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Edition 1.0 2015-08

TECHNICAL REPORT

colour inside

BASIC EMC PUBLICATION

Electromagnetic compatibility (EMC) –
Part 4-38: Testing and measurement techniques – Test, verification and calibration protocol for voltage fluctuation and flicker compliance test systems

IEC TR 61000-4-38:2015-08(en)

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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Electromagnetic compatibility (EMC) –
Part 4-38: Testing and measurement techniques – Test, verification and calibration protocol for voltage fluctuation and flicker compliance test systems

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-38: Testing and measurement techniques – Test, verification and calibration protocol for voltage fluctuation and flicker compliance test systems

FOREWORD

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IEC 61000-4-38, which is a technical report, has been prepared by subcommittee 77A: EMC – Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms Part 4-38 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

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The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
77A/881/DTR	77A/898/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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INTRODUCTION

Flicker measurement systems are used to measure voltage fluctuations from equipment that is tested in accordance with IEC 61000-3-3 and/or IEC 61000-3-11 standards. The IEC adopted measurement and evaluation techniques that are specified in IEC 61000-4-15, but limits, limit comparisons, certain exclusions, and test conditions for a variety of products are specified in IEC 61000-3-3 (for 16 A/phase and below) and IEC 61000-3-11 (up to 75 A/phase).

This TR specifies recommended methods and acceptability criteria for performance verification of test systems designed to measure voltage fluctuations and flicker in accordance with IEC 61000-3-3 and IEC 61000-3-11.

A typical IEC 61000-3-3 and IEC 61000-3-11 compliance test system includes not only the flicker meter, but also a suitable power source and a test impedance. The reference impedance, per IEC TR 60725, is used for IEC 61000-3-3 tests, while the Z_{test} as specified in IEC 61000-3-11 is used for higher power products. This TR therefore also includes a method to verify that the impedance, according to IEC TR 60725 or the Z_{test} specification, is within reasonable tolerances and that the power source does not contribute more to the measured flicker levels as is permitted in IEC 61000-3-3 and IEC 61000-311.

This protocol is neither intended as a type test nor as an exhaustive test of all required flicker meter capabilities according to IEC 61000-4-15. The primary objective is to verify, on a periodic basis, that the flicker test system, consisting of a previously type tested analyzer, a suitable power source and impedance unit, performs correctly, and that the system performance is not adversely affected by the system integration or by deterioration of one of the system components. For example this TR can be one of the methods to achieve accreditation of a test laboratory or facility.

NOTE To characterize individual system components, both digital volt meters 1 and 2 (DVM-1 and DVM-2) in Figure B.1 are needed, and care is taken that DVM-2 measures the exact same voltage point that the flicker meter uses as its input. For previously calibrated systems undergoing a periodic verification, the measurement of current will generally suffice and the use of DVM-2 is not mandatory.

The purpose of the flicker test system is to evaluate voltage fluctuations that may be caused by the tested equipment when this equipment will be connected to the public electricity supply. The flicker test system may have automatic limit evaluation software or firmware, data storage, additional analysis capabilities, and report generation capabilities that facilitate the process of certifying the tested products according to IEC 61000-3-3 and/or IEC 61000-3-11.

The primary purpose of the test, verification, and calibration protocol in this technical report is to establish methods that may be used to verify that a given flicker test system measures and evaluates common voltage fluctuations in accordance with the standards and thus allows the user to perform a correct pass/fail analysis of the tested product. Additional capabilities, such as the data storage, reporting, or analysis functions of the analyzer or test system may also be tested using some of the tests described in this protocol.

The methodology used in this protocol consists of applying a known load to the flicker test system. This known load is modulated on/off, simulating an electrical product with varying power demand, which in turn causes voltage fluctuations. Thus, not only is the flicker meter tested, but also the power source that has to accommodate the varying power level and the reference impedance or the Z_{test} as specified in IEC 61000-3-3 or IEC 61000-3-11 is tested.

The tests as summarized in Table 2 and Clause 10 may also be used to calibrate or adjust the flicker test system, including adjustments to the test impedance and/or power source. This calibration can be done by means of comparing the generated voltage fluctuations, verified by using external reference equipment if so required, with the values reported by the system. This calibration includes the response of the power source and the impedance that are part of the test system.

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-38: Testing and measurement techniques – Test, verification and calibration protocol for voltage fluctuation and flicker compliance test systems

1 Scope

This part of IEC 61000, which is a Technical Report, defines a test protocol for flicker test systems designed to perform compliance tests in accordance with IEC 61000-3-3 and IEC 61000-3-11. It is intended to provide test system manufacturers and testing laboratories with systematic methods to determine if the flicker test system meets the IEC design specifications for a wide range of voltage fluctuations and fluctuation frequencies, as specified in IEC 61000-4-15:2010, Table 5, that have been observed in product testing.

This protocol is intended to be compatible with related standards, in particular with any requirements set forth by listing organizations or measurement standards of the IEC. Meeting the criteria defined herein should not be construed as a waiver of any other relevant performance or safety requirements.

The main purpose of this technical report is to provide guidance and methods for periodic calibration and verification of systems consisting of previously type tested equipment. For complete flicker test systems that exhibit deviations of less than 5 % from the specifications of this protocol, it can be assumed that individual components are performing properly and separate calibration of individual system components is therefore not necessary.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-161, *International Electrotechnical Vocabulary – Part 161: Electromagnetic compatibility*

IEC TR 60725, *Consideration of reference impedances and public supply network impedances for use in determining the disturbance characteristics of electrical equipment having a rated current ≤ 75 A per phase*

IEC 61000-3-3:2013, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection*

IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤75 A per phase and subject to conditional connection.*

IEC 61000-4-15:2010, *Electromagnetic compatibility (EMC) – Part 4-15: Testing and measurement techniques – Flickermeter – Functional and design specifications*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161 as well as the following apply.

