Voltage Fluctuation/Flicker International Standards and Measurement Techniques : Measurement Techniques

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While harmonic current is regulated for maintaining the quality of a power supply network, regulations are also imposed on voltage fluctuations/flicker for the purpose of suppressing the flickering of incandescent lamps, malfunctioning of computer application devices, and inrush current of equipment. The limits for voltage fluctuations/flicker are specified by the international standards IEC61000-3-3 and IEC61000-3-11. These standards are the emission standards in terms of electromagnetic compatibility (EMC) and it is required to comply with them to obtain the CE marking. Also, IEC61000-4-15 defines the requirements for measurement of voltage fluctuations/flicker.

This paper describes the voltage fluctuations/flicker measurement techniques for the WT5000 Precision Power Analyzer.

1. International standard for measuring voltage fluctuations/flicker

The measurement methods for voltage fluctuations and flicker are defined in the international standard IEC61000-4-15, Flickermeter-Functional and design specifications. The measurement parameters required by IEC61000-3-3 and IEC61000-3-11, which specify the voltage fluctuations/flicker limits, are dc, dmax, Tmax, Pst, and Plt, and the methods for measuring these parameters are provided in IEC61000-4-15.

In this standard, flicker meters are divided into three classes, F1, F2, and F3, and the conformance test of IEC61000-3-3 and IEC61000-3-11 requires a flicker meter of F1 or F2. The WT5000 corresponds to F2.

2. Voltage fluctuation/flicker measurement method

The WT5000 has a Block configuration as shown in Figure 1 in order to realize the flicker meter function compliant with IEC61000-4-15 (class F2).

Among the measurement parameters, dc, dmax and Tmax, which are directly obtained from the half-cycle RMS value, are called “d parameters.” dc, dmax, Tmax are determined in Block 1 in Figure 1. Pst is the output of Block 5 and Plt is a parameter calculated from a plurality of Pst’s.

The input voltage analog signal is regulated by the amplifier, passes through the analog filter (cutoff frequency 1 MHz), and then is converted to an 18-bit digital value by the A/D converter at a sampling frequency of 10 MS/s, which is represented in Block 1.

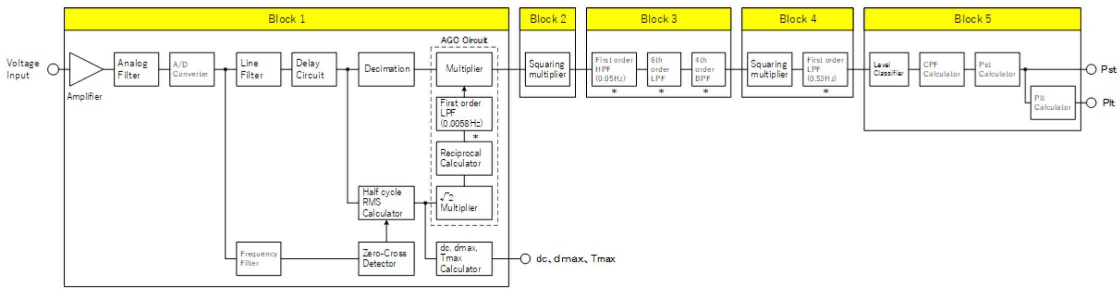


Figure 1. Block diagram of WT5000 flicker mode

Bandwidth limitation is performed on the signal waveform by the line filter (digital filter, cutoff frequency 10 kHz) to prevent the influence of aliasing at the subsequent decimation (thinning out of sampling data).

Next, the waveform signal passes through the Auto Gain Control (AGC) circuit in Block 1, the squarer in Block 2, the three types of filters in Block 3, the squarer and filter in Block 4, the level classifier, Cumulative Probability Function (CPF) calculator and the Pst calculator in Block 5, then Pst is calculated. Plt is calculated by the Plt calculator.

Also, d parameters are calculated through the half-cycle RMS value calculator and dc, dmax, Tmax calculator in Block 1.

2-1 d parameter measurement

d(t) is a value obtained by calculating the RMS voltage for each half cycle and dividing it by the rated voltage, expressed in units of %.

The half-cycle RMS value at this time is defined as the RMS value that is determined by the half cycle between the continuous zero crossings of the fundamental frequency voltage.

The steady state is defined as the period when the change of d(t) is kept within ±0.2% for one second or longer.

dc is the difference between before and after a single voltage fluctuation, dmax is the maximum difference from before a single voltage fluctuation, and Tmax is the time when the voltage value exceeds the limit of dc (3.3%) in a single voltage fluctuation.

