HARMONICS CURRENT/FLICKER MEASURING FUNCTION OF WT3000 PRECISION POWER ANALYZER

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We have added a harmonics current/flicker measuring function to the WT3000 Precision Power Analyzer with world-leading accuracy of power measurement. We have also created PC software for harmonics current/flicker measurement. This PC software and the WT3000 comply with the IEC61000- 3-2 harmonics current standard and IEC61000-3-3 voltage fluctuation/flicker standard, thus enabling the electrical power, harmonics current and flicker of electrical equipment to be measured precisely with a single unit. This paper outlines the harmonics current standard and voltage change/flicker standard, along with the measurement principle and PC-based software of the WT3000.

INTRODUCTION

The international standards on EMC (electromagnetic compatibility) include those for power-supply harmonic current and power-supply voltage change. These standards, known as low frequency EMC standards, regulate the emission or interference to devices connected to the public low voltage power supply/distribution system. In particular, an electrical/electronic device to be exported to EU (European Union) must have a CE marking on it and the power-supply harmonic current and power-supply voltage must be within the limits specified by relevant international standards.

The international standards for power-supply harmonic current/voltage fluctuation have been revised, causing harmonics current (or harmonic current) measurement and voltage change measurement features to be compliant with these latest standards. To meet these requirements, we have added a harmonics current/flicker measuring function to the WT3000 Precision Power Analyzer that provides world's highest accuracy of power measurement.

OVERVIEW OF HARMONICS CURRENT REGULATION

When an electrical/electronic device generates harmonics current, the impedance of the power distribution system distorts the supply voltage waveform and in turn the distorted voltage waveform can be applied to devices connected to the same power distribution system. This distorted voltage waveform may cause malfunction of a phase control device. In addition, an increase in harmonic current may result in overheating of components such as electric power capacitors and DC reactors. To address these problems, the limits for harmonic current have been defined by international standards.

The international standard for harmonic current is IEC61000-3-2, which is applicable to all electrical and electronic equipment with an input current up to 16A per phase and intended to be connected to public low-voltage distribution systems. Under this standard, electrical/electronic devices are divided into A, B, C and D classes, for each of which harmonic current upper limits are specified. For each class, those upper limits are applicable to the average harmonic current and the maximum harmonic current over the set observation time. The upper limits of the maximum harmonic current is 1.5 times the average harmonic current. The standard also provides information such as a negligible amount of harmonic current and the conditions where the regulation for upper limits can be partially alleviated.

PRINCIPLES OF HARMONIC CURRENT MEASUREMENT BY WT3000

Figure 1 is a block diagram depicting the configuration of the circuits of the WT3000. An input current is transformed into

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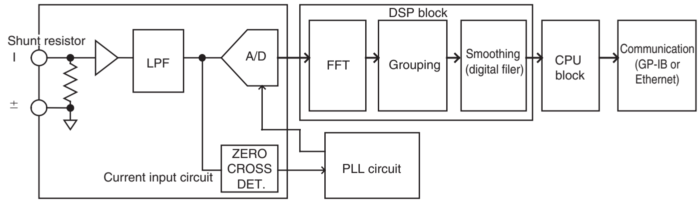

Figure 1 Block Diagram Showing the Circuits of WT3000

voltage by a shunt resistance, regularized by an operational amplifier, and then fed into an A/D converter through an LPF (low pass filter). A zero cross detector detects the frequency of the input current, which is passed to a PLL circuit. The PLL circuit generates a frequency 900 times the input frequency when it is 50 Hz, and a frequency 750 times the input frequency when it is 60 Hz. Using the generated frequency, the A/D converter transmits sampling data to a DSP block.

The DSP block performs an FFT operation of 9000 points. Multiplication constant used by the A/D converter differs depending on the input frequencies because the same number of FFT points is used for both of the 50 and 60 Hz frequencies, and because IEC61000-4-7:2002, the standard for harmonic current measuring equipment, specifies the use of 10 cycles when the input frequency is 50 Hz and 12 cycles when the input frequency is 60 Hz for the window size of FFT.

