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A New Approach for the Voltage Sag Estimation

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***Abstract:-* Voltage sag can be characterized on the basis of its magnitude and duration. Since voltage sag is defined on the basis of its magnitude, hence it is very important to find out a method which can quantify the sag magnitude accurately. In this paper two pre-existing methods namely voltage root mean square method and voltage peak methods, are compared. These two methods have been applied on the test waveform provided by IEEE power quality event characterization working group to study the various parameters of voltage sag. An attempt is also made to find out the effect of sliding window size in terms of point of sag initiation, sag duration and its magnitude. A new method for the calculation of sag magnitude and duration is also discussed. This method is applied on the same test waveform to compare the result with the two existing methods. It is found that the proposed method estimate the sag duration more accurately than the rms voltage method and peak voltage method.**

Keywords: RMS voltage method, peak voltage method, sampling frequency, window length.

1. INTRODUCTION

Voltage sag is one of the major power quality disturbances. Voltage sags are about 61 to 87% of the all power quality disturbances. Bollen[1] has defined the various reasons for the generation of voltage sags. Voltage sag can be introduced in the system because of various faults, induction motor starting, transformer energizing and lightning etc. According to various surveys, for about 80% of the time sag generates due to internal disturbances.

Generally the voltage sag is characterized on the basis of its magnitude and duration [1, 2, 3, 4]. 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 [5,6]. Although voltage sag remain for a very small time in the system but it can have a very severe effect on the system. Hence for the safe operation of the system it is very important to identify and quantify the voltage sag from the PQ point of view. Various methods are given to quantify the voltage sag on the basis of its magnitude and duration [6, 7]. The most commonly used methods for the estimation of voltage sag magnitude are:

1. Rms value method [1,3,4] and
2. Peak voltage method [1,3,4,8]

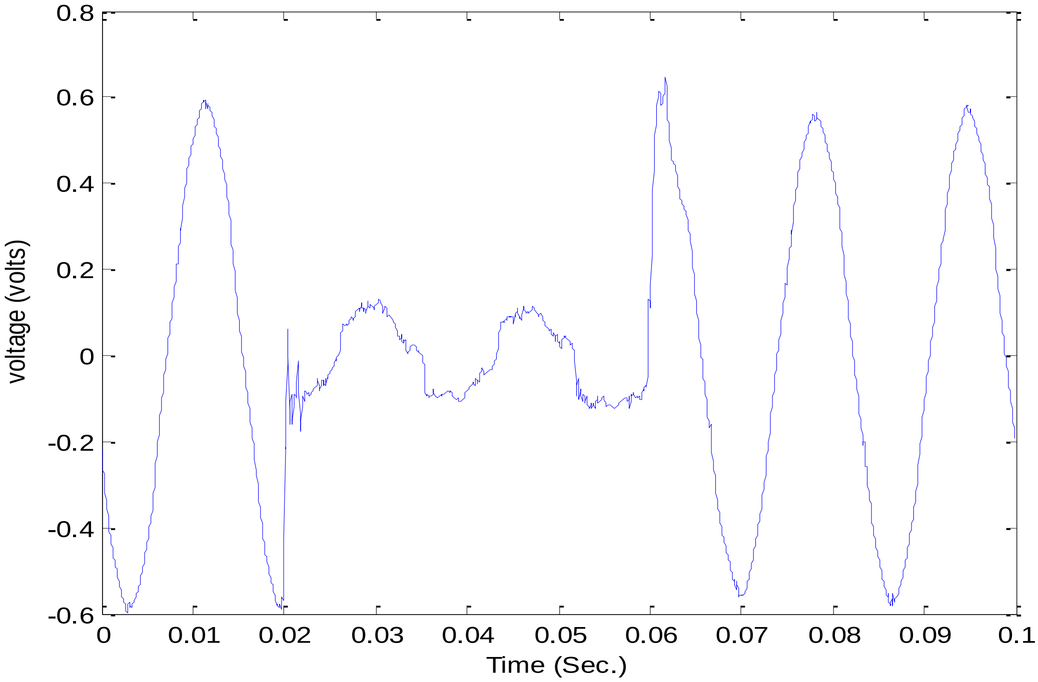

Fig. 1: Test waveform provided by IEEE group

Alongwith the magnitude of the voltage sag; sag duration, point of initiation and point of recovery of voltage sag can also be estimated with the help of above mentioned two methods [1,2,3,5].