3.1
linear resistive load
load unit that is predominantly resistive in nature, with negligible inductance and capacitance

3.2
load modulation
method to turn the load on and off, usually in a 50 % duty cycle pattern, with a frequency that is controlled, either manually by the user or automatically by the test equipment

4 General

In this technical report, all voltages and currents are stated as r.m.s values unless otherwise described.

Flicker meters in accordance with IEC 61000-4-15 may be used for power quality analysis and surveys covering a very wide range of voltage fluctuations. Flicker test systems, used to verify that a product complies with IEC 61000-3-3 and/or IEC 61000-3-11, have a more limited range of applications. The test class definition for flicker meters used in a compliance test system, is Class- F2 according to IEC 61000-4-15, and a reduced set of tests is applied.

For example, the highest permitted d_{max} according to IEC 61000-3-3 or IEC 61000-3-11 is 7 %. Even with a substantial margin, allowing voltage fluctuations of say 10 %, i.e. more than 40 % above the highest permitted d_{max}, the instantaneous flicker sensation P_{inst} will be limited to no more than 1 600. In addition, a d_{max} level of 10 % would require a power source that is capable of delivering up to 58 A for at least a half cycle if the test is done according to IEC 61000-3-3, and in fact, as much as 92 A if tested according to IEC 61000-3-11.

Higher amplitude voltage fluctuations are therefore extremely unlikely during product testing, and thus tests at these higher levels are not provided for in this protocol as they would impose unnecessary demands and costs upon the system and the test method. Equally, the P_{st} level a product is permitted to exhibit is 1,0, and thus tests exceeding a P_{st} of 4,0 are not necessary for a flicker compliance test system. Similarly, since a product is permitted to have a P_{lt} of at least 0,65, it is not necessary to have extreme resolution or accuracy below a P_{st} of 0,4, although the testing authority may include tests to P_{st} and P_{lt} levels below 0,4 or higher than 4,0 using the methodology described in this protocol.

In general, the procedures and methodologies specified in ISO/IEC 17025 should be followed to verify that the test and verification signals, measurement protocols, external reference equipment and evaluation methods specified in this technical report are produced with sufficient accuracy to meet the stated goal of evaluating the flicker test system.

The test protocol uses rectangular voltage fluctuation patterns in accordance with IEC 61000-4-15:2010, Table 5, possibly augmented – at the user's discretion – by additional tests from IEC 61000-4-15:2010, Table 1 and Table 2, and also employs a non-linear current pattern to evaluate not only the flicker meter, but also the suitability of the power source and the flicker test impedance.

5 Objectives of flicker and voltage fluctuations test protocols

The primary objective of this test protocol is to assure that a flicker test system meets the requirements set forth in this technical report and produces results that lead to correct and reproducible pass/fail evaluations when testing products in accordance with IEC 61000-3-3

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and/or IEC 61000-3-11. Thus, it is intended that various test systems that pass the tests described in this protocol produce similar test results, within specified tolerances, when evaluating the same equipment (unit) under test (EUT or UUT) under identical or near identical environmental and test conditions.

Flicker test systems that are evaluated using this protocol should be obtained with the cooperation of the system owner or the system manufacturer. The testing authority should ensure that only the tests of this protocol are applied and that they correspond to the power and current range for which the system is specified.

6 Manufacturer's or owner's information required

To assist the user in correctly applying the tests in this protocol, the manufacturer or system owner should provide detailed accuracy specifications on the flicker test system in accordance with its intended use. That is, the user should have enough information so that, in its intended environment, the flicker test system will be used within its voltage, current, d_{max}, d_c, P_{inst}, and P_{st} ranges. Essential information should be provided with the flicker test system package. The following list is provided as an example, and may be expanded as required.

a) Manufacturer's name or trademark.
b) Product name and/or model number, serial number, and software or firmware identification.
c) Mains voltage and frequency operating range.
d) Limits for nominal voltage and current input range(s).
e) Limit for voltage variations at the flicker meter input ($\pm x,x$ % d_{max} and d_c).
f) Operating range of output 5 (P_{inst}) of the flicker meter.
g) P_{st} operating range of the flicker meter.
h) Compliance with applicable standards (e.g. IEC 61000-3-3, IEC TR 60725, IEC 61000-3-11, IEC 61000-4-15 and applicable editions).
i) Device specifications and accuracy specification.
j) Installation and usage instructions.
k) Maintenance instructions as appropriate.

7 Performance criteria

IEC 61000-4-15 defines the flicker meter in detail and provides certain accuracy requirements including those shown in Table 1 (reproduced from IEC 61000-4-15:2010, Table 5). It has been shown, however, that different flicker test system implementations– all claiming to meet the accuracies defined in IEC 61000-4-15 – can still disagree significantly in some actual measurements. It has been shown that the AC test source and the reference impedance can substantially affect the measured parameters. Problems with flicker analyzer implementations, and initial differences in interpretation of requirements in standards IEC 61000-3-3 and IEC 61000-3-11 have been found as well, although IEC 61000-4-15 has substantially reduced the interpretation ambiguities. The informative Annex C provides some examples of typical integration problems that have been found using the methods defined in this protocol.

The individual steps of the test protocol in this technical report are intended therefore to provide a set of tests to ensure that the analyzer, AC power source, reference impedance or Z_{test} and overall system implementation are correct and produce the desired results. To characterize individual system components, both DVM-1 and DVM-2 in Figure A.1 are mandatory, and care should be taken that DVM-2 measures the voltage at the exact same point that the flicker meter uses as its input. For complete flicker test systems that exhibit deviations of less than 5 % from the specifications in Clause 10 of this protocol, it can be assumed that individual components are performing properly and separate calibration of individual system components is therefore not necessary. If performance requirements are not

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met during a periodic verification, the use of DVM-2 is necessary in order to isolate and identify the cause of deviations.