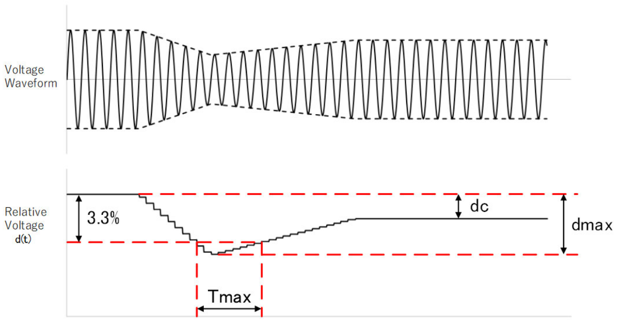
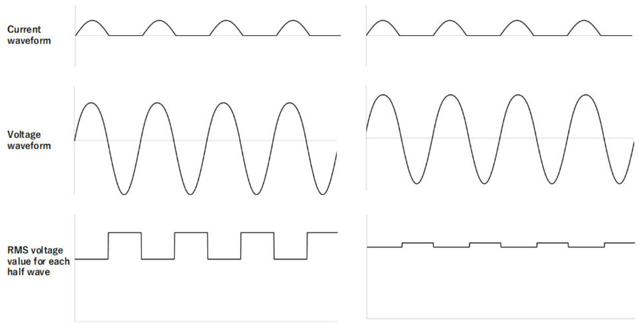


Figure 2. How to calculate d parameters *1)

(1) Detection of zero crossing level when measuring half-cycle RMS value

On the conventional model (WT3000E) and the current model, DC coupling is used from the voltage input terminal to the half-cycle RMS calculator when calculating the RMS value for each half wave.

This is to make the zero crossing detection level exactly 0 V even when the amplitudes of the positive half wave and the negative half wave are different. As shown in Figure 3, in a device performing half-cycle rectification, current flows only on either the positive side or the negative side. If AC coupling is performed in that state, the zero crossing level may be detected at a level different from the actual 0 V and the voltage fluctuation may be measured smaller than the actual value.



DC coupling (WT series) AC coupling

Figure 3. Voltage fluctuation in half-cycle rectifier

To prevent erroneous detection at a time other than the time when the actual zero crossing occurs due to noises superposed on the input waveform, a zero crossing is detected by the zero crossing detector after high frequency components are cut by the frequency filter (digital filter, cutoff frequency 1 kHz) as shown in Figure 1.

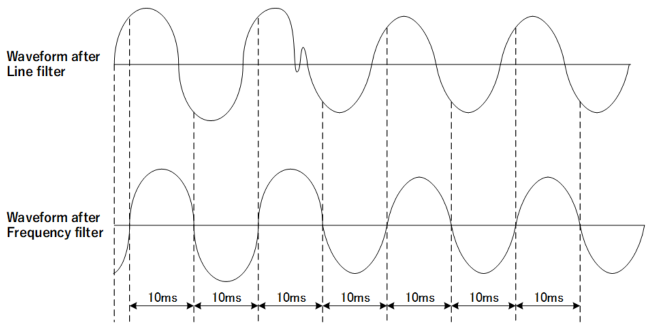


Figure 4. Signal waveform after line filtering and waveform after frequency filtering

The cutoff frequency differs between the line filter and the frequency filter. The phase delay at 50Hz/60Hz also differs between them. Therefore, the position of the zero crossing after the line filtering and the position of the zero crossing after the frequency filtering deviate from each other. (Figure 4)

To account for this, a delay circuit is inserted after the line filter so that the signal side has the same delay time as the frequency filter. (Figure 5)

After aligning the zero crossing positions on the signal side and the zero crossing on the detection side, the half-cycle RMS value calculator calculates the RMS value for each half-cycle.

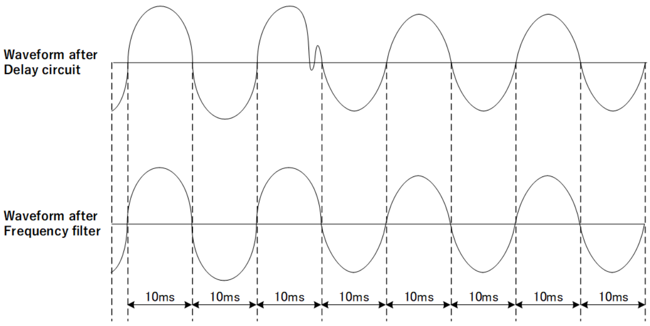


Figure 5. Signal waveform after delay circuit and waveform after frequency filtering

2-2 Measurement of Short-Term Flicker Value Pst and Long-Term Flicker Value Plt

This section describes how to measure the short-term flicker value, Pst, and long-term flicker value, Plt, according to the Block diagram in Figure 1.