Based on the results of FFT operations, the following equations will give the effective value of the group of harmonic currents including intermediate harmonic currents, *Gg,n*, which represents a harmonic current component, whose frequency is an integral multiple of the input frequency. The first equation (1) is for cases when the input frequency is 50 Hz and the second (2) 60 Hz.

$$G_{g,n}= \sqrt{\frac{C_{k-5}^{2}}{2}+\sum_{i=-4}^{4}C_{k+i}^{2}+\frac{C_{k+5}^{2}}{2}} \quad \cdots(1)$$

$$G_{g,n}= \sqrt{\frac{C_{k-6}^{2}}{2}+\sum_{i=-5}^{5}C_{k+i}^{2}+\frac{C_{k+6}^{2}}{2}} \quad \cdots(2)$$

Where, n is the order of a harmonic current, and Ck is the effective value of the k-th frequency spectrum.

Then this effective value for the group of harmonic currents, *Gg,n*, is smoothed using the digital filter whose time constant is 1.5 seconds, as shown in Figure 2. After smoothing, measurement values are transmitted to the CPU block and then fed to a PC (personal computer) through a communication interface every 200 ms without any loss of data. Table 1 lists basic specifications for harmonic current measurement.

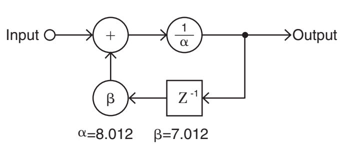

Figure 2 Digital Filer

PC SOFTWARE FOR HARMONIC CURRENT MEASUREMENT

PC software for harmonics measurement controls the WT3000 to perform measurement and decision as per required standards. This software allows for setting of a measurement period up to 24 hours, an efficient management of the program cycle of equipment and a test with high reproducibility. In addition, average and maximum values in each order of measurement and their reproducibility can be obtained by specifying multiple files, each of which contains the results of an individual measurement. This allows users to easily know about the reproducibility required by the standard. Figure 3 shows a screen that contains a bar chart of measured harmonic current.

OVERVIEW OF THE REGULATION ON VOLTAGE CHANGE AND FLICKER

Flicker is defined as the "unpleasant visual sensation induced by change in brightness of lighting (flickering)". Flicker occurs as follows: the start of the motor in an electrical device causes a large current to flow into the impedance of the distribution system, which lowers the supply voltage level and darkens the incandescent lamps connected to the power supply (refer to Figure 4). A change in power-supply voltage causes flickering of incandescent lamps, resulting in an unpleasant sensation to some people.

IEC61000-3-3 has been developed as an international standard to address problems caused by voltage changes. This standard is for devices of 16 A or less per phase, which are

Table 1 Basic Specifications for Harmonic Current Measurement

Item	Specification
Target of measurement	Select one target from input elements or Σ connection units
Method	PLL synchronization method
Frequency range	45 Hz to 66 Hz (PLL source)
PLL source	Select one source from a voltage, current or external clock of each input element
FTT data length	9000 points
Window function	Rectangular
Anti-aliasing filter	Set using line filter (5.5 kHz)
Current accuracy when line filter (5.5 kHz) is active	45 Hz≦f≦66 Hz 0.2% of reading+0.04% of range 66 Hz <f≦440 Hz 0.5% of reading+0.05% of range 440 Hz <f≦1 kHz 1% of reading+0.05% of range 1 kHz<f≦2.5 kHz 2.5% of reading+0.05% of range

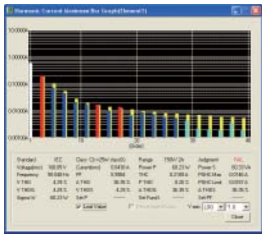

Figure 3 Screen Sohwing a Bar Chart of Measured Harmonic Current

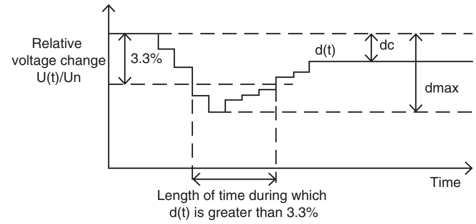

Figure 5 Relative Voltage Change

connected to the public low-voltage distribution system. The standard defines five types of measurements: a relative steady state voltage change, dc; a maximum relative voltage change, dmax; a period during which relative voltage change exceeds the threshold level, d(t), is greater than 3.3%; a short-term flicker value, Pst; and a long-term flicker value, Plt.

