STEADY-STATE SIGNAL GENERATION COMPLIANT WITH IEC61000-4-30:2008

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ABSTRACT

IEC61000-4-30:2008 has been released for four years, which include various power quality components like flicker, unbalance, harmonics, interharmonics and frequency variation. The current solutions in the world are either not accurate or too complex. The technical design could be verified, however, it will be too costly and not flexible to conduct routine tests.

The study suggested an easy way in generating various power quality components/events using a universal test set with satisfying accuracy level. This study successfully generated the most difficult signal which is a single signal contains all the steady state influencing quantities.

INTRODUCTION

In the recent 20 years, the switched mode power converter has been widely used in various aspects of the power industry. The utilization of power electronics leads to a better control over the energy, but at the same time causes electromagnetic interference (EMI) to the power system. Despite the recent development in power electronics may help reduce the EMI emission, great impacts and concerns still exist.

Power quality meters are used for monitoring the performance of power system or power source and to capture the power quality events precisely. Therefore, the Electromagnetic Compatibility (EMC) of power quality meter is critical to the users. As a concern on degradation of performance over electromagnetic disturbance, IEC61000 series standards focus on the various requirements with the EMC and Part 4-30 is specialized in the EMC of power quality instruments.

The outcome of this study is a convenient tool to generate a complex signal according to the current international standard IEC61000-4-30:2008 [1]. This application developed in this study is named Power Quality Steady-State Verification Application (PQSSVA). PQSSVA is fast and easy to provide routine tests in accordance with IEC standard. Its testing applicability covers the steady-state parameters verification among the influence quantities.

REVIEW ON PREVIOUS STUDIES

The influence quantities are the power quality events which are clearly defined in IEC61000-4-30. The influence quantities could be divided into triggered events and non-triggered events. The remaining parameters are non-triggered events. Triggered events are the special incident that happened at a definite time, while non-triggered events are the continuous circumstance, or the steady-state status. Triggered events, like dips and transients/fast transient, under/over-deviation, main signalling voltage, are verified separately and excluded from the steady state verification. According to the guideline of the test specified in IEC61000-4-30, the certain testing signal which contains influence quantities is regarded as the simulation of the industrial environments. Therefore, the verification signal generated by PQSSVA is then contains flicker, harmonics and interharmonics, unbalance and frequency fluctuation. The following section is some brief review on the previous studies for the interested influence quantities.

Voltage Flicker

Voltage flicker refers to the continuous light voltage fluctuation. The flicker waveform is likely to be multiplied by another signal. Normally, the modifying signal has a frequency lower than the fundamental frequency, indicated as the blue lines in Figure 1.

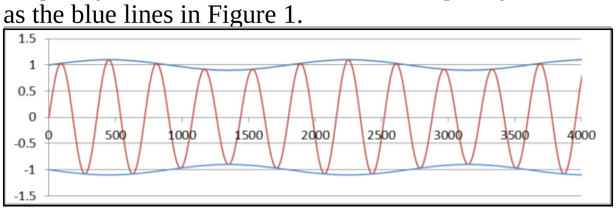

Figure 1 - 50Hz wave with 10% flicker at 10Hz

Voltage flicker occurs when heavy loads within the system periodically operate. The heavy loads, e.g. electric arc furnaces in the steel making factories, may cyclically distort the system voltage and cause voltage flicker [2]. The most severe flicker occurs at 8.8Hz which would heavily affect the performance of the power quality instruments. Therefore, voltage flicker is one of the most concerned issues related to power quality [3].

Voltage harmonics

The harmonics mentioned in [1] refer to the low-order voltage harmonics up to 3000 Hz. Voltage harmonics occur when the heavy non-linear loads feedback to the system and distort the system voltage. The major impact of such influence is the sampling error of transducers in harmonic contents [4], which will affect the accuracy of power quality instruments.