(1) Block 1: decimation

The filter related to the calculation of Pst that is marked with an asterisk in Figure 1 has a minimum cutoff frequency of 0.0058 Hz.

The A/D converted data is the data sampled at 10 MS/s. However, attempting to achieve a digital filter of 0.0058 Hz with that sampling frequency will result in a calculation error unless the calculation bit length is made very long.

Therefore, decimation is performed and the sampling frequency is reduced so that the computation accuracy can be satisfied with a practical calculation bit length. Specifically, the sampling data is thinned out to 1/50, which is 200 kS/s. Before this down-sampling, the components of 100 kHz or more are attenuated to -80 dB or less by the line filter 10 kHz to avoid the influence of aliasing.

(2) Block 1: AGC (Automatic Gain Control) circuit

The half-cycle RMS value is multiplied by √2 to obtain the amplitude value. The reciprocal of the amplitude value is calculated and passed through the 1st LPF with a time constant of 27.3 seconds (cutoff frequency 0.0058 Hz), and then the value is multiplied by the signal. As a result, the input level to Block 2 is automatically adjusted and the amplitude is controlled to be kept constant.

(3) Block 2: Square law demodulator

This restores the voltage fluctuation by squaring the input voltage and simulates the properties of a lamp.

(4) Block 3: filter

This consists of three filters. The first stage filter is a 1st High Pass Filter with a cutoff frequency of 0.05 Hz. The second stage filter is a 6th Low Pass Filter (fc=35 Hz for a 50 Hz power supply, fc=42 Hz for a 60 Hz power supply). The first and second stage filters eliminate the DC components and the components whose frequencies are two times the power supply frequency.

The third stage filter is a 4th Band Pass Filter and defines a transfer function to simulate the frequency response of the human visual system to voltage fluctuations of a lamp.

The conventional model performed the filter calculation with the firmware. Therefore, if the filter order was large, the calculation processing time became a bottleneck and the sampling frequency had to be reduced considerably. Since the WT5000 performs the processing by hardware, the calculation processing time does not become a bottleneck. As mentioned earlier, it processes at 200 kS/s. The frequency characteristics of each filter of Block 3 in the WT5000 are shown in Figure 6.

There are two types of 6th Low Pass Filters, one for a 50 Hz power supply and the other for a 60 Hz power supply. Also, there are two types of 4th Band Pass Filters, one for a 230 V power supply and the other for a 120 V power supply. All of them accurately follow the characteristics specified in the standards.

(5) Block 4: Square and smoothing

The squarer simulates the non-linearity from eyes to the brain and the 1st Low Pass Filter simulates the brain's memory effect. The output of Block 4 represents instantaneous flicker sensation.

(6) Block 5: Level classifier and cumulative probability function (CPF)

The output of Block 4 is sampled at 1 kS/s and level-classified. At the time, 0.0001 to 6400 Perceptibility Unit (P.U.) is divided in log scale into 1400 classes so that the output can be classified with high precision accuracy even when the level is low.

The number of counts in the corresponding class is increased by one for each sampling, and after the measurement period, the number of counts in all classes is added up. Then the number of counts in each class is divided by the total number to obtain the probability density function of the flicker level. The probabilities are accumulated from the largest class of the probability density function to the smallest class to obtain the cumulative probability function (CPF).

Figure 7 shows an example in which flicker levels of 0 to 6400 P.U. are divided in linear scale into 10 classes. In actual classification, there is a larger number of classes and the log scale is used instead of the linear scale as mentioned above.

(7) Block 5: Short-term Flicker Value, Pst

The short-term flicker value, Pst, is calculated from the cumulative probability function using the equation below.

$$Pst = \sqrt{0.0314P_{0.1} + 0.0525P_{1S} + 0.0657P_{3S} + 0.28P_{10S} + 0.08P_{50S}}$$

① *3)

