ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 1, January 2016

Review On Single Phase Voltage Sag Detection Methods

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ABSTRACT: Voltage sag detection is considered as a first step of compensation/mitigation or disconnection the system. In electrical power distribution system near above 92% of all disturbances are due to the voltage sag. Determining the voltage sag event is very important for sag mitigation. Generally, there are several methods to detect the voltage sag, namely, Synchronously rotating reference frame (SRRF), RMS method, Peak voltage evaluation, Missing voltage technique, Rectified voltage processing method and Continuous wavelet transform (CWT). In this paper we have presented a comprehensive review of that involves various methods to detect the voltage sag event. Although this paper does not exhibit a numerical performance comparison, most of the research publications under the subject of voltage sag detection method have be sorted..

KEYWORDS: Voltage sag, detection, RMS, Peak, SRRF, CWT, Missing voltage.

I.INTRODUCTION

Among this year, in electrical power distribution system, the voltage sag is one of power quality related problem, though sag is major factor which affects the power quality of power system [1]. Voltage sag is defined as short duration reduction in the rms value of supply voltage for few milliseconds to few cycles. As an IEEE definition, the voltage sag is decrease to between 0.1 and 0.9 pu in rms voltage or current (voltage dip in IEC term).

Power system have non-zero impedance, it is increase in current corresponding reduction in voltage. These reductions of voltages are small enough that remain within tolerance range of supply voltage. But when there is large amount of current increase or system impedance is high, the voltage drop expressively/significantly. Voltage sag is major factor in power disturbances; these can be arriving from the user end. In the most cases, voltage sag generated inside a building such as, in residential wiring and the common causes of voltage sag is the starting current of motor. However, some sensitive or critical loads have insufficient internal energy storage. Therefore, cannot ride through voltage sag in supply voltage [2].

There are conventional or novel solution to voltage regulation or compensation currently available to face these types of problem at power distribution network and utility side, such as: ferroresonant transformer, tap-changing transformer, static compensator, uninterruptible power supplies (UPS), static transfer switches (STS), superconducting magnetic energy storage devices (SMES) and dynamic voltage restorer [3],[4],[5].

Many ideas or proposed work have been reported on detection methods, such as: Synchronously rotating reference frame[6], RMS method[7], Peak voltage evaluation[8], Missing voltage technique[9], Rectified voltage processing method and Continuous wavelet transform [10]. Some of these works are based on the abc-dq transformation which gives AC signal provides DC signal that are easier to process. Advantage of this method is that there is no delay in the process.

Another popular idea is based on the RMS value of voltage, calculation of the RMS values, continuously calculated for moving window of input voltage samples. Some methods calculate the peak value of input voltage.

The voltage sag detection and evaluation is necessary when mitigation or disconnection is considered. Precise and fast and detection of voltage sag are key important. In this paper several voltage sag detection methods are given to generate the sag signal for the voltage compensation or isolation system.

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II. BACKGROUND

In this section describe the voltage sag and classification of voltage sag.

2.1 Voltage Sag:

Voltage sags are related to power quality problems. These are usually the results of faults in power system and switching action in isolate the faulted line. Voltage sag can occurs in utility system at distribution voltage and transmission voltage. They are distorted characteristics in rms voltage outside the normal range of line voltage.

Voltage sag is a short duration (0.5 to 30 cycles) reduction in rms value of voltage caused by the internal or external fault in power system and starting current of large load such as motors and disoperation of equipments. Due to the disoperation of equipment that can generated the fault on own circuit. Fig. 1 shows the fault location that causes the disoperation of equipment with contribution. 23 percent of voltage sag events due to disoperation of equipment in own circuit. The effect of voltage sag mainly affects on sensitive electronics equipment. Sensitive electronics equipments such as computers, PLC, adjustable speed drive, microcontroller etc.

Magnitude (depth), duration and phase angle jump are important characteristics of voltage sag. The magnitude of voltage sag can be determined in number of ways. RMS voltage method is mostly used for determining the magnitude. Sag duration is defined as the number of cycle during which RMS value is reduce by threshold value, threshold value is set at 90% of normal value. Sag duration time is between the starting point of voltage sag to end point of voltage sag.

