AN ALGORITHM TO CHARACTERISE VOLTAGE SAG WITH WAVELET TRANSFORM USING LabVIEW SOFTWARE

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ABSTRACT

Voltage sags caused by the short-circuit faults in transmission and distribution lines have become one of the most important power quality problems facing industrial customers and utilities. Voltage sags are normally described by characteristics of both magnitude and duration, but phase angle jump should be taken into account in identifying sag phenomena and finding their solutions. A new voltage sag detection method based on wavelet transform is developed. Voltage sag detection algorithms, so far have provided their efficiency and computational ability. Several windowing techniques take long durations for disturbance detection. Due to increasing power quality standards new high quality performance disturbance detection techniques are necessary to obtain high power quality standard. Also research has been carried out for the last decade to isolate voltage sag detection form other voltage disturbances. In this seminar a novel approach of wavelet transform has been carried out to detect voltage sag duration and magnitude. Results show that, the new approach provides very accurate and satisfactory voltage sag detection.

For monitoring power quality problems,the wavelet transform is a powerful tool. Different wavelet analysis (discrete or wavelet-packet transform), with different mother wavelet, decomposition tree and different sampling rate is performed on the input signal in real-time. The wavelet transform and the proposed hardware and software solutions adopted for setting up the instrument are presented. The real signals from chroma programming are used in LabVIEW algorithm by Data Acquisition (DAQ) card. To obtain the results sDAQ digitizes the input line signal.It demonstrates performance of the instrument developed for the detection and analysis of different power quality disturbances.

Keywords: Dyadic Analysis, Labview, Point-On Wave, Power Quality, Voltage Sag, Wavelet Transform

I. INTRODUCTION

According to IEEE standard 1159-1995, a voltage sag is defined as a decrease in rms voltage down to 90% to 10% of nominal voltage for a time greater than 0.5 cycles of the power frequency but less than or equal to one minute Voltage sag may be caused by switching operations associated with a temporary disconnection of supply, the flow of inrush currents associated with the starting of motor loads, or the flow of fault currents.

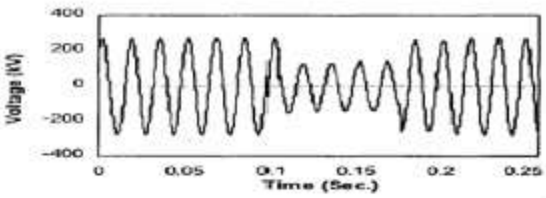

Fig.1 Voltage Sag

Lighting strikes can also cause voltage sags. The interests in the voltage sags are increasing because they cause the detrimental effects on the several sensitive equipments such as adjustable-speed drives, process-control equipments, programmable logic controllers, robotics, computers and diagnostic systems, is sensitive to voltage sags. Malfunctioning or failure of this equipment can caused by voltage sags leading to work or production stops with significant associated cost voltage sags are characterized by its magnitude and duration.

The magnitude is defined as the percentage of the remaining voltage during the sag and the duration is defined as the time between the sag commencement and clearing power-electronics converter that use phase angle information for their firing instants may be affected by the phase angle jump. Electrical contractors were determined to be an example of a device that is extremely sensitive to point-on-wave of sag initiation.In order to find any solutions for voltage sag problems due to faults, it is necessary to identify characteristics of magnitude, duration, point-on-wave and phase angle variations.

II. VOLTAGE SAG CHARACTERIZATION

Voltage sag characterization consists in defining and quantifying the most relevant parameters of this disturbance, such as: magnitude, duration, phase-angle jump and shape. Specific scenarios, in a given power system, are studied by using simulation tools to determine and quantify the parameters of interest, according to the following criteria

Sag duration depends on fault clearing time provided by the electrical protection in a power system. It can be determined by simulating electrical protection behavior when dealing with system faults.

Magnitude and phase-angle jump depend on fault location and line impedance. They can be determined at different nodes of a power system by simulating system faults.

IEEE Standard 1346-1998 explicitly states that information about the phase shift and point on wave “are not typically available in the sag environment data, therefore, for compatibility evaluation, it is recommended that phase shift and point of initiation should not be considered.” However, behavior of certain equipment is influenced by the phase shift and point on wave. If these sag parameters are not known, sensitivity of equipment cannot be fully assessed.