The performance criteria can be separated into two main categories, one being the directly measured parameters such as d_c and d_{max} and the other being the correct indication of the P_{st} value and calculation of the P_{lt} value. The first category can be viewed as a system level test, as it will reveal any errors in either the flicker meter, the test impedance, the power source, or the overall system integration.

For test systems with a limited scope of use, only a subset of the tests might be required so as to demonstrate acceptable performance over some specific range of application. For example, if a particular manufacturer's EMC test facility only needs to test to a reduced power level, there is no need to apply current levels that are higher than needed for the user's products.

In some cases, the user may adjust the system impedance, either by changing passive components or by adjusting the programmable impedance. If required, and provided the flicker meter has appropriate adjustments, the accuracy of directly measured parameters – mainly voltage – may be optimized by adjusting the instrument.

A test system meeting the requirements of this TR is recommended for testing in accordance with the requirements of IEC 61000-3-3 and IEC 61000-3-11. Alternatively, this TR may be used to demonstrate that a test system is not recommended for testing in accordance with IEC 61000-3-3 and IEC 61000-3-11.

Table 1 – Calibration points from IEC 61000-4-15:2010, Table 5

Rectangular changes per minute (CPM)	Voltage fluctuation %			
	120 V lamp 50 Hz system	120 V lamp 60 Hz system	230 V lamp 50 Hz system	230 V lamp 60 Hz system
1	3,178	3,181	2,715	2,719
2	2,561	2,564	2,191	2,194
7	1,694	1,694	1,450	1,450
39	1,045	1,040	0,894	0,895
110	0,844	0,844	0,722	0,723
1 620	0,545	0,548	0,407	0,409
4 000	3,426	Test not required	2,343	Test not required
4 800	Test not required	4,837	Test not required	3,263
NOTE 1 620 rectangular changes per minute correspond to a rectangular square wave modulation frequency of 13,5 Hz.				

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Table 2 – Summary of tests to verify/calibrate flicker test systems

IEC 61000-3-3 and IEC 61000-3-11	Test no.	Description of load settings and current	Required result	Comments
Initial system test with a linear load, producing a sinusoidal current at approximately 8 A modulated on/off	1	Linear load of approximately 29 Ω resulting in a current level of 8 A. The reference impedance is in bypass mode, or the source with programmable impedance is set to minimal impedance	< 0,4 P_{st}	This test verifies that the AC source impedance is low enough, so that the source does not contribute more than 0,4 to the P_{st} value, in accordance with IEC 61000-3-3:2013, 6.3
Linear/non-linear current flow, generating current and voltage harmonics that permit the inductance of the test impedance to be determined	2	Approximately 6 A linear load plus approximately 6 A load that is controlled at approximately 90° and 270° to generate harmonics. The reference impedance or source programmable impedance is in flicker mode for this test	Inductance is within tolerance	The inductance is calculated from the impedance at odd harmonics, which in turn is computed from the voltage and current harmonics
IEC 61000-4-15:2010, Table-5, modulation tests of 1 CPM, 2 CPM, 7 CPM or 39 CPM at the user's discretion	3 to 6	Load with controlled modulation frequency producing current levels sufficient to generate voltage fluctuations that result in P_{st} levels between 0,65 and 1,5	P_{st}, P_{lt}, d_c and d_{max} levels proportional to modulation levels	For the low frequency modulation tests, the d_c parameter is verified and the resistive part of the test impedance is verified. The d_c and d_{max} levels, verified with external DVMs, if so required, are indicative of the resistive part of the test impedance
IEC 61000-4-15:2010, Table 5, modulation tests of 110 CPM and higher at the user's discretion	7 to 9	Load with controlled modulation frequency producing current levels sufficient to generate voltage fluctuations that result in P_{st} levels between 0,65 and 1,5	P_{st}, P_{lt}, and d_{max} proportional to modulation levels	For higher modulation rates, the d_c parameter is "0". Higher or lower P_{st} levels may be generated if so required
NOTE All tests in this report are defined for an r.m.s voltage of 230 V ±0,23 V and a frequency of 50 Hz, but can be adjusted to other nominal voltages and frequencies as required.				

8 General test guidelines

8.1 General

This technical report is intended to be used for the verification and calibration of flicker test systems that are obtained with the cooperation of the manufacturer or the user of the test system in order to ensure that the analyzer and system are being tested with the intended use of the device.

To assist the user in correctly applying the analyzer or test system, the testing authority should obtain detailed accuracy specifications for the analyzer or test system in accordance with its intended use. That is, the user or testing authority should have enough information to assure that the analyzer or system is used within its voltage, current, and power range(s) and within the scope of its intended testing capabilities.

8.2 Essential information

Essential information should be marked on the device and supplementary information provided with the analyzer or test system package. The following list is provided as an example of the minimum information requirements.

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a) Manufacturer's name or trademark.

b) Product name and/or model number, and all system components serial numbers.

c) Mains frequency operating range(s).

d) Limits for voltage and current measurement inputs.

e) AC voltage source requirements.

f) AC voltage source output, accuracy and stability specifications.

g) Compliance with applicable standards (e.g. IEC 61000-4-15, IEC 61000-3-3, IEC 61000-3-11).

h) Flicker meter accuracy specifications and measurement range.

i) Reference impedance, and/or Z_{test} specifications.

j) Software and/or firmware version of the flicker meter and power source.

k) Installation and usage instructions.

9 Test equipment and accuracy

Different types of test equipment are required for the individual tests given in this report. The test equipment accuracy should be at least a factor of three better than the accuracy specifications given in the individual performance tests. The responsibility to verify this accuracy rests with the testing authority, but the methods, procedures, and general and management requirements specified in ISO/IEC 17025 should be followed. The recommended performance specifications for external reference equipment, as given in Annex A of this report, provide a margin of at least 5:1 versus the requirements specified in IEC 61000-4-15, IEC 61000-3-3, and IEC 61000-3-11.