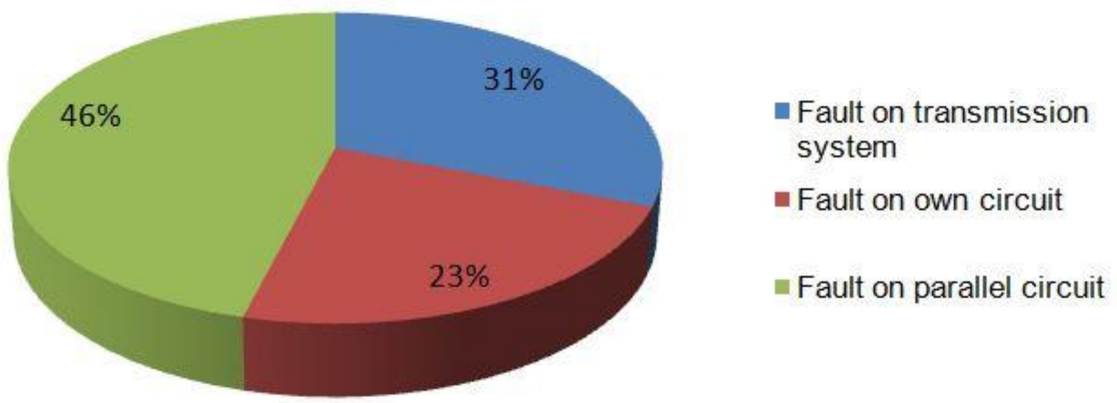

Fig-1Example of fault location that caused disoperation of equipment

During the fault in power system causes a drop in magnitude of voltage and also changes the phase angle of voltage. To measure the change phase angle of voltage sag, phase angle of voltage sag compare with normal voltage phase angle before the voltage sag appear. A positive shifted phase angle means the phase angle of voltage sag is leads to normal voltage phase angle. A negative shifted phase angle means the phase angle of voltage sag is lags to normal voltage phase angle.

2.2 Classification of voltage sag

The voltage sag is classified into the two categories, 1) Momentary voltage sag and 2) Temporary voltage sag. These types are based on time duration of voltage sag. Momentary voltage sag defined as decrease in RMS value of voltage for duration from 0.5 cycles to 3 seconds. Temporary voltage sag defined as decrease in RMS value of voltage for duration from 3 second to 1 minute. If the voltage sag is appear for time duration more than one minute than it is called as under voltage.

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III. DETECTION METHODS FOR VOLTAGE SAG

3.1 RMS method

Voltage measurement in power system using the calculation of the Root Mean Square (RMS) value is the most common tool. Most of system uses the continuously moving window of input voltage sample for the calculation of RMS value. Continuously moving window has N samples per cycles. The resulting RMS value at N sampling instant 'i' can be calculated by:

$$v_{rms}(i) = \sqrt{\frac{1}{N}\sum_{j=0}^{N-1} v^2(i)}$$

Where, N is number of the sample per cycle. v(j) is j^{th} sample of recorded voltage waveform. $v_{rms}(i)$ is i^{th} sample of calculated RMS voltage.

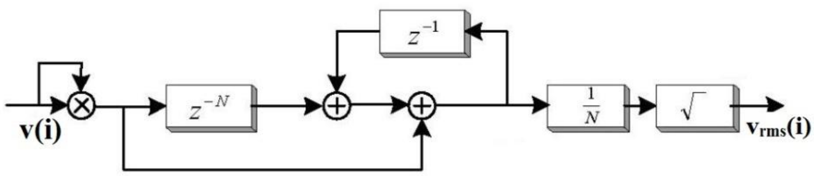

Fig-2 RMS value evaluation using moving window

Fig. 2 illustrates a z-domain representation for the RMS value evaluation using moving window. During the voltage sag, the RMS value of voltage is drop below the normal voltage value. This drop is proportional to the level of voltage sag.

3.2 Peak value evaluation method

The input voltage $V_i(t)$ is given by:

$$V_i(t) = V_m \sin(wt)$$

Where, V_m is the peak value of input voltage.

If $V_i(t)$ is sent to the 90^o phase shifter circuit then $V_i(t)$ is obtain as:

$$V_i^{'} = V_m \sin(wt + 90^o)$$
$$= V_m \cos(wt)$$

The two signal $V_i(t)$ and $V_i^{'}(t)$ are a pair of orthogonal function. They are sent to separate squared. Then two equation can be obtained:

$$V_1(t) = V_m^2 sin^2(wt)$$
$$V_2(t) = V_m^2 cos^2(wt)$$

Now it is easy to obtain peak value of input voltage:

$$V_{peak} = \sqrt{V_1(t) + V_2(t)}$$

The single phase line to neutral voltage is measured and cosine value of the voltage is determining using 90^o phase shifter. Both voltage are squared and summed to get V^2_m. Obtaining the square root of V^2_m result in the peak value of the detected voltage.

