAGE METHOD

The missing voltage is calculated from the following expression.

$$Vpll(t) = A\sin(wt - \Phi a)$$

$$Vsag(t) = B\sin(wt - \Phi b)$$

$$R = \sqrt{A^2 + B^2 - 2AB\cos(\Phi b - \Phi a)}$$

$$\tan(\Psi) = \frac{A\sin(\Phi a) - B\sin(\Phi b)}{A\cos(\Phi a) - B\cos(\Phi b)}$$

$$m(t) = R\sin(wt - \Psi)$$

Where,
Vpll (t) =desired voltage signal.
A= peak amplitude of the desired voltage signal.
Vsag (t) =disturbed waveform.
B=peak amplitude of the disturbed waveform.
R=amplitude of missing voltage.
m (t) = the instantaneous deviation from the known reference.

CONCLUSION:

Voltage sags and Harmonics are most important power quality problems affecting industrial and commercial distribution systems. The utility of sag and harmonic determination can improve system fault performance. The customers will have to improve the ride-through capability of their sensitive equipment by either power quality mitigation equipment or embedded solutions. It will be much more economical in the long term to improve the distribution system disturbances ride-through capability of the actual process equipment. In this paper have discussed the various power quality issues & detection methods such as RMS, Peak, Fourier Transform & Missing Voltage Methods.

ACKNOWLEDGEMENT:

We acknowledge the guidance received from Dr Swati Gadgil, Professor (Rasshatra) BVDU college of Ayurved, Pune for formulation of Ayurvedic products, Dr Rahul Gujarathi (Paediatrician) and the assistance received for statistical analysis of data from Dr Rekha Sharma, Associate Professor, UGC- Human Resource Development Centre, RTMNU, Nagpur (MS).

REFERENCES:

A.Domijan G.T.Heydt, APS meliopoulas, S.S Venkata and S.West “directions of research in Electric power quality” IEEE Transactions power delivery Vol.8pp429-436 feb1993.

M.H.J. Bollen, “Understanding power quality problems: Voltage sags and interruptions” IEEE press, New York 2000.

Surya Santoso, W.MackGrady, Edward J. Powers, Jeff Lamoree and C. Bhatt” Characterization of Distribution power Quality Events with Fourier and Wavelet Transforms” IEEE trans. On power del., vol.15, no.1, Jan 2000.

A.K. Ghosh and D.L. Lubkeman, “The classification of Power system Disturbance waveforms using Neural approach” IEEE Trans on power Delivery Vol.10 No.1, pp 109-115 Jan 1995.

Ching-yin Lee,Bin-kwie chen,wei-jenLee, Yen-Feng hsu, “Effects of Various unbalanced voltages on the operation performance of an Induction motor under the same voltage unbalance factor codition” IEEE Industrial and commercial power systems technical conference, 1997, pp.51-59.

P.K.Dash, S.Mishra, M.M.A..Salama, and A.C.Liew “Classification of Power system Disturbances using a Fuzzy Expert system and a Fourier Linear Combiner” IEEE Transactions on power delivery Vol.15, No.2, pp.472-477, April 2000.

M.H.J.Bollen “Algorithms for characterizing measured 3 phase unbalanced voltage dips IEEE Trans. on power delivery, Vol.18,No.3,July2003 pp 937-944.

M.H.J.Bollen, M.R.Qader, and R.N.Allen, "Stochastic assessment of voltage dips in large transmission networks theory and case study," in proc. Int. Conf. Large High Voltage Electric Systems, Paris, France, Aug. 30-sep.5 1998.

Myo Thu Aung, Student Member, IEEE, and Jovica V.Milanovic, Senior Member, IEEE, "Stochastic Prediction of Voltage sags by Considering the Probability of the Failure of the Protection system" IEEE Transactions on power delivery, vol.21, NO.1, Jan 2006.

N. Nimpitiwan, G.T. Heydt, R. Ayyanar, J. Blevins, K.Koellner K. Kittredge, M. Chandler, "The propagation of disturbances in power distribution systems", 2003 IEEE PES Transmission and Distribution Conference and Exposition, vol. 1, pp 6-12, Sept. 2003.