In this paper these two methods are applied on the test waveform provided by IEEE power quality event characterization working group [10]. It is shown that where rms value method overestimates the voltage sag, the peak voltage method underestimate the voltage sag duration. A new method is also proposed in this paper. The newly proposed method is applied on the same test waveform to investigate the sag event. It is shown that the proposed method estimate the sag duration more accurately than the other two methods. The effect of sliding window length is also discussed in the paper.

2. VOLTAGE SAG MAGNITUDE CALCULATION

In this section voltage sag magnitude is calculated with the help of two above mentioned methods. These two methods are applied on the test waveform. The frequency of the given waveform is 60 hz with 256 samples/cycle. The actual sag duration is 2.4 cycles. The waveform is shown in Fig. 1.

2.1 RMS voltage Method

Since the voltage sag is defined in terms of the rms value of the voltage hence it is quite obvious to quantify the voltage sag in terms of its rms value. If N being the number of samples per period then the RMS-voltage at any sample point n can be calculated by using the equation (1),

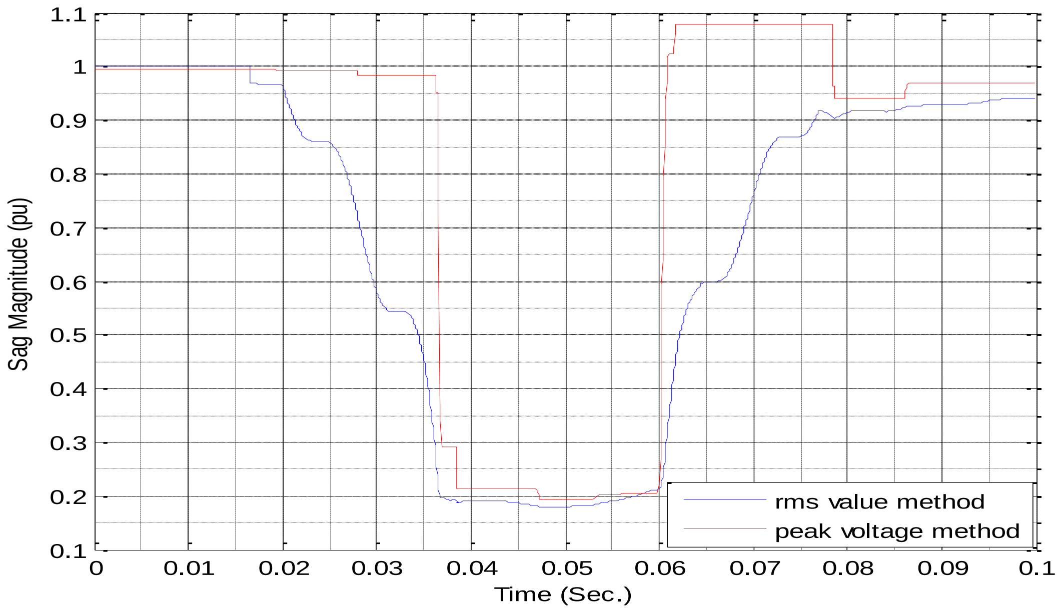

Fig 2: Comparison of rms value method and peak voltage method for full length window

$$V_{rms}(n) = \sqrt{\frac{C}{n}\sum_{i=n-N/C+1}^{i=n} v_i^2} \qquad \textbf{(1)}$$

Where,
C=1 for full cycle window and C=2 for half cycle window. And v_i is the instantaneous sample voltage. Here it is important to note that n≥ N/C. The rms voltage calculated by above method is post estimated i.e. at any instant the value of rms voltage is calculated with the help of previous N samples.

