A Practical Approach for Calibration of Harmonics and Flicker Test Systems

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Abstract **- Harmonics and Flicker (H&F) measurements are an important part of the EMC suite of tests required for CE marking and by Energy regulators. It is expected that manufacturers of H&F test equipment meet the (ill-defined) requirements of the standards. Ongoing accredited calibration of equipment is problematic for test laboratories. Compliance is often claimed by only calibrating part of a system. Examples of calibrations and inter-lab tests are given in this paper to highlight the issues. Two recently released technical reports (IEC TR61000-4-37 & TR61000-4-38) provide recommended methods for the verification of complete H&F test systems. Using these methods, laboratories will find it easier to comply with ISO 17025 accreditation requirements**

Keywords—Harmonics; Flicker; IEC 61000-3-2; IEC 61000-3-3; IEC 61000-43-15; IEC 61000-4-7; TR61000-4-37; TR61000-4-38; ISO 17025

I. BACKGROUND

Flicker refers to lighting variations that are detectable by the human eye and are caused by voltage fluctuations on the mains supply. The phenomenon was first observed as early as the 1920s when it was noticed that electric arc furnaces were causing voltage fluctuations causing incandescent lamps to flicker. Exposure to cyclic lighting fluctuations may not be noticed by the human eye but are registered by the brain, causing annoyance and avoidable stress.

Harmonics refers to current harmonics caused by non-linear loads such as rectifiers, power converters and lighting connected to the mains.

Harmonics are undesirable because they can cause a reduction in energy efficiency, failures in transformers and capacitors and also erratic operation of relays and control devices.

Harmonics and Flicker (H&F) measurements have become an important part of the EMC suite of tests required for CE marking and by many Energy regulators.

The existing H&F emission standards describe the technical requirements for test equipment to carry out the measurements in an accurate and repeatable manner.

For Harmonics, IEC 61000-3-2 [1] is used to set the limits and sets requirements for repeatability and reproducibility of the measurements.

The description of the Harmonics measuring system meter's functional design and specification is described separately in IEC 61000-4-7 [4]

For Flicker, IEC 61000-3-3 [2] is used to prescribe test methods, limits, accuracy requirements, and also the supply source accuracy and its impedance.

The description of the flicker meter functional design and specifications are described separately in IEC 61000-3-15 [5].

II. THE PROBLEM:

It is expected that manufacturers of H&F test equipment meet the requirements and specifications of the measurement standards, albeit, ill defined. It is up to the equipment manufacturer to ensure that a new H&F test system or components comply with all requirements. When a customer takes delivery of a measurement system, they expect a compliant system that has a full ISO17025 [8] calibration and a statement of compliance with the relevant standards.

For ISO17025 test labs, the H&F test systems must be calibrated at least yearly and must remain compliant with the appropriate standards.

Ongoing ISO 17025 calibration of H&F test systems can be problematic for laboratories. Complete test systems can be large, cumbersome, and fragile (***See Fig 1***). Most laboratories are wary of the risk of damage or the downtime and costs incurred when shipping complete systems to a calibration facility (often overseas). The experience in Australia is that there were no ISO17025 H&F calibration facilities. The cost of the calibration itself can also be overly expensive *($20 K upwards*) for a system calibration. When added to the shipping costs and test capability downtime, this can be a major problem for labs.

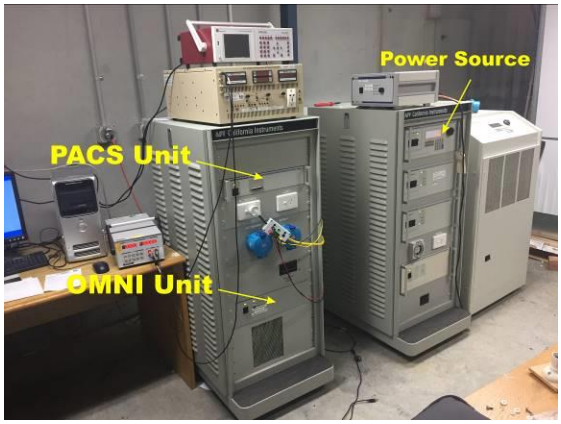

Fig. 1. Large 3 phase H&F Test System.

The result is that many systems are either not calibrated regularly or are only partially calibrated. It appears that convenient interpretation of the standards is used to justify partial calibrations.

In the case of Flicker, compliance is often claimed by calibrating only the flicker measurement meter part, to the requirements of IEC 61000-3-15 [5].