2.1 Voltage Sag Magnitude

Voltage sags are short duration (0.5 cycles to 1 minute) reductions in RMS voltage caused by short circuits, overloads and starting of large loads. There are various ways of obtaining one value for the sag magnitude as a function of time. The most common approach to obtain the sag magnitude is to use rms voltage. There are other alternatives, e.g. fundamental rms voltage and peak voltage. Hence the magnitude of the sag is considered as the residual voltage or remaining voltage during the event. In the case of a three phase system, voltage sag can also be characterized by the minimum RMS-voltage during the sag. If the sag is symmetrical i.e. equally deep in all three phases, if the sag is unsymmetrical, i.e. the sag is not equally deep in all three phases, the phase with the lowest remaining voltage is used to characterize the sag

2.2 Duration

The duration of a sag in various standards is defined in the range from 0.5 cycle to one minute. It should be noted that the voltage reduction events shorter than 0.5 cycles influence the sensitivity of some equipment. To resolve this, the term "under-voltage transients" is proposed in [1] for description of such a very short voltage sag. Determination of the sag duration is straightforward in the case of single-phase sags. For poly phase sags, however, sag duration is usually defined as the time between the instant that the RMS voltage of any phase drops below 0.9 pu to the instant that the RMS voltages of all sagged phases rise above the above 0.9 pu.

2.3 Phase-angle jump

The Phase-angle jump manifests itself as a shift in zero crossing of the instantaneous voltage. Phase-angle jumps during three phase faults are due to a difference in the X/R ratio between the source and the feeder. Phase-angle jumps are not of concern for most equipment but power electronic converters using phase angle information for their switching may be affected.

2.4 Point on wave

Points on wave of initiation and ending are phase angles at which instantaneous voltage starts and ends to experience reduction in voltage magnitude, i.e. between which the corresponding RMS voltage is below the defined threshold limit (usually defined as 90% and 10% of the nominal voltage, respectively). Point on wave of initiation corresponds to phase angle of the pre-sag voltage, measured from the last positive-going zero crossing of the pre-sag voltage. Similarly, point on wave of ending corresponds to phase angle of the post-sag voltage, measured with respect to the positive-going zero crossing of the post-sag. Both point-on wave values are usually expressed in degrees or radians.

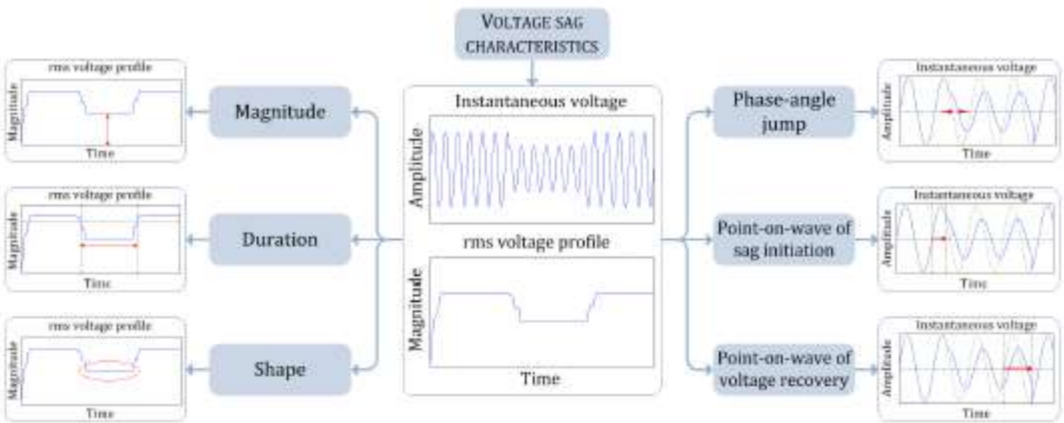

Fig.2 Characteristics of Voltage Sags

III.VOLTAGE SAG DETECTION TECHNIQUE

Voltage sag detection is important because it determines the dynamic performance of system. Following methods are described to detect and characterize the voltage sag.

1. Missing Voltage Technique
2. Specific RMS method
3. New detection method
4. Novel detection method
5. Discrete Wavelet Transform Method

IV. FROM FOURIER ANALYSIS TO WAVELET

Drawbacks of signal processing techniques used in power quality disturbances:

1. RMS is major tool used in signal processing techniques. The RMS of signal is not an analysis technique but it gives some basic information about an electrical system. The main disadvantages of this algorithm are its dependence on size of sample window [3]. As a result of small window RMS parameter becomes less relevant and loses meaning of mean value of power.
2. Another most widely used tool in signal processing is Fourier analysis. It helps in analysis of harmonics and essential tool for filter design. The DFT and FFT are essential tools for estimation of fundamental amplitude of signal. The DFT importance in area of frequency (spectrum) analysis as it takes a discrete signal in time domain and transforms that signal into the discrete frequency domain representation. A FFT used for transformation of signal from time domain to frequency domain. Speed is main advantage of this technique and also high speed calculations.
3. In time frequency signal processing, a filter banks is special quadric time frequency distortion (TFD) that represents signal in joint time frequency domain. This technique used for estimation of specific sub-band components.
4. Another special type of filter is Kalman Filter. Their solutions are based on set of state space equations. These are used for real time tracking harmonics as proposed in [4], frequency estimation under distorted signal [5], estimating voltage and current parameters on power system protection and parameter of transient [6].
5. In 1994, use of wavelets was proposed which led to study of non stationary harmonic distortion in power systems. This technique decomposes signals in different frequency sub-bands and characteristics can be studied separately.
6. The STFT mainly used in power quality analysis and called as sliding window version of FFT. The advantage of STFT is its ability to give the harmonic content of signal at every time period specified by defined window.