2.2 Peak Voltage method

The following equation can be used for finding the value of peak voltage:

$$V_{peak}(n) = \max(v(n - N + 1): n) \qquad \textbf{(2)}$$

Here n is the sample point and n ≥ N. Again the peak voltage is post estimated by this algorithm. The value of peak voltage for first N-1 samples is equal to the peak value for Nth sample.

Algorithms described by (1) and (2) are applied to the test waveform and results are shown in Fig. 2. The peak voltage shows a sharp variation in the magnitude at sag initiation and recovery point. The sag initiation point is detected after 36.5 ms and 21.2 ms in peak voltage method and rms value method respectively. Hence, rms value method is faster than the peak voltage method in detection of voltage sag initiation. Sag durations observed by two methods are 1.45 cycles and 3.32 cycles respectively. The actual duration of voltage sag is 2.4 cycles. hence it can be concluded that the rms value method detects the voltage sag initiation faster than the peak voltage method, but the accuracy of full length window algorithm is not very good for sag duration estimation point of view. The same sag depth is measured by both methods.

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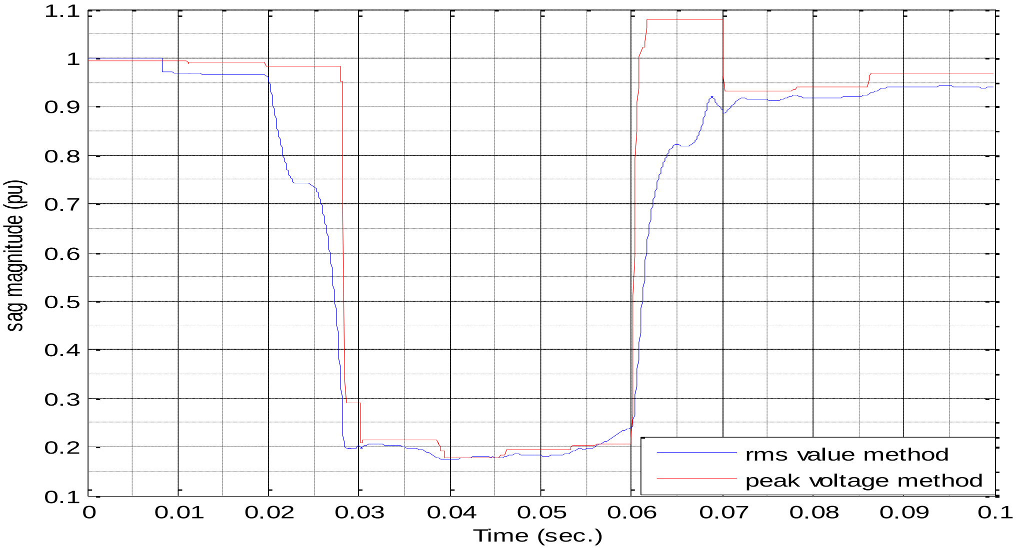

Fig 3: Comparison of rms voltage method and peak voltage method for half cycle window

3. EFFECT OF LENGTH OF WINDOW

In this section the effect of length of window is discussed on the sag magnitude and duration. Two different length windows i.e. full cycle window and half cycle window are considered for the investigation. Now the (1) and (2) are applied on the test waveform with C=2 to find out the effect of change of the size of the window. The results are shown in Fig. 3. It can be observed that now the point of sag initiations are after 20 ms and 28 ms for rms value method and peak voltage method respectively. A change in the sag duration is also observed. The sag duration for rms value method has been changed to 2.87 cycles whereas the new value of sag duration is 1.94 cycles for peak voltage method.