Reviewing Li and Zhang's work [5] on detecting equipment calibration, they use Direct Digital Synthesis (DDS) to generate referencing signals and then amplify signal to a certain power rating. The advantage of this method is that the frequency, phase angles and harmonic levels are fully adjustable. One major concern is whether flicker contents could be implemented and merged into the signal.

Voltage Interharmonics

Interharmonics have a non-integer order of fundamental. Therefore the effect of interharmonics cannot be continuously expressed from cycle to cycle at nominal frequency. This indicates that interharmonics and flicker are closely related. IEEE working document [6] points out one major source of interharmonic is cycloconverter, which converts one AC waveform at a certain frequency to another AC waveform at a lower frequency. The flicker caused by interharmonics has different fluctuating manner compared with the voltage flicker. A typical interharmonic influenced sine wave is shown in Figure 2 below:

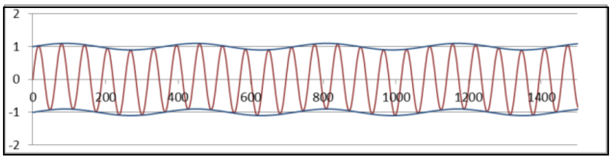

Figure 2 - 50Hz system with 10% 8.8Hz interharmonics

The impact of interharmonic is not only the heating effect and visual flickers, but also the overload of various filters (such as LC-tuned filters) and communication interference. Additionally, the analysis of discrete Fourier transform [7] employed by some power quality instruments could be unreliable under fluctuating waveform. Therefore, the IEC standard also includes the interharmonics as one of the background of the steady-state test.

Summary of the Previous Studies

The influence quantities for steady-state verification include six major parameters. All the parameters have already been studied thoroughly with mature design of testing. The limitations could be briefly concluded into three points as listed below:

1) Design-space for other parameters is restricted.
2) Modification work on both hardware and software is needed but the implementation could be very complicated.
3) Most designs are for laboratory tests only.

It could be summarized that the previous studies are focusing on one or two parameters at most. Hardly any study has ever considered the possibility of generating a signal with influence quantities. The design of the tests limits the flexibility in real life. Therefore, PQSSVA has its unique value in the power quality instrument industry.

HARDWARE AND SOFTWARE

Hardware

The test setup is a computer-controlled program with an existing hardware. This project adopts the hardware, OMICRON CMC 256plus. The specifications of CMC 256plus is presented in Table I.

Table I - CMC 256plus Technical Data (Partial)

Item	Technical Data
Voltage output	Max 300V
Power of Voltage output	85VA per phase
Accuracy	Typical < 0.02% Guaranteed < 0.07%
THD	< 0.05%
Frequency	10 – 3000Hz
Bandwidth (-3dB)	3.1kHz
Sampling Rate	28.5 kS/s

The verification equipment used is DEWE-3020-PNA. The key features of DEWE-3020-PNA are: IEC61000-4-30 Class A instrument; harmonics 2-9000Hz; interharmonics supported; flicker supported; symmetrical components supported. These features are most suitable for the IEC61000-4-30:2008 compliance tests.

The test set up is simple, by connecting CMC 256plus voltage outputs with the DEWE-3020-PNA voltage inputs. For some cases, a voltage transformer is needed. The test set up is show in Figure 5 below:

Figure 3 - Test setup with CMC and DEWE

Software

This application contains both Visual Basic Applications (VBA) and Microsoft Excel functions. VBA codes are the core structure of the background program. The codes applied in the application are a combination of Visual Basic programming language and the installed OMICRON CMEngine commands.

PQSSVA was then developed mainly based on the standard. Beyond the requested items from the standards, PQSSVA could also generate more complex contents or with more specific parameters.

SIGNAL GENERATION AND VERIFICATION

The generated voltage signals are verified based on the complex steady state events and the each influence quantity itself. All the parameters involved are referring to IEC61000-4-30:2008 with extended requirements on harmonics mentioned in IEC61000-4-15:2010 [8].

Steady-state tests

The steady-state tests are clearly specified in the standard, in order to decide the class of the test object. There are 3 different test states, which regards as clean, light disturbances and heave disturbances.

