

Analysis of the Harmonic Influence to the Engineering Measurement

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Abstract

Purity of power supply is become one of the most serious problems to the measurement project. With the diversification of electronic devices, harmonic interference in the power system is more and more complicated. The paper uses FLUKE6105A as harmonic power source, and four models of digital multi-meters (DMM) to constitute the test equipment. With the different frequency, distortion, and phase angle, doing the experiment with each DMM respectively. According to the test result, make a further analysis of the harmonic influence. Suggestions are given for engineering application in the end.

1. Introduction

In practical operation, engineering measurement accuracy can be affected by many factor, some of the factor is too complex to analyze. As the diversifying application of power and electronic devices, voltage or current does not affecting pure in power supply system will bring in serious problems. Distorted power waveform which contains a large number of harmonics will have a severe impact on engineering measurement and accuracy reliability of the instrument. The paper uses electrical harmonic power standard FLUKE 6105A, which can provide an AC source contains harmonics that can be set experimentally. Different types of the DMM are planed to do measurement with the output of 6105A. Record the testing result, figure out the relative error, calculate the measurement error and analyze the influence of harmonics to each DMM.

2. The Causes of Harmonic

There are mainly two reasons to generate harmonics, one is the electrical equipment and the other is from the transmission and distribution system. Harmonics generated by electrical equipment is the mainly reason for power system. Thyristor rectifier equipment, and electrical equipment powered by low-voltage supply power usually cause harmonics. Thyristor rectifier equipment generally adopts the phase shifting control technology. Some of the missing angle sine wave is absorbed into the grid, so large number of harmonic is brought into part of the missed angle sine wave consequently. It will contain odd harmonics while the single-phase rectifier circuit is connected to an inductive load, the 3rd harmonic of them is about 30%THD, and the content of harmonic will increase along with the increase of the capacitance value. Source of harmonic in the power transmission and distribution system is mainly produced by the power transformer, which is located in the iron core saturation and nearly saturated magnetization curve. It makes the magnetization current spire waveform, so harmonic generated. Harmonic generation is related to the size and the structure of magnetic circuit, and the saturation degree of the iron core. The higher the saturation degree, the farther the operating point of power transformer is deviating from

the linear, and greater the harmonic current is, where the 3rd harmonic can be up to 0.5%THD of the rated current. It will affect all related equipment while a certain amount of harmonic come into grid, lead to some equipment does not work, more serious, even can cause equipment failure.

3. Basic Principle of DMM and the Influence of Harmonic

The principle of AC voltage measurement of DMM is to amplify or attenuate the measured signal into the input scope of the A/D converter firstly, and then convert them into digital quantity through the A/D converter, finally disposal for test result display. AC current measuring principle is based on the I-V converter and AC-DC converter. Convert the AC current into AC voltage when it flowing through the I-V converter first, and then convert it into a DC signal through AC-DC converter, finally select the range, modulus conversion processing for test result display. The bandwidth of DMM is limited, for example, bandwidth of 8508A for AC voltage measurement is up to 1MHz, and the bandwidth for the AC current measurement of it is from 1Hz to 100kHz. The bandwidth of 34401A for AC voltage measurement is from 3Hz to 300kHz, the bandwidth of AC current measure for it is from 3Hz to 5kHz. The AC voltage and AC current measurement bandwidth of 15B is 500Hz and 200Hz respectively. According to theoretical analysis, high frequency harmonic components in the circuit will cause interference to measurement process of DMM, hence affecting the accuracy of measurement. Secondly, such as the DMM of true RMS principle (e.g. 8508A and 34401A) and the other principles (e.g. FLUKE 15B), difference between the DMM of true RMS principle from the other DMM is that they used to measure the power consumption of the resistance. Power in proportion to the square of the measuring true RMS voltage, but the actual waveform has nothing to do with it. Only when measuring sine wave, the average response DMM has the same readings as the true RMS DMM. To other waveform and waveform distortion, the average response DMM may have different degree of indication errors, ultimately affects the accuracy of the measurement.