IEC 61000-3-15 [5] only specifies the flicker meter design and specification. It does not mention anything about the important contribution to the system calibration of the reference impedance and the power source.

In the case of harmonics, compliance can be claimed by calibrating the harmonics meter part only, to the requirements of IEC 61000-4-7 [4] which has specific requirements for power source voltage and frequency accuracy. Compliance is often assumed when parts are separately calibrated.

Without calibrating a complete system, factors that can affect measurements such as impulsive load response and source inductance will be missed, rendering the calibration flawed and incomplete

Typically, a calibration source is used to generate accurately known flicker and harmonics signals into the meter with no connection to the actual system power source or to the standard impedance.

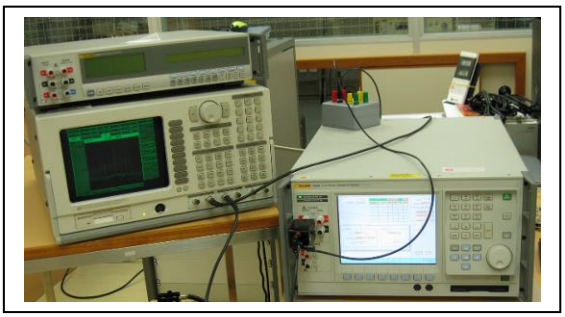

Fig. 2. Example using Fluke calibrator

Excessively long cables between system components adds to measurement errors. Source resistance can particularly affect flicker measurements. This error can only be avoided by a full system calibration that includes the actual power source used for the measurements.

Fig. 3. Long interconnecting cables can cause errors.

III. The Solution:

Two recently released Technical Reports (IEC TR61000-4-37 [6] & TR61000-4-38 [7]) provide calibration and verification protocols for complete H&F test systems. Their primary use is to verify the performance of H&F Test Systems so that they meet ISO 17025 [8] requirements for calibration including realistic measurement uncertainty.

Regular verification is important to ensure that system performance has not degraded over time, and that system integration has not affected accuracy or measurement uncertainty.

Verification is achieved by simulating actual test conditions using modulated and phase controlled loads that generate known fluctuating currents and harmonics which are introduced into the H&F test system.

A. IEC TR61000-4-37[6] Harmonics

Verification of the harmonics measuring system is achieved by using a phase controlled load that creates current harmonic patterns that represent pass and fail conditions for each class of test defined in IEC 61000-3-2. Performance of the source supply under extreme peak load conditions can also be assessed.

TABLE I. Harmonics Verification Tests

Test	Description
0.	Sine wave test with linear load to verify power source.
1	Class A test to verify overall accuracy and allow verification of the measuring ranges being used
2	Class A test failing the limits

*3a	Class A with higher orders failing limits
*3b.	Class B with higher orders at passing limits
4.	Class B failing limits
5.	Class C just passing the limits
6.	Class C failing the limits
7	Class D at ~540 W passing the limits
8	Class D failing the limits
9	Class D with harmonics that pass the POHC limit
10	Class A test with higher order harmonics failing the POHC limit
11	Class A to test analyzer and source dynamic range
*12.	Class A with > 30 A peak current

**Note: Tests for systems with current capability above 16 amps IEC 61000-3-12 [3]*

The results of these tests can very accurately test the harmonic measuring system's ability to make pass/fail decisions for all classes. Also, results can be compared to ideal calculable harmonic results.

B. IEC TR61000-4-38[7] Flicker

Calibration of a flicker meter is achieved by using a rectangular modulated load unit that creates fluctuating currents in the H&F test system. These fluctuating currents are converted into voltage drops across the system reference impedance and are measured by the flicker meter.

TABLE II. FLICKER VERIFICATION TESTS

Test	Description
1	Power Source qualification test. Does system meet specification for Pst < 0.4 for no flicker modulation?
2	Verification of *Zef* and or *Ztest* impedance. Does *Zref* resistance and inductance meet specification?
*3 to 7	Low frequency rectangular modulation *Pst* and *Dmax* 1 to 39 CPM
*7 to 9	High frequency rectangular Modulation *Pst* 110 CPM and higher

**Note: Actual Pst & Dmax Tests can be varied at user discretion.*

Both H&F verifications can be carried out using equipment that is easily transportable to carry out on-site calibrations.

Equipment used for verification must be itself ISO 17025 calibrated, traceable to national standards with an appropriate measurement uncertainty.