V. WAVELET TRANSFORMATION TECHNIQUE

The wavelet transform is representation of signal as sum of wavelets at different location and scales. The main advantage of wavelet transform is its varying length window. The wavelet transform can be classified in three different ways. The continuous wavelet Transform possesses ability to construct a time-frequency representation of signal that offers very good time and frequency realization. The second type of transform known as wavelet series which maps function of continuous variables into sequence of coefficients. The third is Discrete wavelet in which wavelets discretely sampled and has advantage of temporal resolution as it captures both frequency and location information.

Figure.1(a) *Wavelet Transform*

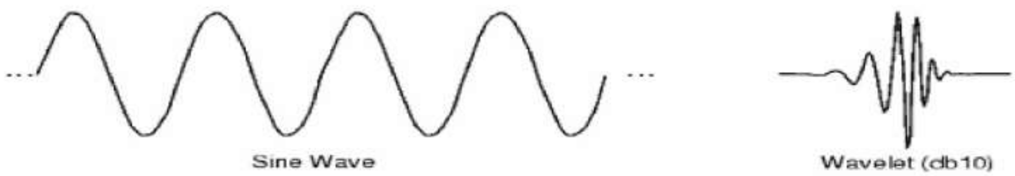

Fig.3 Comparison between sinusoidal Wave and Wavelet

The continuous wavelet transform was developed to overcome resolution problem to short time Fourier transform. It is correlation between wavelets at different scales and signal with scale being used as measure of similarity. DWT are applied to discrete data sets and produce discrete outputs. The DWT is special case of wavelet transform that provides a compact representation of signal in time and frequency that can be computed efficiently. When compared to Fourier transform, wavelet can obtain both time and frequency information of signals while frequency information obtained by Fourier transform [7],[8]. The signal can be represented in terms of both the scaling and wavelet functions as follows:

$f(t) = \sum_n cj(n) n\, \Phi(t-n) + \sum_n \sum_{j=0}^{j-1} dj(n)\, 2^{j/2} \psi(2^j\, t-n)$……………………(1)

where

cj is the J level scaling coefficient,

dj is the j level wavelet coefficient,

$\Phi(t)$ is the scaling function,

$\psi(t)$ is wavelet function,

J is the highest level of wavelet transform,

t is time.

For practical applications and for efficiency reasons one prefers continuously differentiable function with compact support as mother wavelet. Wavelet theory can be expressed by continuous wavelet transformation as, CWT x (a, b) = Wx (a, b) = $\int_{-\infty}^{\infty} x(t)\ \psi_{a,b}(t)\ dt$ ……………………………...... (2)

where

Ψa, a (scale) and b (translation) are real numbers.

The discretization of this equation is necessary for practical application.

For Discrete time system,

DWTψ$x(m,n)$=$\int_{-\infty}^{\infty} x(t)\ \psi_{m,n}(t) dt$……………..(3)

$\psi_{m,n(t)}=a_0^{-\frac{m}{2}}\psi(t-b_0 a_0 m/a_0 m)$………..(4)

Where a = a0

m and b = $nb_0 a_0^m$

The DWT analysis can be performed using fast pyramidal algorithm related to multirate filter banks . Various power quality disturbances for small scale signal decomposition can be detected by use of choice of analysis of mother wavelet. Daub 4 and Daub 6 wavelets are useful for fast and short transient disturbances. Daub 8 and 10 are suitable for slow and long transient disturbances. At scale 1, mother wavelet localized in time and oscillates more rapidly in short spam of time. As wavelet reaches higher scale analyzing wavelets become less localized in time and oscillations, so as a result of high scale signal decomposition, fast and short transient disturbances detected st lower scales and for high scales, slow and long transient disturbances will

be detected. Both time domain & frequency domain methods can be used to analyze vibration signals. The time domain refers to a display or analysis of the vibration data as a function of time. The frequency domain approach allows both the amplitude & phase spectrum to be an identified and are more useful for vibration analysis. The Fourier transform is a frequency domain approach which converts a continuous time signal

into frequency domain. Fourier representation X (f) which is calculated by the Fourier transforms integral shown by:

x(f)= $\int_{-\infty}^{\infty} x(t) e^{-i2\pi ft} dt$……………………………… (5)

The disadvantage of frequency-domain analysis approach is that a significant amount of information (transients, non repetitive signal components) may be lost during the transformation process. This information is non retrievable unless a permanent record of the raw vibration signal has been made. The problem of Fourier transform is overcome up to some extent using Short Term Fourier Transform. STFT is simply the result of multiplying the time series by a short time window and performing a discrete Fourier transform.