In principle, the test patterns can be verified with readily available high accuracy digital voltmeters, current shunts, and digital oscilloscopes or with data acquisition systems with sufficient resolution, accuracy and memory. Annex A provides instructions for selecting appropriate test equipment to verify that the intended test patterns are indeed present.

A suitable method for generating the desired test patterns is provided in Annex B, but the testing authority may use different methods to generate the required voltage fluctuations provided that the chosen method controls a load such that the required current variations are achieved and the method is accompanied by analysis and/or measurements, following the requirements of ISO/IEC 17025, that prove the suitability of the method.

Furthermore, the test patterns described in Clause 10 and in Annex B were defined with the specific intent to verify complete flicker test systems. The test patterns are not necessarily intended for type testing, but they could be used to test specific system functions. For the purpose of verifying just the flicker meter, including type testing, alternative test equipment has already been developed, supported by detailed analysis and verification, and methods have been successfully used. There are various testing methods used by national laboratories worldwide. Such alternative methods are not excluded by this report, but the reader is cautioned that various tests have shown that the AC power source and reference impedance, as well as system integration, can have significant impact on the result for IEC 61000-3-3 and IEC 61000-3-11 testing. Thus, testing just the flicker meter, or individual system components such as the reference impedance, to be compliant with the applicable standards is no guarantee that correct pass/fail evaluations according to IEC 61000-3-3 or IEC 61000-3-11 can be performed when the certified flicker meter and impedance are integrated into a complete system with an untested AC power source.

For the purpose of verifying a complete system, intended for compliance testing in accordance with IEC 61000-3-3 and/or IEC 61000-3-11, the protocol outlined in this report should be followed. The protocol uses a load unit that can be modulated to produce the specified current and loading patterns for the AC power source, as described in Annex B. If the tested flicker meter or complete system has provisions for adjustments, or has software defined adjustment

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routines, a subset of the specified modulation patterns may be used to adjust the analyzer, reference impedance, or system.

The loading patterns are not intended to be an exhaustive test, and it may reasonably be expected that some deviations will be found when comparing systems with different types of power sources. Such differences need to be within the permitted tolerance levels, but – more importantly – should not affect the correct pass/fail decision of the system. The accuracy requirements allowed according to IEC 61000-3-3 and IEC 61000-3-11 provide sufficient tolerances to allow for minor deviations in reference impedance, flicker meter response, and system integration aspects, thereby providing sufficient margin to prevent the deviations from leading to false PASS or false FAIL evaluations by systems tested according to this protocol.

The procedures used in this protocol are based on controlling the current flow through a defined resistive load. It is necessary therefore, to determine the value of the resistive load to within 0,5 % and to make sure that the resistive value does not change by more than 0,5 % from the established nominal value under varying load conditions. Alternatively, the user may employ external reference meters and current shunts to accurately measure the current patterns, in which case the absolute load values are not important, provided the load is sufficiently stable.

10 Detailed test procedures

10.1 Procedures common to all tests

Proceed as follows:

a) connect the flicker meter, AC power source, reference impedance and modulation load unit as shown in Figure B.1;

b) make sure all input power requirements according to the manufacturer’s specifications are met;

c) record the software and firmware versions of all system building blocks;

d) prepare the system according to the manufacturer’s instructions;

e) adjust the flicker meter measurement settings such as the selected test voltage (e.g. 100/120 V, 230 V, 50/60 Hz) and configuration for single or 3-phase tests as required for the specific test system;

f) make sure the system is configured for a 12-period P_{lt} test, if the system allows user defined observation periods;

g) configure the AC power source and test impedance (Z_{ref} or Z_{test}) for the specific test including programming the power source impedance if applicable;

h) configure the modulation load unit to produce the desired current modulation pattern;

i) perform the test and compare the obtained data and pass/fail decision against the expected results as specified in the Tables 1 and 2. If the flicker meter, reference impedance, power source, or test system is adjustable in hardware or software, a selection of the tests may be used to make adjustments needed to optimize system performance. The selected tests used for this purpose shall be included in the report. The adjusted system should meet the performance requirements of this protocol.

j) if the flicker meter or system being verified is suitable for 3-phase testing, the specified tests can be performed for every phase individually. The testing authority may use a single phase load and test each phase consecutively or use a 3-phase load and test all three phases simultaneously. Care should be taken to account for the neutral impedance effects which are different for single vs. 3-phase loads as shown in IEC 61000-3-3:2013, Figure 1.

NOTE The methods in this protocol can be applied at different nominal voltages. For example, the user can apply all tests at nominal 220 V. Therefore the nominal test voltage in items b) in of 10.2.2, 10.3.2, 10.4.2 and 10.5.2 can be replaced by a different voltage ±0,1 %.

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10.2 Test no. 1 – Simple power source qualification test

10.2.1 Rationale

This test is to verify that the power source meets the requirements of IEC 61000-3-3, which states that the power source may not contribute more than 0,4 to the measured P_{st} value. For this verification, an 8 A load is modulated on/off at the rate of 7 changes per minute (CPM) (0,0583 Hz) or at 39 CPM (0,325 Hz square wave modulation). The 8 A is the mid-point of the IEC 61000-3-3 test range, and the 39 CPM is sufficiently demanding on the power source control stability. Alternatively, the testing authority may modulate the load to be varying between different current levels, such as between 2,7 A and 10,8 A as shown in Figure 1. In either case, the power source should not contribute more than a P_{st} of 0,4.

This test may also be modified slightly and used as a simple overall system test. By using the test impedance, i.e. setting it to the nominal value as opposed to the minimal or by-pass mode specified in 10.2.2c) below, the generated d_c level can be verified to be within the permitted tolerance. The dynamic response of the power source may not be ideal, but this may not affect the observed d_c level. Using the test impedance will at least give a first order verification of the resistive part of the reference or test impedance and will verify general functionality of the measurement instrument.