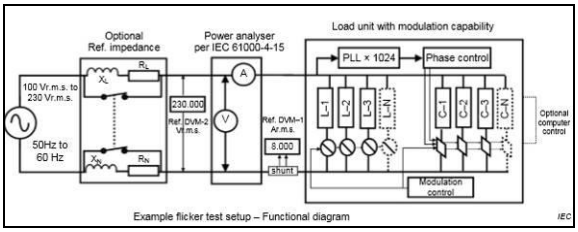

Fig. 4. Load unit Circuit

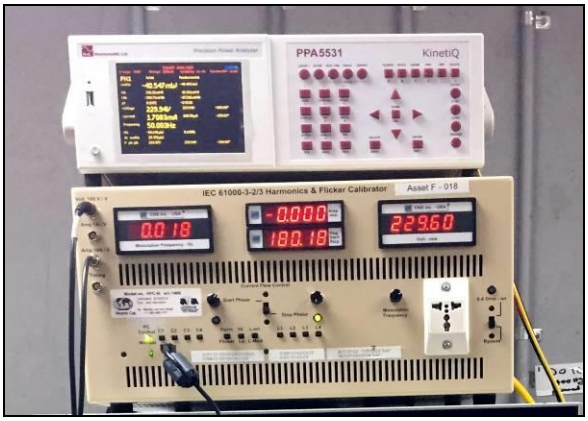

Fig. 5. Example of Load unit.

IV. RESULTS OF CALIBRATIONS

The experience in Australia is that it has been impractical (if not impossible) for the complete calibration of H&F Test systems. Within our company there are a total of five systems that need to be maintained and ISO 17025 calibrated annually.

It took a considerable effort to develop the capability and to gain NATA (ISO 17025) accreditation for calibration. The publication of the two IEC Technical Reports had made it all possible by exactly defining the requirements and dealing with the issues.

The following results from the calibration of our systems using IEC 61000-4-37 and IEC 61000-4-38 can be used as examples of what may be happening where labs are using separately purchased components or hybrid systems that have only been partly calibrated.

A. System 1

California Instruments (Ametek) system comprising of a CX5001iX power source with Power Analysis Conditioning System (PACS) and external Omni (Ref impedance) unit.

The components were purchased at separate times and hence it was not actually calibrated as a full H&F Test system. The only calibration was for the power source alone. It was assumed that the individual components were compliant when supplied.

The system was originally configured to use the external Omni unit (resistor and inductor) as the reference impedance. The power source also has an optional built in electronic reference impedance.

The original verification measurements on this system showed it to be out of specification for the flicker 8% P_{st} requirement of the standard. Low frequency flicker modulations were measuring over 15% high and high frequency modulation tests were over 20%. The Harmonics Part was within specification.

Modifications and adjustments were performed and were successful with the final results now better than 5 % compared to the required specification of 8%.

Modifications included:

- Using the Internal electronic impedance instead of the external Omni which was causing the higher frequency problems.
- Replacing the interconnecting wires from the Power Source to the PACS unit with shorter thicker ones.
- Adjustment of the electronic impedances within the power source. (Luckily this was possible)

B. System 2

EMC Partner Harmonics 1000 system.
Self-contained system with integral power conditioner as a source.
This system had an old manufacturer's calibration that showed it to be in compliance with the H&F measurement standards (IEC 61000-3-2 and IEC 61000-3-3).
The verification of this system showed it to be out of specification for the Flicker calibration by around 20%, reading high across all modulations. Adjustments could only be performed with a return to the manufacturer.
The Harmonics measurement section was within the specification.

C. System 3

California Instruments system comprising of a 3 x CX5001iX power sources with 3 phase PACS unit and external 3 phase Omni.
This system is relatively large. It can also be configured with a 75 amp 3 phase MX45 power source.

The system was originally configured to use the external Omni (resistor and inductor) as the reference impedance. CX5001iX power sources also have optional built in electronic reference impedances.

The original measurements on this system showed it to be out of specification for the 8% Flicker requirement of the standard (IEC 61000-3-3). All modulations were measuring low by more than 20%. Harmonics were within the specification.

After modifications and adjustments, the results were within the specification at better than 4% compared to the 8% requirement.

Modifications included:

- Using the Internal electronic impedances. The external Omni was causing lower readings at all modulations.
- Adjustment of the electronic impedances within the power source. (Luckily this was possible)

Further investigations are needed to establish why the Omni was causing low readings however, it is suspected that the reference impedances in the Omni were configured incorrectly.