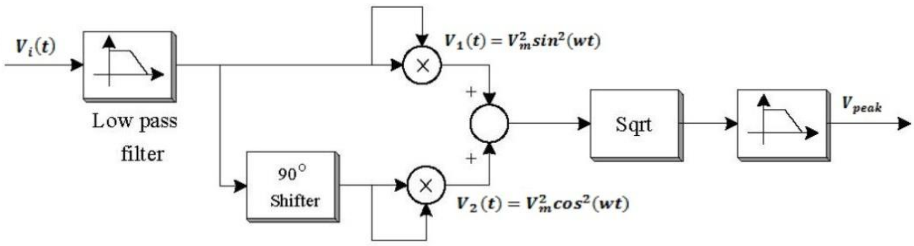

Fig-3 Voltage measurement using peak method

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3.3 Missing voltage method

The RMS value evaluation method is based on the averaging value of previously sample data. It is not momentary value, it represent previous average value. To avoid this difference value of voltage another approach called the missing voltage method. The missing voltage method defined as the difference between the desired instantaneous voltage and the actual instantaneous value.

$$V(t) = A\sin(wt - \emptyset_1)$$
$$V_e(t) = B\sin(wt - \emptyset_2)$$
$$V_{amplitude} = \sqrt{A^2 + B^2 - 2AB\cos(\emptyset_2 - \emptyset_1)}$$
$$\tan\theta = \frac{A\sin(\emptyset_1) - B\sin(\emptyset_2)}{A\cos(\emptyset_1) - B\cos(\emptyset_2)}$$
$$V_m(t) = R\sin(wt - \theta)$$

Where, V(t) is desired voltage signal.

$V_e(t)$ is distorted waveform.

A is peak amplitude of desired voltage signal.

B is peak amplitude of distorted waveform.

$V_{amplitude}$ is amplitude of missing voltage.

$V_m(t)$ is instantaneous deviation from known references.

3.4 Rectifier voltage processing method

In this method rectifier voltage is use for voltage sag detection. The rectifier voltage processing algorithm is based on the comparison of instantaneous rectifier voltage $V_r(n)$ with reference rectifier voltage $V_{rr}(n)$ using moving average finite impulse response (FIR) filter. This comparison perform using adjustable threshold k. Instead of three phases input voltage algorithm operates on only rectifier voltage because of save the computation time and memory storage of processor. Therefore the rectifier voltage $V_{rr}(n)$ is set to rated no-load voltage given by

$$V_{rr}(n) = 1.35V_{rms}$$

The reference voltage is obtaining from the filter, which is continuous take the real average value.

3.5 Continuous wavelet transform

Continuous wavelet transform is the mathematical algorithm or process to detect the voltage sag. It is excellent signal processing algorithm to detect the voltage sag signal because of its superior time scale and frequency analysis capability []. CWT is transforming voltage signal to wavelet coefficient that represent the time and scale of voltage signal. The continuous wavelet transform is defined as the sum of time of given signal multiplied by scale. Wavelet theory can be expressed by CWT as:

$$CWT_x(a,b) = W_x(a,b) = \int_{-\infty}^{\infty} x(t)\Psi_{a,b}(t)dt$$

Where, $\Psi_{a,b}(t)$ is wavelet function of a & b.

x(t) is given signal.

3.6 Synchronously Rotating Reference Frame (SRRF) Method

Generally, the SRRF based voltage sag detection is used for three-phase system. In this method, abc-dq transformation is applied to get the dc voltages by using of following equation:

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos wt & -\sin wt \\ \sin wt & \cos wt \end{bmatrix}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix}$$

In this method there is two transformation 1)Clark transformation & 2)Park transformation, but in single phase system clark transformation can't generates orthogonal AC voltage. To generate orthogonal AC voltage (V_α,V_β) by using the differentiator use as 90^o phase shifter as follows:

$$V_{in} = V_m\sin(wt) = V_\alpha$$
$$V_{in}' = (V_m\sin(wt))' = wV_m\cos(wt)$$
$$V_\beta = \frac{V_{in}'}{w} = V_m\cos(wt)$$

Where, V_{in} is single phase line voltage.

V_m is the peak value of single phase voltage.

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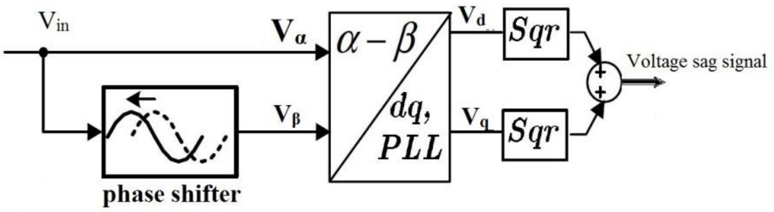

Fig-4 Voltage sag detection using SRRF method

Now, the parks (αβ-dq) transformation can be used to get DC voltage (V_d,V_q) and compare with reference signal to generate the voltage sag signal. This method with an addition processing that minimizes the effect of point-on-wave and provides a very short time of sag detection.

VI. CONCLUSION

Thus it allows each node with message to decide whether to copy the message to a path node by optimizing its transmission effort in order to provide a sufficient level of message delay. Using a channel selection scheme provides spectrum utilization while it minimizes the interference level to primary system. Using trustworthy algorithm, it improves the trustworthiness of the Spectrum sensing in CR-Networks. It enables network nodes to adaptively regulate their communication strategies according to dynamically changing network environment.

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