If we compare these results with the results of full length window results then it can be concluded that the accuracy for the calculation of sag duration for both the methods has improved. It is also observed that half cycle window method detects the voltage sag initiation faster than the full length window method.

4. VOLTAGE SAG CALCULATION BY NEW PROPOSED METHOD

Half cycle window algorithm is more accurate than the full length window algorithm. But still there is an error of about 19.6 % in sag duration estimation. Hence for estimate the voltage sag duration accurately a new method is proposed. This method is the hybrid of both the above mentioned methods. The procedure for the estimation of voltage sag from the new proposed method is as follows:

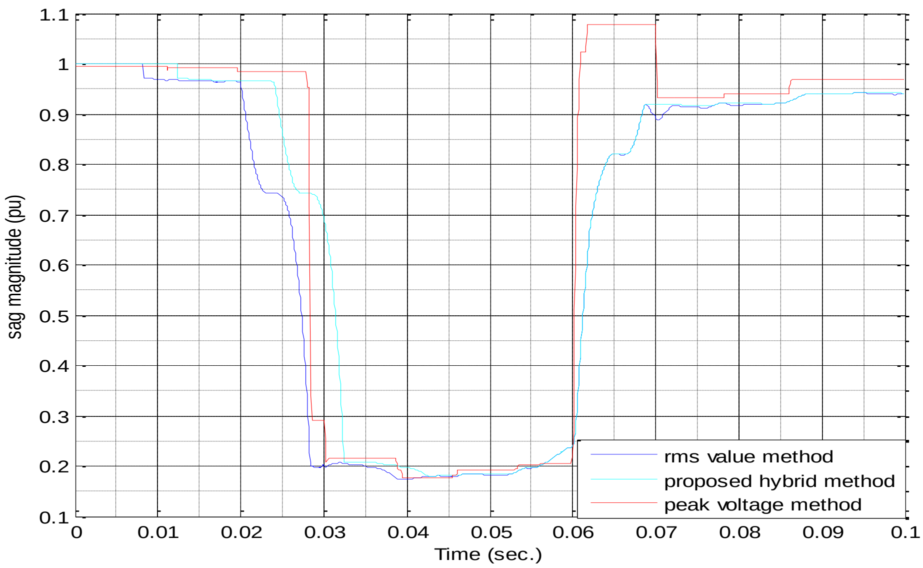

Fig. 4: Comparison of proposed hybrid method with two existing methods

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1. First determine the sample point voltages with the help of instantaneous voltages.
2. Now calculate the rms voltage for various sample point using (1) for a selected length of window and sample frequency. In this paper calculation has been made at a sampling
3. frequency of 256 samples/cycle and half cycle window.
4. In the third step calculate the peak value by using following equation

$$V_{peak} = \max(V_{rms}(i - 127{:}\, i)) \qquad \mathbf{(3)}$$
$$V_{peak}(1{:}\, 127) = V_{peak}(128) \qquad \mathbf{(4)}$$

The above proposed algorithm is applied to the test waveform and results are shown in Fig. 4 along with the result of rms value method and peak voltage method for comparison. It can be observed that the sag duration estimated by new proposed method is 2.61 cycles, which has a error of only 8.75 %. Hence it can be concluded that the proposed method can estimate the voltage sag duration more accurately than the two existing methods.

CONCLUSION

As discussed before the voltage sag can be characterised on the basis of its magnitude and duration. Hence it is very important to find out above parameters accurately. The rms value method is observed far accurate then peak voltage method in terms of estimation of sag initiation and sag duration. But rms voltage method has an error of approximate 38% and 19.6% in case of full length and half length windows. Hence to minimize this error a new method has been proposed. It was found that when this method was applied on the same waveform the error was reduced to 17.35% and 8.75% respectively for full length and half length window respectively. The sag magnitude measure by both the cases was approximately equal. Hence it can be concluded that the new proposed method has the better accuracy in the estimation of voltage sag duration. It can also be suggested that the half length window method is more accurate than the full length window algorithm.

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