The neutral line reference impedance can often mistakenly be short circuited when earthed at each end.

Adjustment of the electronic impedances within the power source was needed to compensate for the extra losses on the long interconnecting cables between racks. ***See Fig 3.***

V. Results of Inter-laboratory Comparison

In 2015 our lab participated in an inter-laboratory comparison test for Flicker and Harmonics Measurements. The measurement program was conducted by UK based 17025 Assessments Ltd, an independent laboratory assessment company. The program included measurements from six test laboratories in Australia and Europe.

The Round Robin test was conducted using a York HFG01 unit that produces two standard flicker modulations and two standard Harmonic patterns when used as a load unit on H&F measuring systems.

Fig. 6. York HFG01 Unit.

Flicker results showed that some measurements from the participating laboratories varied by more than the acceptable amounts with respect to the accuracy requirements in the standards.

Flicker was measured with rectangular modulations of 1.0 and 8.33 Hz

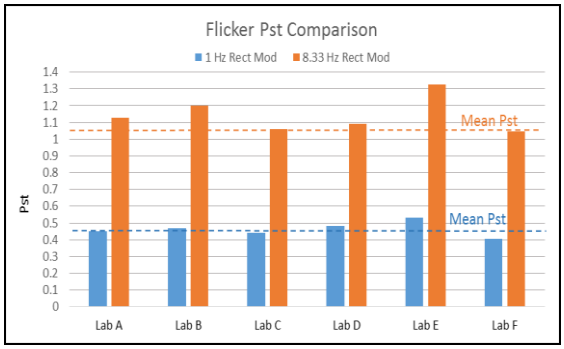

Fig. 7. Plot of overall measured Pst values.

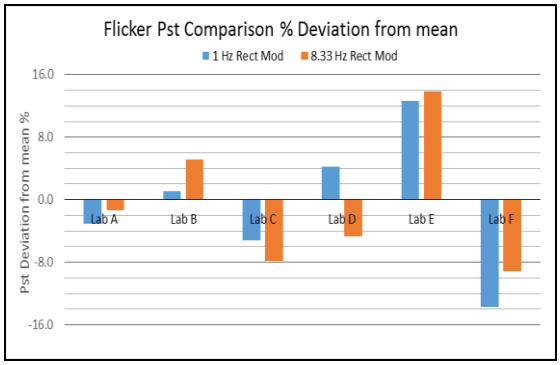

Fig. 8. Plot showing deviation from mean

Results show that lab C, E, and F were found to have deviations of more than the 8% accuracy requirement for *Pst.*

Lab E and F actually measured a 26 % difference in the 1 Hz Modulation.

Harmonics results were more encouraging and showed measurements from the participating laboratories were just inside the ±5mA 0.3% accuracy requirements in the standard.

VI. Conclusion:

It is expected that H&F test systems are fully compliant with the applicable standards when supplied new from the manufacturer. Maintaining quality with regular calibrations for laboratories is expensive and fraught with risk if equipment has to be is shipped off site.

Examples in this paper show that measurement accuracy cannot be guaranteed without properly verifying the full H&F test system.

Currently it seems that incorrect calibration procedures are being justified by questionable interpretation of the H&F measurement standards.

Using the verification methods in the recently published IEC Technical Reports will give laboratories confidence and make it easier to comply with ISO 17025 accreditation for Flicker and Harmonics measurements.

Importantly, a consistent and more rigorous technical assessment by the accreditation bodies will provide more confidence in measurement repeatability and reproducibility for ISO 17025 test and calibration labs.

References

[1] IEC 61000-3-2 Limits for harmonic current emissions for equipment ≤ 16 A /phase

[2] IEC 61000-3-3 Limitation of voltage changes, fluctuations, and flicker for equipment ≤ 16A /phase

[3] IEC 61000-3-12 Limits for harmonic current emissions for equipment 16A to ≤ 75 A /phase

[4] IEC 61000-4-7 General guidelines for instrumentation for harmonic and inter-harmonic measurements

[5] IEC 61000-4-15 Flickermeter, functional and design specifications

[6] IEC 61000-4-15 Flickermeter, functional and design specifications

[7] IEC TR 61000-4-37 Calibration and verification protocol for harmonic emission compliance test systems

[8] IEC TR 61000-4-38 Test, verification and calibration protocol for voltage fluctuation and flicker compliance test systems

[9] ISO 17025 General requirements for the competence of testing and calibration laboratories

[10] 17027 Assessments. Flicker and Harmonics round robin report 2016. Phil Carter