4. The Test Equipment and the Test Procedure

The paper use a high-precision harmonic power source FLUKE 6105A, output AC standard signals contains different harmonic distortion, record the measurement data of each DMM to the various sorting, analysis, calculate the relative error of each measurement. According to the output capacity of standard source and the bandwidth of the DMM, as well as considering the practical test, the paper set the AC parameters and harmonic content selectively. For example, in the frequency of 50 Hz, the fundamental wave voltage 220Vrms, the 3rd, 5th, 7th harmonic waves are set to 15% THD, the 9th, 11th, 13th harmonic waves are set to 7.5% THD, 15th, 17th, 19th, and the 21st harmonic waves are set to 3.75% THD, the total harmonic distortion is up to 30% THD. Use a DMM (8508A, 34401A, 15B) to measure the amount of this exchange, recording the data to calculate the relative error. Then, 3rd, 5th, 11th...up to the 21st harmonic are set to 5% THD and 30% THD respectively, measure with the DMM and record the data, calculate the relative error. While in the frequency of 400Hz, the fundamental wave voltage 110Vrms, it can only be set up no further than the 14th harmonic. The setting of current harmonic and AC current is similar to the above. Using the FLUKE 8508A the eight and a half high precision DMM, HP 34401A a six and a half DMM, and FLUKE 15B, three and a half handheld digital meter as test subjects respectively. Test selected in the laboratory environment to ensure the result reliable and credible, the temperature is $20\pm1^\circ\text{C}$, humidity of $45\pm5\%$ of the standard working conditions.

5. Test Results and Analysis

5.1 Harmonic Influence to the AC Measurement of DMM

According to the specifications of 8508A, 34401A, and 15B provided by the manufacturers, technical indicators are calculated in appropriate range and the test points respectively, values of relative error and permissible error are shown in table 1. Harmonics contain different frequencies and distortions are inducted to the measuring process of AC voltage and AC current of the DMM. Calculate the relative error between the DMM and 6105A from the testing data, results shown in table 1. It can be seen from the calculated results that the influence of harmonic cannot reduce the accuracy if the DMM has a wide bandwidth and based on the true RMS principle, such as 8508A. 34401A, a true RMS principle DMM, the bandwidth of which is not as wide as 8508A, the harmonic causes a larger error for the measurement, but not that obviously to reduce its accuracy. However, harmonic does the most severely influence to reduce the accuracy on 15B, which is not based on true RMS principle and has a narrowband. In addition, the paper do an extra contrast test using the UT804, which has both true RMS measurement function (the AC function) and the AC+DC function for measuring AC voltage. Testing results shown in table 1 make out that, influence of harmonic is small when choosing AC function, on the other way it makes the relative error many times larger when using the AC+DC function.

Table 1. Under the influence of harmonic, testing result of each DMM

Test Equipment	Permissible error of the DMM, and relative error under the influence of harmonic							
	50Hz 220V		400Hz 110V		50Hz 1A		400Hz 220V	
	permissible error	relative error	permissible error	relative error	permissible error	relative error	permissible error	relative error
FLUKE 8508A	±0.019%	<0.006%	±0.010%	≤0.004%	±0.04%	≤0.017%	/	/
Agilent 34401A	±0.16%	<0.11%	±0.16%	≤0.041%	±0.33%	≤0.04%	/	/
FLUKE 15B	±1.14%	<5.06%	±1.14%	≤7.80%	±1.8%	≤8.14%	/	/
UT804 (AC)	±0.54%	<0.048%	/	/	/	/	±0.54%	<0.048%
UT804 (AC+DC)	±0.54%	<0.206%	/	/	/	/	±0.54%	<0.206%

5.2 Experiment with Additional Phase Shift

Change the phase angle between each harmonic and the fundamental wave periodically (from 0° to 360°) to continue the experiment of DMM and 6100A under the measuring conditions that have been set above. Testing data shows that this experiment does the most obviously impact on the 15B handheld multi-meter. Relative error calculated from the results of the experiment presents a periodical alternation similar to the sine function while the phase angle shifted periodically, as shown from table 2 to table 5, and figure 1 to figure 4.

Table 2. Frequency 50Hz, fundamental wave voltage 220Vrms, phase shift testing data as follows

(Electrical Power Standard 6105A) frequency 50Hz, fundamental wave 220Vrms													
Phase shift angle	0°	30°	60°	90°	120°	150°	180°	-180°	-150°	-120°	-90°	-60°	-30°
Relative error%	7.973	7.538	5.883	3.184	-0.255	-1.649	-1.866	-1.866	-1.91	-1.257	1.878	5.013	7.146

Table 3. Frequency 400Hz, fundamental wave voltage 110Vrms, phase shift testing data as follows

(Electrical Power Standard 6105A) frequency 400Hz, fundamental wave 110Vrms													
Phase shift angle	0°	30°	60°	90°	120°	150°	180°	-180°	-150°	-120°	-90°	-60°	-30°
Relative error%	7.799	7.189	5.535	2.836	-0.212	-1.170	-1.431	-1.344	-1.170	-0.299	2.662	5.448	7.189

Table 4. Frequency 50Hz, fundamental wave 1Arms , phase shift testing data as follows

