Power Engineering Letters

Characterization of Voltage Variations in the Very-Short Time-Scale

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***Abstract*—This letter presents a method for characterizing the fast voltage variations that occur on a time scale between the subsecond fluctuations covered by the flickermeter standard and the 10-min values covered by standards like EN 50160 The method is fully compatible with IEC 61000-4-30 class A. The new characteristic is correlated to small switching actions, such as domestic load switching and transformer tap-changer operation.**

***Index Terms*—Power quality, voltage fluctuations, voltage variations.**

I. Introduction

The IEC standard for power quality measurements [2] defines two aggregated time intervals for variations in the rms voltage: a 3-s ("*very-short-time*") interval and a 10-min ("*short-time*") interval. For a detailed definition of these intervals, please refer to the standard document [2]. Only the 10-min values are used to quantify the performance of the system, e.g., in EN 50160 [3]. The fastest variations ("*fluctuations*") in voltage magnitude are covered by the flickermeter standard [1]. Variations with a time scale between 3 s and 10 min are not covered by any standard. In this letter an approach is suggested to characterize these medium-scale variations. The term "*very-short variations*" is proposed for variations at this time scale.

II. Definition of Very-Short Variations

The IEC power-quality measurement standard [2] prescribes, for compliance under class A, the use of 150/180 cycle values (often referred to as 3-s or *very-short time values*) and 10-min values of the rms voltage. The 10-min or *short-time values* U_{sh} are obtained as the rms of the 3-s (or very-short time) values U_{vs} over the preceding 10 min

$$U_{sh}(t_k) = \sqrt{\frac{1}{N}\sum_{i=k-N+1}^{k} U_{vs}^2(t_i)} \tag{1}$$

with N the number of 3-s values in the 10-min window, and t_k a time sample corresponding to the end of a 10-min clock interval, i.e., a value is calculated at 12:10, at 12:20 at 12:30,. etc., over the preceding 10-min interval.

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To characterize the voltage variations at time scales shorter than 10 min, the difference between the 3-s values and the 10-min values is used. Using the 10-min values as defined in IEC 61000-4-30 would result in a step at every 10-min time stamp. Therefore the 10-min value is updated every 3 s in the proposed method. The "*3-s very-short variation value*" is defined as the difference between the 3-s rms voltage and the rms of the 3-s values over the preceding 10 min

$$\Delta U_{vs}(t_k) = U_{vs}(t_k) - U_{sh}(t_k) \tag{2}$$

where the short-time voltage $U_{sh}(t_k)$ is calculated as in (1), with the difference that the value is updated for every new 3-s value. This can be interpreted as a high-pass residue of the very-short values after taking the 10-min averages. From the 3-s very-short variation values a *10-min very-short variation value* is calculated for every 10-min time stamp:

$$\Delta U_{sh}(t_k) = \sqrt{\frac{1}{N}\sum_{i=k-N+1}^{k} \Delta U_{vs}^2(t_i)} \tag{3}$$

with t_k a time sample corresponding to a 10-min time stamp, as in (1). The result is that a voltage measurement results in three values over every 10-min interval:

- the short-term flicker severity as defined in IEC 61000-4-15;
- the 10-min very-short variation as in (3);
- the short-time (10-min) rms voltage as in (1).

This method allows the inclusion of 3-s values without the need to store excessive amounts of data.

III. Measurement Example

The characterization method described here has been applied to the very-short-time voltages U_{vs} measured over an 8-day period in a residential area in Gothenburg. The very short (3 s) and short (10-min) rms voltages for a 24-h period (midnight to midnight) are shown in Fig. 1. The 10-min values updated every 3 s, are shown in the top curve of Fig. 2. The bottom curve gives the 3-s very-short variation values as in (2). The 10-min very-short variation values as in (3) are shown in Fig. 3.

In these figures the results are shown for one day only. The very short variations show a continuous level with superimposed spikes. The continuous level shows a daily pattern, which is further enhanced in Fig. 4. The 10-min rms values are plotted as a function of the time of day in the top curve. The bottom curve is obtained by calculating the (arithmetic) average over all values within the same half-hour slot of the day. The very short

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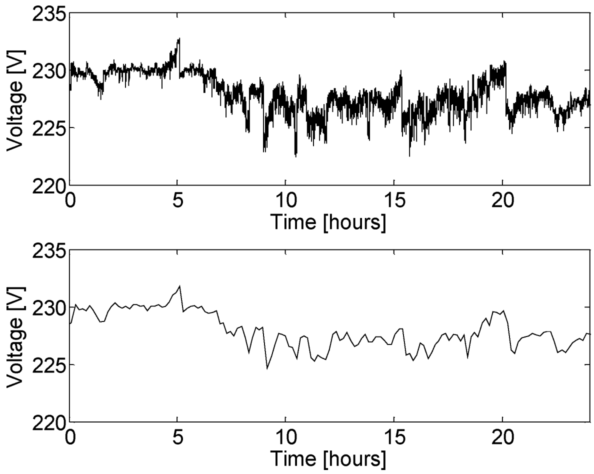

Fig. 1. 3-sec rms voltage U_{vs} (top) and 10-min rms voltage U_{sh} (bottom).