For larger test systems, this test may also be run at much higher currents, such as for IEC 61000-3-11 applications.

10.2.2 Test procedure

Proceed as follows:

a) follow the common procedures specified in 10.1;

b) configure the AC power source for the nominal voltage, e.g. 230 V ± 0,23 V, 50 Hz;

c) set the test impedance (Z_{ref} or Z_{test}, or the source programmable impedance) to minimal;

d) use a suitable programmable load, or the modulation load unit illustrated in Annex B, to create a rectangular current modulation pattern similar to the illustration in Figure 1.

e) verify that the measured P_{st} value is < 0,4.

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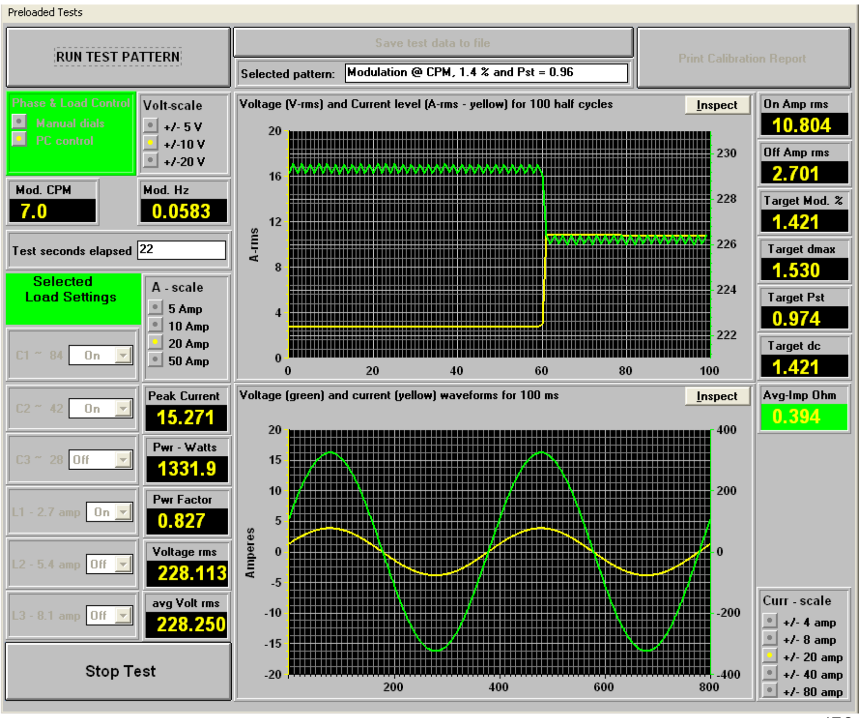

Figure 1 – Illustration showing a rectangular 8 A current modulation pattern at 7 CPM

10.3 Test no. 2 – Verification of the Z_{ref} and/or Z_{test} impedance

10.3.1 Rationale

This test is to verify that the test impedance (Z_{ref}, Z_{test} or the programmable impedance of the power source) has the desired inductance.

10.3.2 Test procedure

Proceed as follows:

a) follow the steps given in 10.1;

b) configure the AC power source for the nominal voltage, e.g. 230 V ± 0,23 V, 50 Hz;

c) use either a suitable programmable load or the modulation load unit illustrated in Annex B to create a waveform as shown in Figure 2, with linear load, and a phase controlled load which is capable of generating current harmonics which in turn produce voltage harmonics due to the reference impedance;

d) verify that the Z_{ref}, Z_{test}, or programmable impedance of the power source has the required characteristics. The illustration in Figure 2 gives an example. There is no normative impedance requirement in IEC 61000-3-3 other than at 50 Hz; the corresponding value for the inductive part of Z_{ref} and Z_{test} impedances is 796 µH. For the purpose of this protocol, a tolerance in inductance of ±10 % is recommended;

e) alternatively, the complex values of Z_{ref} or Z_{test} may be determined individually by appropriate methods.

NOTE Some power sources with a programmable impedance might not have a linear frequency response up to 2 kHz. Provided the response is linear to at least 100 Hz, the effect on flicker measurement is insignificant.

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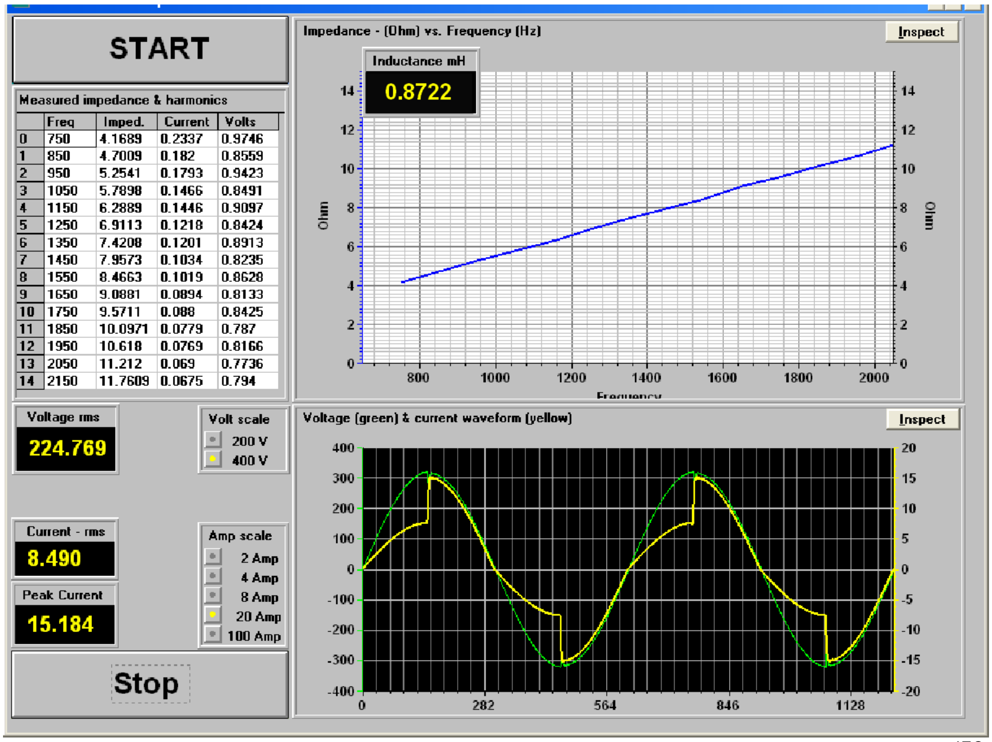