The values of d(t), dmax and dc can be obtained as follows: where, a rated voltage is Un; an effective value for a half wave of the voltage waveform is U(t), and the magnitude of voltage change between the level in a steady state and the level in the next steady state is ΔU(t); the difference between the minimum and the maximum of ΔU(t) is a maximum voltage change, ΔUmax; the difference between voltages in two steady states is a steady state voltage change, ΔUc; Figure 5 illustrates these factors and their relationship.

Relative voltage change, d(t): ΔU(t)/Un

Maximum relative voltage change, dmax: ΔUmax/Un

Relative steady state voltage change, dc: ΔUc/Un

The standard defines four methods to calculate the short time flicker value, Pst. The WT3000 supports the Flicker Meter Method that can observe any voltage change. The specifications for this feature are compliant with IEC61000-4-15. The long time flicker value, Plt, can be obtained based on the short time flicker value, Pst.

PRINCIPLES OF VOLTAGE CHANGE AND FLICKER MEASUREMENT BY WT3000

The WT3000 uses DSP to perform processing for voltage change and flicker meter. Figure 6 shows a block diagram depicting the circuits for measuring voltage change and flicker.

Values of the relative steady state voltage change, dc, the maximum relative voltage change, dmax, and the period during which relative voltage change exceeds the threshold level, d(t), is greater than 3.3% can be obtained as follows.

Zero-cross detection is performed to calculate the effective value of the half wave. Based on this effective value U(t) and the rated voltage Un, the relative voltage, d, is obtained. This relative voltage, d, is used to determine the state (steady or non-steady) and then dc, dmax, and the length of time during which d(t) is greater than 3.3% are calculated and output. These values are reset at every INTERVAL (normally 10 minutes), and this calculation sequence is repeated certain times (normally 12 times). In addition, the instantaneous values of dc, dmax, and d (t) are generated at every data update (2 seconds).

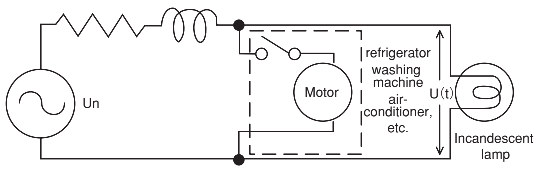

Figure 4 Causes of Flickering

The short time flicker value, Pst, and the long time flicker value, Plt, are calculated as follows.

Block 1(Figure 6) is an input voltage adapter for adjusting the level of the input voltage to the internal reference level. For the input voltage, step response from 10% to 90% is 60 seconds.

In Block 2, the input is squared to simulate the properties of a lamp.

Block 3 consists of three filters. The first stage filter eliminates the direct-current components, and the second stage filter eliminates the components whose frequency is two times the power supply frequency. The third stage filter simulates the human visual system and the frequency response of the lamp.

Block 4, consisting of a square machine and a low pass filter, simulates non-linear perception of the eyes and the brain, and brain's memory effect. The output from Block 4 represents instantaneous flicker sensation.

The level classification unit in Block 5 divides the output from Block 4 into many classes, and, after one measurement period (normally 10 minutes), establishes a probability density function based on the total number of counts in all classes and the number of counts in each class. Using this probability density function, a cumulative probability function (CPF) is obtained, and the following equations are used to calculate the short time flicker value, Pst.