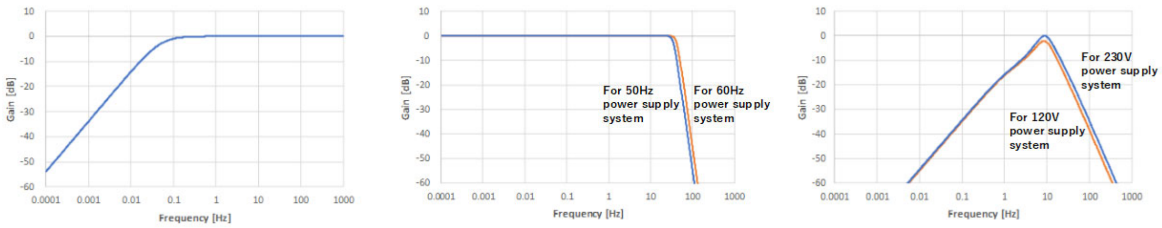
$P_{1S}=(P_{0.7}+P_1+P_{1.5})/3$

$P_{3S}=(P_{2.2}+P_3+P_4)/3$

$P_{10S}=(P_6+P_8+P_{10}+P_{13}+P_{17})/5$

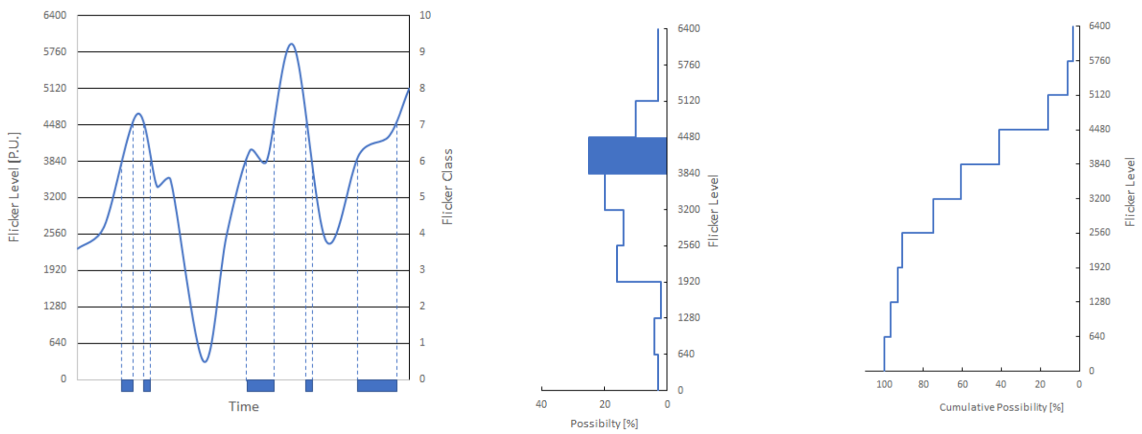
$P_{50S}=(P_{30}+P_{50}+P_{80})/3$

Pk indicates the flicker level when the cumulative probability is k%. (Figure 8)



1st High Pass Filter 6th Low Pass Filter 4th Band Pass Filter

Figure 6. Frequency characteristics of filters of Block 3



Output of Block 4 Probability Density Function Cumulative Probability Function

Figure 7. How to determine the Cumulative Probability Function (CPF) *2)

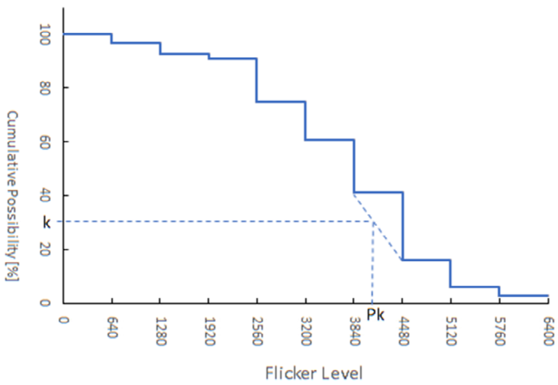


Figure 8. How to determine Pk *4)

(8) Long-term Flicker Value, Plt

The long-term flicker value, Plt, is determined using the equation below.

$$Plt = \sqrt[3]{(Pst_1^3 + Pst_2^3 + \cdots + Pst_{12}^3)/12} \quad ② \quad *5)$$

Pst_n: Pst of the nth 10 minutes

3. Conclusion

This paper described the voltage fluctuation/flicker measurement techniques using the WT5000.

Compared to the conventional model, the WT5000 has improved in the following points:

For the calculation of the half-cycle RMS value, a frequency filter has been installed for zero crossing detection to increase the resistance to noise and improve the accuracy of d parameters.

The bandwidth of the input stage is 10 kHz, which is sufficiently wider than the 450 Hz required by the standard.

By speeding up the sampling rate of the level classifier to 1 kS/s from 100 S/s of the conventional model (WT3000E) and expanding the minimum level value from 0.01 P.U. to 0.0001 P.U., Pst can be calculated with higher accuracy.

With the high accuracy and performance of the WT5000, engineers can reliably verify if their products are complying with the latest Voltage fluctuation and flicker standards.

References

・IEC61000-4-15 Ed 2.0：2010

*1)：Annex B B.2 Figure B.2

*2)：4.6 Block 5 - On-line statistical analysis Figure 3a

*3)：5.7.2 Short-term flicker evaluation

*4)：4.6 Block 5 - On-line statistical analysis Figure 3b

*5)：5.7.3 Long-term flicker evaluation

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