Testing State 1

The testing state 1 is the clean condition in without interference. Therefore, the signal generated in this section is a 230V/50Hz system. The results are not mentioned here.

Testing State 2

The testing state 2 is the dirty condition which includes light interference. Therefore, the signal generated in this section is with flicker, unbalance, harmonics and interharmonics. The results are shown in Table II and Table III. It contains the standard requirements, the generated values 'Exp.' and the actual measured values from DEWE-3020-PNA. The results indicate that all the parameters are correctly generated with very satisfying accuracy level.

Table II - Testing State 2 Verification Results

Parameter	Standard	Exp.	Results
Frequency	f_{nom} -1Hz	49	49
Voltage (3ϕ)	Determined by other factors	167.9 184 200.1	168.613 184.700 200.908
Flicker	P_{st}=1; Rectangular; 39 CPM	1	0.98
Unbalance	73%, 80%, 87% of U_{din} (u_0 =5.05%, u_2 = 5.05%)	5.05	5.04
Harmonics	10% 3rd; 5% 5th; 5% 29th	Table III	
Interharmonics	1% 7.5th		

Table III - Harmonic Components in Testing State 2

Order	Frequency (Hz)		Magnitude (V)	
	Expected	Measured	Expected	Measured
1	49	48.98	200	200.10
3	147	147.02	23	23.10
5	245	244.98	11.5	11.50
7.5	367.5	367.51	2.3	2.30
29	1421	1420.97	11.5	11.50

The waveforms of Testing State 2 are shown in Figure 4 for the reference. Three phases of the voltage were recorded and the waveforms are slightly distorted.

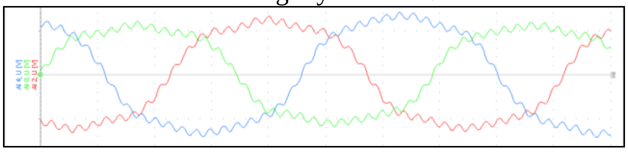

Figure 4 - Waveform of testing state 2

Testing State 3

The testing state 3 is the dirty condition which includes heavy interference. It should be noticed that 152% of U_{din} (349.6Vrms) exceeds the output limit. Thus, the external voltage transformer is used. The results are shown in Table IV and Table V.

Table IV - Testing State 3 Verification Results

Parameter	Standard	Exp	Results
Frequency	f_{nom} +1Hz	51	51
Voltage	Determined by other factors	349.6 322 294.4	350.647 323.149 295.191
Flicker	P_{st} =4; Rectangular; 110 CPM	4	4.05
Unbalance	152%,140%,128% of U_{din} (u_0 =4.95%, u_2 = 4.95%)	4.95	4.96
Harmonics	10% 7th@180°,5% 13th,5% 25th	Table V	
Interharmonics	1% 3.5th		

Table V - Harmonic Components in Testing State 3

Order	Frequency		Magnitude	
	Expected	Measured	Expected	Measured
1	51	50.96	349.6	349.00
3.5	178.5	178.53	2.3	2.29
7	357	356.98	23	23.00
13	663	662.99	11.5	11.50
25	1275	1275.02	11.5	11.50

The waveforms of Testing State 3 are shown in Figure 5 for the reference. Three phases of the voltage were recorded and the waveforms are obviously distorted.

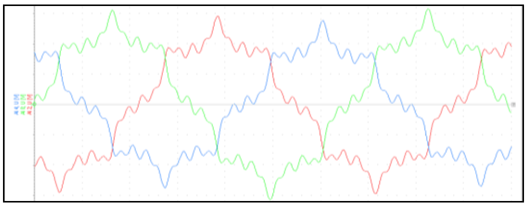

Figure 5 - Waveform of testing state 3

Therefore, PQSSVA successfully generates the required signal according to IEC61000-4-30:2008 steady-state verification testing state 1, testing state 2 and test state 3.