(Electrical Power Standard 6105A) frequency 50Hz, fundamental wave voltage 1Arms													
Phase shift angle	0°	30°	60°	90°	120°	150°	180°	-180°	-150°	-120°	-90°	-60°	-30°
Relative error%	7.851	7.372	5.553	2.679	-0.673	-1.919	-2.110	-2.014	-2.014	-1.152	2.200	5.169	7.181

Table 5. Frequency 200Hz, fundamental wave 1Arms, phase shift testing data as follows

(Electrical Power Standard 6105A) frequency 200Hz, fundamental wave 1Arms													
Phase shift angle	0°	30°	60°	90°	120°	150°	180°	-180°	-150°	-120°	-90°	-60°	-30°
Relative error%	6.610	6.132	4.505	1.921	-1.525	-4.587	-5.257	-5.161	-4.587	-1.812	1.729	4.409	6.036

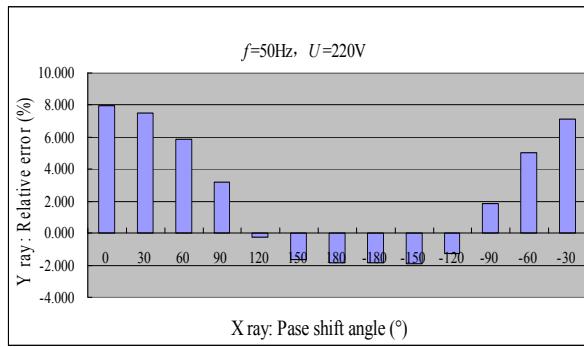


Fig. 1. Frequency 50Hz, fundamental wave 220Vrms

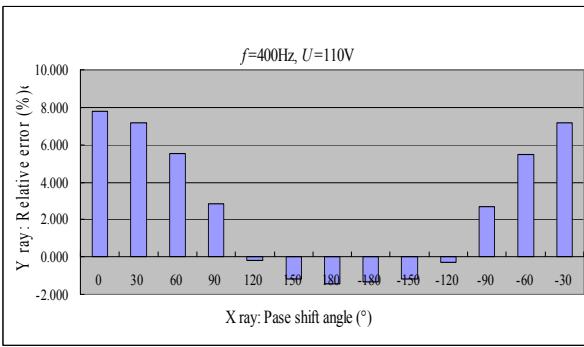


Fig. 2. Frequency 400Hz, fundamental wave 110Vrms

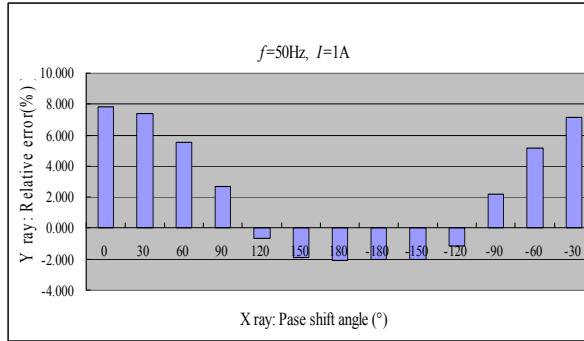


Fig. 3. Frequency 50Hz, fundamental wave 1Arms

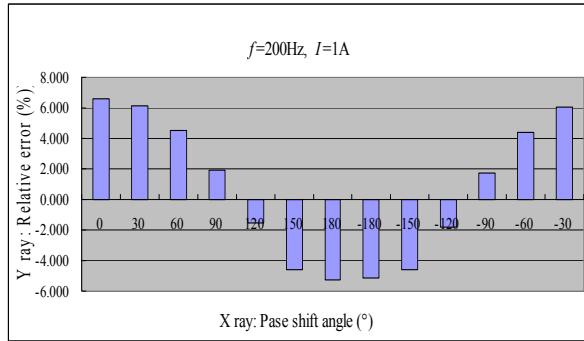


Fig. 4. Frequency 200Hz, fundamental wave 1Arms

6. Conclusion

In summary, harmonics in the circuit will bring in different influence to the AC measurement of different types of DMMS. The influence will cause to reduce the accuracy when the DMM is not based on true RMS principle or it has a narrow band. The impact becomes severely when there exist phase shift between harmonics and the fundamental wave. Relative error of the result is too complex to analyze for compensating or removing. Thus it is proposed to choose the appropriate instrument to carry on the measurement if there may exist the interference of harmonic. In order to make the test result dependable, it is recommended that you can also use a wideband power analyzer (for example the voltage and current bandwidth of WT1800 can reach up to 5MHz, and up to 10MHz for NORMA4000) for engineering measurement while the specification, scope, and the test condition meet the requirements of applications.

7. References

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