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

$$P_{1S}=\frac{P_{0.7}+P_{1}+P_{1.5}}{3} \quad \cdots(4)$$

$$P_{3S}=\frac{P_{2.2}+P_{3}+P_{4}}{3} \quad \cdots(5)$$

$$P_{10S}=\frac{P_{6}+P_{8}+P_{10}+P_{13}+P_{17}}{5} \quad \cdots(6)$$

$$P_{50S}=\frac{P_{30}+P_{50}+P_{80}}{3} \quad \cdots(7)$$

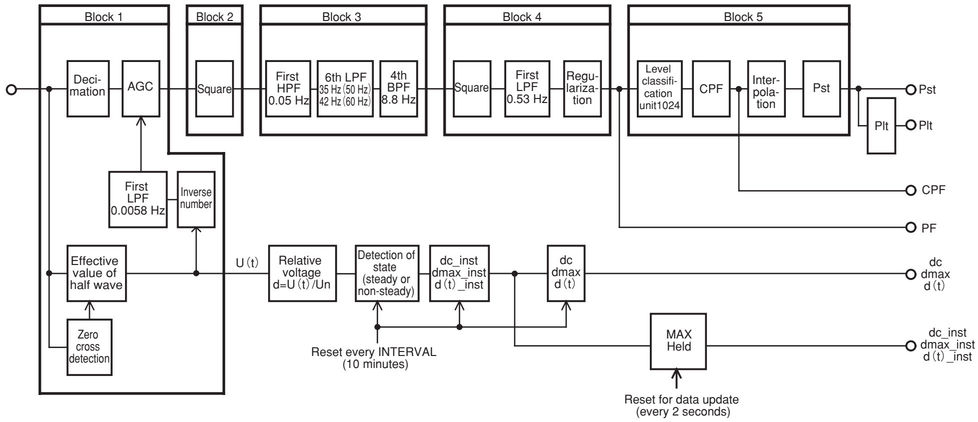

Figure 6 Block Diagram Depicting the Circuits for Measuring Voltage Change and Flicker

Where, Pk is the flicker level when the cumulative probability exceeds k%. Pk, the flicker level, is calculated by interpolating the values from CPF which are obtained by dividing the range of flicker level (0.01~6400 P.U.) in log scale into 1024 class. The flicker level 6400 P.U. corresponds to the flicker class 1024, and the flicker level 0.01 P.U. corresponds to the flicker class 0. When the measurement has been repeated a predefined number of times (normally 12 times), the long time flicker value, Plt, is calculated using the following equation; where, Psti is the i-th occurrence of the short flicker value Pst, and N is the count of measurements performed.

$$\mathrm{Plt}=\sqrt{\frac{\sum_{i=1}^{N}\mathrm{Psti}^3}{N}} \quad \cdots(8)$$

Table 2 shows basic specifications for measuring voltage change and flicker.

PC SOFTWARE FOR MEASURING VOLTAGE CHANGE AND FLICKER

PC software for measuring voltage change and flicker controls the WT3000 to perform measurement and decision as per required standards.

The WT3000 sends the measured values to a PC every 2 seconds. These values are the relative steady state voltage change, dc; the maximum relative voltage change, dmax; the length of time during which the relative voltage change, d(t), is greater than 3.3%; the short time flicker value, Pst; the long time flicker value, Plt; the cumulative probability function, CPF; the instantaneous flicker value, PF; the instantaneous dc; the instantaneous dmax; and the instantaneous d(t).

Using these values the PC software displays the results of numerical decision and the charts that illustrate trends and CPF. The PC stores the values of the instantaneous flicker value, PF, the instantaneous dc, the instantaneous dmax, and the instantaneous d(t), allowing users to not only view the measurement results but know when large voltage changes occurred. These features are useful for identifying measures and taking suitable actions.

Table 2 Basic Specifications for Measuring Voltage Change and Flicker

Item	Specification
Input voltage/frequency	230 V/50 Hz, 120 V/60 Hz
Target elements	Elements 1- 4
Measurement items	dc (relative steady state voltage change), dmax (maximum relative voltage change), d(t) (length of time during which the relative voltage change is greater than a threshold in one voltage change period), Pst (short-time flicker value), Plt (long-time flicker value)
Accuracy	dc, dmax: ±4% (when dmax = 4%) Pst: ±5% (when Pst = 1)

CONCLUSION

This paper discussed the causes of harmonics, voltage change and flicker, the content of the relevant standards, the principles of measurement of harmonic current, voltage change and flicker performed by the WT3000 Precision Power Analyzer, and features of PC software.

We hope and expect that the WT3000 will be used in the development and evaluation of electrical and electronic equipment for the purpose of not only the measurement of power supply but also measuring harmonic current, voltage change and flicker. ◆

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