Parameter tests

All signal generation of the three test states are proved to be successful, in this section each parameter is evaluated according to the range required by the IEC61000-4-30:2008, with extended requirements in IEC61000-4-15:2010. The parameter tests are used to assess the competence of the application in generating EMI signals with influence quantities. Voltage magnitude is only a reference parameter. The frequency and unbalance are verified during the steady-state tests. No individual discussions are included in the following section.

Flicker

Flicker test is critical in this application. P_{st} is the short term flicker severity, the measurement has to be in a 10 minutes time-interval with rectangular modulation at 39 CPM. The visualized results are shown in Figure 6.

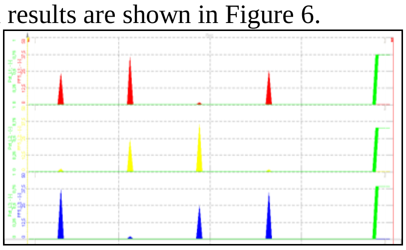

Figure 6 - P_{st} in 10 min record

Harmonics

The tests on harmonics are conducted for three testing states. The harmonic components are generated on a 230V/50Hz system according to 200% of the IEC61000-2-4:2002 [9], with detail values attached in Table VI. Because the signal contains more than 60 harmonic components, the results of the three tests are selectively extracted.

Table VI - Harmonic Components Verification

Order	Exp. frequency (Hz)	Measured Frequency (Hz)	Exp. (V)	Results (V)
1	50	49.97	230	230
3	150	149.99	27.60	27.60
17	850	849.99	18.40	18.40
19	950	950.01	8.11	8.10
21	1050	1050.03	8.05	8.04
29	1450	1449.97	4.92	4.91
37	1850	1849.98	3.61	3.59
43	2150	2149.96	2.94	2.92
50	2500	2500.00	4.60	4.57

Therefore, the harmonics requirements are fully fulfilled by the application, according to the IEC61000-4-15:2010.

Interharmonics

The interharmonics are verified through using the following two samples, 2% at 37.4th and 1% at 49.2nd interharmonics. They are respectively applied to the 230V/50Hz system. The 37.4th interharmonic is tested under testing state 2, while the 49.2nd one is under testing state 3. The results are shown in Table VII and Table VIII.

Table VII - Interharmonic Verification for Testing State 2

Order	Frequency		Magnitude	
	Expected	**Measured**	**Expected**	**Measured**
1	49	48.98	200.1	200.01
3	147	147.02	23	23.00
5	245	244.98	11.5	11.50
29	1421	1420.97	11.5	11.50
37.4	1832.6	1832.58	4.6	4.58

Table VIII - Interharmonic Verification for Testing State 3

Order	Frequency		Magnitude	
	Expected	**Measured**	**Expected**	**Measured**
1	51	50.96	200.1	200.00
7	357	356.98	23	23.00
13	663	662.99	11.5	11.50
25	1275	1275.02	11.5	11.50
49.2	2509.2	2509.23	2.3	2.30

It could be concluded that the generation on interharmonic is successfully implemented. PQSSVA provides sufficient interharmonic selections with satisfying accuracy level.

CONCLUSION

This project has adopted the computer-controlled signal generation methods to generate signals containing influence quantities according to IEC61000-4-30:2008. The signal is used as the EMI for the steady-state verification on power quality instruments.

A R&D-oriented application PQSSVA is developed to conduct the testing procedures. PQSSVA is designed according to the structure illustrated by state transition diagram and data flow diagram.

Difficulties which are the insufficient higher order frequency response and inflexible interharmonic generating capability are encountered and well-solved.

The application is fully capable of the steady-state verification according to IEC61000-4-30:2008 standards. Besides, the range of each parameter in the influence quantities is much broader than the standard requirements, which could satisfy users' different needs.

Future research can be extended to solve the limitations and constraints on the hardware in terms of triggered condition verification, maximum voltage and applicable influence quantities. Meanwhile, IEC 62586 is on schedule. This project can be considered as a pilot study with potentials for future modification.

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