Mathematically for a signal, it is written as

STFT{(t)}≡$X(\tau,\omega)$=$\int_{-\infty}^{\infty} x(t)\,\omega(t\ -\ \tau) e^{-j\omega t} dt$ ……………(6)

For discrete signals, this transform is known as Short Term Discrete Fourier Transform (STDFT) expressed mathematically with signal x n & window ω (n) as

STFT{[n]}≡$X(m,\omega)$= $\sum_{n=-\infty}^{\infty} x[n]\omega[n-m]e^{-j\omega n}$ … … …..(7)

Application of STFT have been used to for analyzing different vibration signals for different application but having problem that time resolution is same for all spectral components.

This problem is overcome by using the wavelet transform. It is a technique which allows the time-frequency place to be divided in a more flexible way such that a smaller time is user for higher frequencies & larger time is used for lower frequencies. It is calculated by convolving the wavelet with the original signal, multiply the shifted wavelet with the original signal, then sum the result to produce a single value.

VI. LabVIEW SOFTWARE

LabVIEW is a highly productive development environment for creating custom applications that interact with real-world data or signals in fields such as science and engineering.

The net result of using a tool such as LabVIEW is that higher quality projects can be completed in less time with fewer people involved. So productivity is the key benefit, but that is a broad and general statement. To understand what this really means, consider the reasons that have attracted engineers and scientists to the product since 1986. LabVIEW is unique because it makes this wide variety of tools available in a single environment, ensuring that compatibility is as simple as drawing wires between functions.

LabVIEW makes the process of integrating hardware much easier by using a consistent programming approach no matter what hardware you are using. The same initialize-configure-read/write-close pattern is repeated for a wide variety of hardware devices, data is always returned in a format compatible with the analysis and reporting functions, and you are not forced to dig into instrument programming manuals to find low-level message and register-based communication protocols unless you specifically need to.

VII. DEVELOPMENT OF ALGORITHM

1. Algorithm to Find Missing Voltage, Voltage Sag Magnitude and Duration by Using RMS Evaluation Method

step 1 Start

step 2 Get instantaneous sag waveform data, instantaneous ideal waveform data, and RMS waveform data as input from workspace.

step 3 Find maximum voltage of RMS waveform (vmax).

step 4 Find maximum voltage of ideal instantaneous waveform (Vmax).

step 5 Find pre-fault RMS voltage.

step 6 Find minimum voltage of RMS waveform i.e. Magnitude of remaining waveform.

step 7 Calculate voltage sag magnitude in percent.

step 8 Calculate Missing voltages.

step 9 Find Start of voltage sag by considering fall of RMS voltage by 0.9pu.

step 10 Find End of voltage sag by considering rise of RMS voltage by 0.9pu.

step 11 Calculate duration of Voltage Sag.

2. Algorithm to Find Duration of Voltage Sag by Using DWT Method

step 12 Apply Discrete Wavelet Transform db4 at scale 1 to the instantaneous waveform in Workspace and get the WTC data.

step 13 Calculate the Threshold (THR) by de-noising the Wavelet transform coefficients (WTCs) obtained in Step 12.

step 14 Find the de-noised WTC data of data vector P of length N that violets the Threshold.

step 15 Search for the point(S) that corresponds to the Sag Start Time. To narrow the search, first find the RMS sag start time of the voltage sag. Then, define a search window extending from one cycle before the RMS start time to the RMS start time.

step 16 To find the Sag End Time, start from S, which corresponds to nth element P (n) that fall outside the end time threshold which may be different from the start time Threshold.

step 17 Calculate Duration of Voltage sag.Duration of Voltage sag by DWT=Sag End Time Sag Start Time.

3. Algorithm to Find POW Initiation Of Voltage Sag By Using DWT Method

step 18 Define difference in time and corresponding angel by considering constant frequency.

step 19 Find zero crossing time before start of voltage sag obtained from Algorithm 2

step 20 Calculate difference in time between start of voltage sag and positive zero crossing of instantaneous waveform, by referring Algorithm 2

step 21 Find POW initiation angel by using Newton interpolation technique.

VIII.CONCLUSION

For voltage sag ride through evaluation on a piece of equipment they should not be considered. However, the behaviour of the equipment is influenced by the phase shift and point on wave.Recent advances in monitoring equipment allow recording of both RMS and instantaneous voltages and current during the sags from which information about all relevant sag characteristics can be extracted. Some approaches are described in for measurement of point on wave initiation.

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