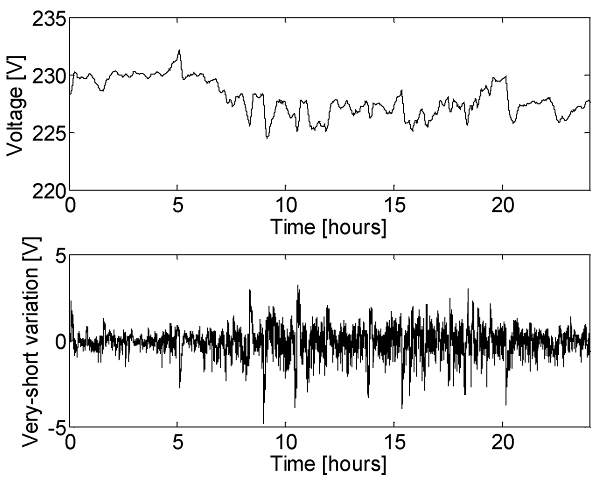

Fig. 2. Short-time rms voltages updated every 3 s (top) and residues ΔU_{vs} calculated every 3 s (bottom).

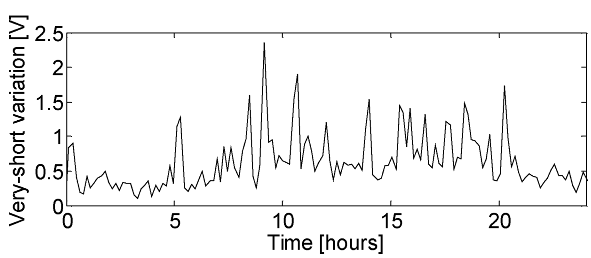

Fig. 3. 10-min values of the very-short variation ΔU_{sh}.

time variations are larger during daytime when there is more activity (more connecting and disconnecting of equipment) than at nighttime.

Comparing the top curve in Fig. 1 with the bottom curve in Fig. 2 and with Fig. 3 shows that the spikes in very-short variation correspond to steps in rms voltage. The steps in turn are due to transformer tap-changer operation and capacitor-bank switching. Such voltage steps are rather common in the late evening when the domestic load drops. This explains the late evening peak in Fig. 4.

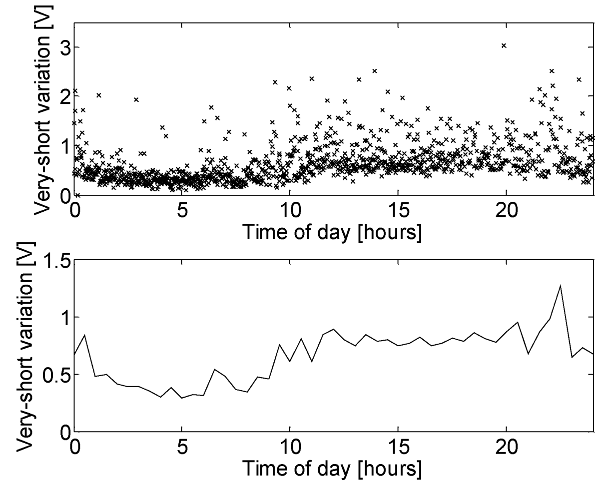

Fig. 4. Daily pattern in very-short variations: 10-min values versus time of day (top); average over each half-hour interval (bottom).

IV. Time Aggregation

The aggregation from 150/180 cycle (3-s) values to 10-min values is the most complex aggregation step in IEC 61 000-4-30. The 150/180-cycle values are linked to the power-system frequency whereas the 10-min values are linked to the clock time. The result is that the number of 150/180-cycle values in a 10-min interval is not constant. The next interval may have the same number of samples as the current interval, one less or one more. The continuous update of the 10-min value requires an accurate administration of the duration of each 150/180-cycle interval. It is possible to obtain recursive expressions for the calculation, but those are outside of the scope of this letter.

V. Conclusions

A method has been introduced to characterize fast voltage variations on a time-scale between 3 s and 10 min. This range is not covered by any of the existing power-quality standards. The basis of the method is formed by the 3-s values obtained as an intermediate result by IEC 61000-4-30. The residue after calculating the 10-min values is averaged over a 10-min window. The method only marginally increases the amount of data to be stored.

It is shown that this new characteristic is correlated to small switching actions, like domestic load switching and transformer tap-changer operation.

References

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