IEC

Figure 2 – Illustration showing the method to determine the inductance of Z_{ref} or Z_{test}

The angle where the current is turned on does not have to be exactly 90° but should be within ±10°. Linear and phase controlled loads, both having a resistance of 40 Ω to 43 Ω, yield 8,5 A to 9,1 A total current. The analysis of voltage and current can be performed with a harmonic analyzer meeting IEC 61000-4-7 (±5 % accuracy), or an oscilloscope with FFT capability and similar accuracy.

With a +10 % deviation in inductance, the total impedance becomes 0,485 Ω instead of the ideal 0,472 Ω, i.e. a deviation in overall impedance of 2,8 %. This 2,8 % has in fact virtually no effect on the current modulation that is produced with a resistive load. When testing low power factor equipment, however, the effect of deviations in the inductance value can be higher.

10.4 Tests no. 3 to 6 – Low frequency rectangular modulation rates of 1 CPM to 39 CPM

10.4.1 Rationale

These tests verify that the flicker measurement system evaluates the directly measured parameters d_c and d_{max} correctly, as well as the P_{st} for these low frequency modulation rates. The correct evaluation of d_c and d_{max} is indicative of the Z_{ref} and/or Z_{test} impedances having the correct resistive values and the correct operation of the overall system. If d_c and d_{max} deviate, P_{st} most likely deviates accordingly. Other modulation rates, not specified in IEC 61000-4-15:2010, Table 5, may be used for testing as well. For example, the 3,166 7 Hz modulation for a modulation percentage of 0,473 % is illustrated in Figure 3.

Several of the low frequency modulation rates such as 7 CPM and 39 CPM can also be used for a simple system check. The d_c value should be in accordance with the applied current modulation level. If the d_c value deviates by more than the permitted 8 %, further system testing is not justified until the reason for the discrepancy has been found and corrected.

10.4.2 Test procedure

Proceed as follows:

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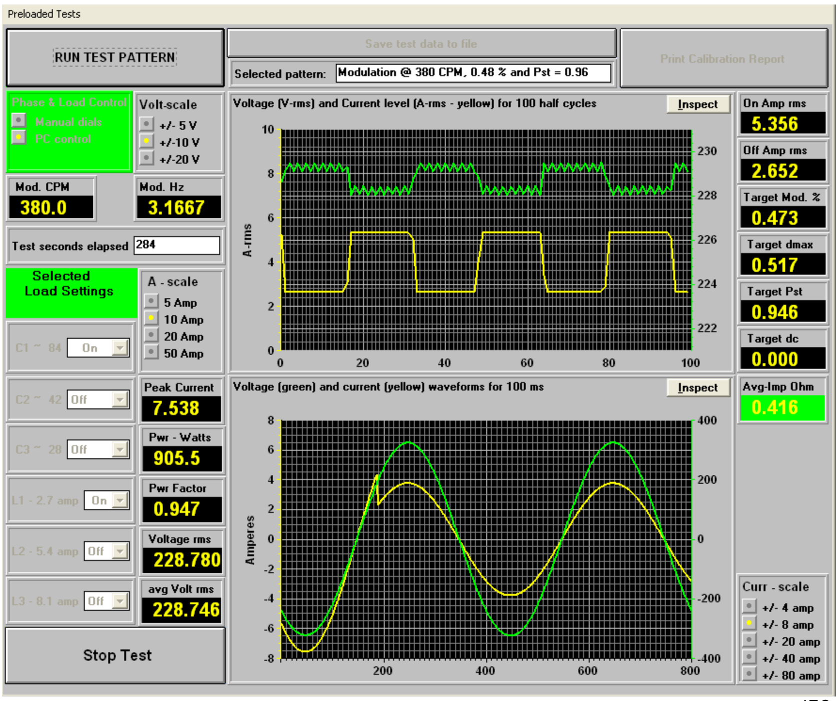
a) follow the common procedure steps in 10.1;

b) configure the AC power source for 230 V ± 0,23 V, 50 Hz;

c) configure the Z_{ref} or Z_{test} impedance, or set the source programmable impedance, to the required value;

d) use either a suitable programmable load or the modulation load unit illustrated in Annex B to create a current modulation pattern with the current and timing characteristics as given in Figure 3. If the current levels are higher or lower than the nominal values given in Table 2, adjust the target P_{st} values accordingly. It is strongly recommended to use a load pattern that results in a target P_{st} of at least 0,65 and no more than 1,5. Additional tests for higher P_{st} values may be made in addition to the test in the range from 0,65 to 1,5;

e) verify that the observed d_c, d_{max}, and P_{st} values for each of the four tests are within the required tolerances. The permitted tolerance according to IEC 61000-3-3 for each parameter is ±8 % of the target value.



IEC

Figure 3 – Illustration showing a rectangular modulation pattern at 3,166 7 Hz

10.5 Tests no. 7 to 9 – High frequency rectangular modulation rates of 110 CPM and up

10.5.1 Rationale

These tests verify that the Flicker measurement system evaluates the P_{st} measurement accuracy for the modulation rates of 110 CPM, 1 620 CPM, or 4 000 CPM (110 CPM, 1 620 CPM or 4 800 CPM for 60 Hz systems). The correct evaluation of d_c will yield a reading of “0” and d_{max} should be equal to the selected modulation level.

10.5.2 Test procedure

Proceed as follows:

a) follow the common procedure steps in 10.1;

b) configure the AC power source for 230 V ± 0,23 V 50 Hz;

c) configure the Z_{ref} or Z_{test} impedance, or set the source programmable impedance, to the required value;

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d) use either a suitable programmable load, or the modulation load unit illustrated in Annex B to create a current modulation pattern with the current and timing characteristics as given in Figure 4. If the current levels are higher or lower than the values given in Table 2, adjust the target P_{st} values accordingly. It is strongly recommended to use a load pattern that results in a target P_{st} close to 1,00, but at least 0,65 and no more than 1,5. Additional tests for higher or lower P_{st} values, such as illustrated in Figure 4, may be made in addition to the test in the range from 0,65 to 1,5;

e) verify that the observed d_c, d_{max}, and P_{st} values for each of the four tests are within the required tolerances. The permitted tolerance according to IEC 61000-3-3 for each parameter is ±8 % of the target value.

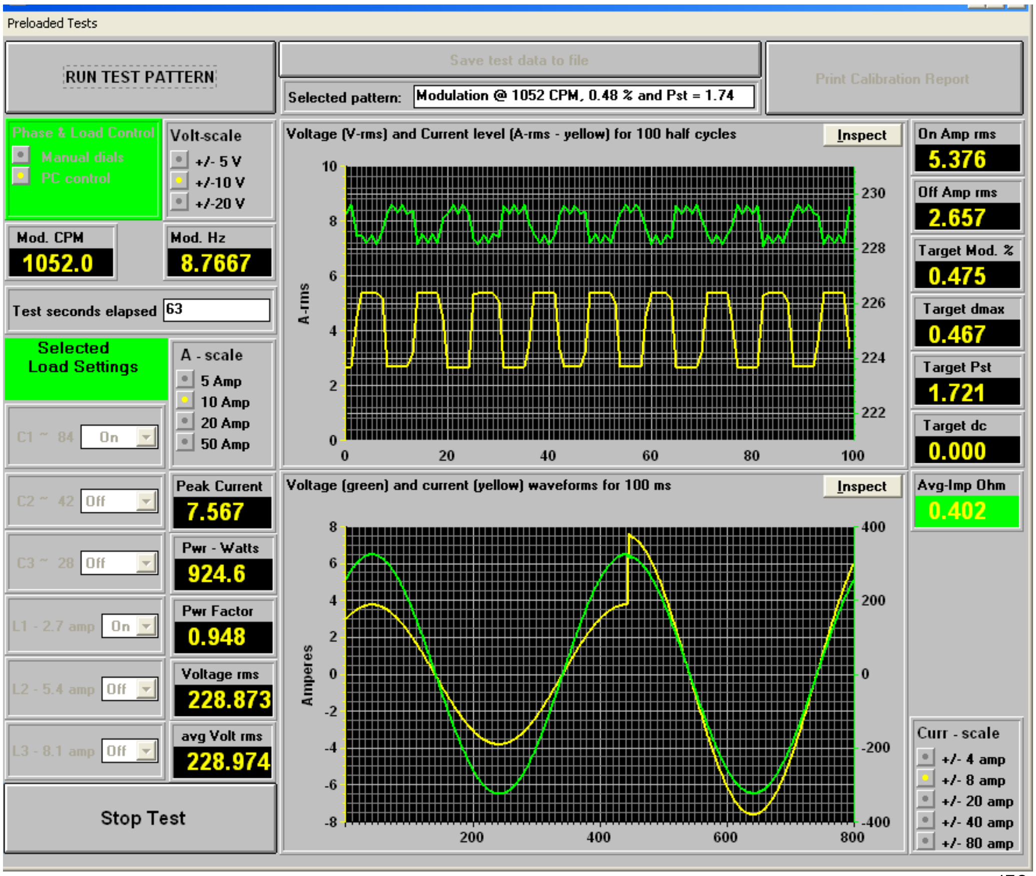

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Figure 4 – Illustration showing a rectangular modulation pattern at 1 052 CPM

10.5.3 Uncertainties of this protocol, and methods to verify modulation accuracy

The test uncertainties when using this protocol, largely depend on the current measurement accuracy. Most square wave generators, used to produce the modulation frequency, have accuracies that go far beyond the ±0,5 % specified in IEC 61000-4-15. Equally, the duty cycle accuracy of square wave generators is much better than the ±2 % specified for the modulation pattern in IEC 61000-4-15:2010, Table 5.

Consequently, the accuracy of the patterns specified in this protocol are mainly determined by the produced voltage fluctuations. These fluctuations are determined by the applied current level, in conjunction with the reference impedance. For low frequency modulations, up to at least the 39 CPM (0,325 Hz) point, the voltage can be measured either directly by DVM-2 in Figure B.1, or by measuring the current level, using DVM-1, and calculating the “ideal” voltage modulation that the measured current should produce. Generally, the current measurement is the easier method, as the calculation involves substantial current changes, versus the relatively small voltage changes that result from these current changes. For example, a current step

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through a resistive load from “0” A r.m.s. to 8,0 A r.m.s. would ideally cause a voltage change from nominal 230,00 V to 226,80 V or a 1,39 % change.

So, for the lower modulation rates, one can observe both DVMs and verify that the measured current produces the expected voltage change. In fact, the resistive part of the reference impedance plus source and system wiring/integration, can be directly computed from the measured voltage change and the observed current level.

The values of the resistors in the load unit are subject to temperature variations, but if the load unit is operated for the duration required to obtain stable conditions, the load changes are automatically taken into consideration with the DVM-1 and DVM-2 measurements.

The modulation frequency and duty cycle can easily be measured to within the requirements in Annex A with a modern digital oscilloscope or a standard counter.

Given the required uncertainties for external measurement equipment in Annex A, one can conclude that the following worst case uncertainties apply:

a) Calculated ideal “DC” and expected P_{st} value: ±0,2 % based on current reading of DVM-2.

b) Calculation of the resistive part of the total impedance up to DVM-2: ±0,3 %.

These uncertainties are a very small fraction of the permitted tolerances in IEC 61000-4-15 and IEC 61000-3-3.

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Annex A
(normative)

Requirements for external test equipment to verify modulation accuracy

The following requirements should be met:

a) digital voltmeter (DVM) accuracy for frequency range ≤ 50 Hz to ≥ 500 Hz;

b) r.m.s voltage for 100 V to 250 V ± 0,1 % of reading;

c) r.m.s voltage for 0,1 V to 1 V ± 0,1 % of reading ±0,1 mV;

d) direct r.m.s. current measurement < 1 A ± 0,1 % of reading ±0,3 mA;

e) direct r.m.s. current measurement < 10 A ± 0,1 % of reading ±1 mA;

f) current shunt accuracy ±0,1 % from 50 Hz to 2400 Hz;

g) recommended shunt values;

h) ≤ 100 mΩ for current ≤ 2,5 A;

i) 10 mΩ for current ≤ 8 A;

j) 5 mΩ for current ≤ 16 A;

k) 1 mΩ for current from 16 A to 75 A;

l) frequency measurement ±0,1 %;

m) duty cycle measurement ±0,5 %.

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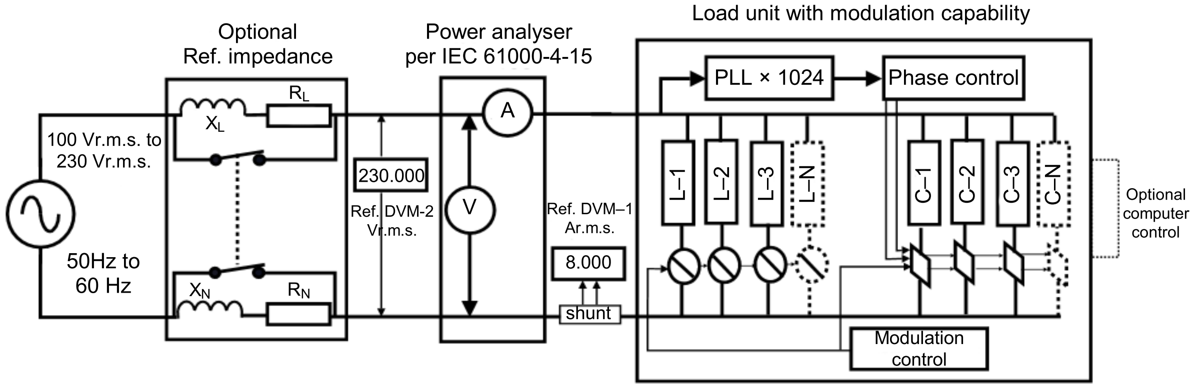
Annex B
(informative)

Example test setup for modulation load unit



Example flicker test setup – Functional diagram IEC

Key

A ampere

V volt

Figure B.1 – Typical test setup for tests 1 to 9

A typical compliance test system setup is shown in Figure B.1. Most compliance test systems are suitable for both harmonics and flicker testing. For IEC 61000-3-3, the IEC TR 60725 reference impedance is used, while for IEC 61000-3-11, the Z_{test} values are specified. The reference impedance is shown in bypass mode in Figure B.1.

Some systems utilize a power source with programmable impedance which synthesizes the resistive and inductive part of the required Z_{ref} or Z_{test}. Most 3-phase systems utilize an actual impedance box, as the neutral impedance is required according to IEC 61000-3-3 or IEC 61000-3-11, and it is exceedingly difficult to emulate the neutral impedance with active semiconductor elements.

The load unit can be implemented with a series of linear loads and a set of phase controlled loads. The phase controlled loads can be turned on/off at user defined phase angles, such as illustrated for the inductance test.

DVM-1 measures the current in conjunction with the shunt, while DVM-2 measures the applied voltage at the point where the flicker meter is connected. If deviations from expected values are found, DVM-2 may be used to verify the voltages at the flicker meter input and thus determine whether the deviations are caused by the power source and/or reference impedance inaccuracies, or by inaccuracies in the flicker meter. Measuring the voltage with this DVM-2, at low frequency modulation rates, also permits the user to verify the resistive part of the impedance.

The loads used in the above example are resistive, with minimal parasitic inductance or capacitance, although this is not very critical provided the phase shift between current and voltage is less than 5°. The resistors should be stable to within ±0,5 % under modulation conditions. Letting the system warm up for a few minutes with the selected modulation pattern should assure sufficient stability. The voltage generated across the shunt and measured by DVM-1 may also be used to verify that the modulation rate and duty cycle of the modulation are in accordance with the expected patterns.

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Annex C
(informative)

Some typical flicker test system integration issues to avoid

Annex C lists several of the more common issues found when an individual user either integrates a flicker test system with instruments from various suppliers or makes site specific wiring arrangements. All the examples were encountered and easily identified by applying the load patterns described in this technical report.

The first example (see Figure C.1) includes a nearly perfect power source, a perfect single phase reference impedance with the exact Z_{ref} values from IEC TR 60725, and yet produced measurement errors in the order of 10 % to 12 %. When the interconnect impedance and the (very low) output impedance of the source are added to the value of the reference impedance, the total impedance is 10 % to 12 % too high.

Some power sources have “external sense” capability, and if the user were to connect these as shown, this effectively bypasses the reference impedance similar to using the bypass switch as is done for harmonics analysis. Obviously, the flicker readings would be very low, only a very small fraction of the real values.

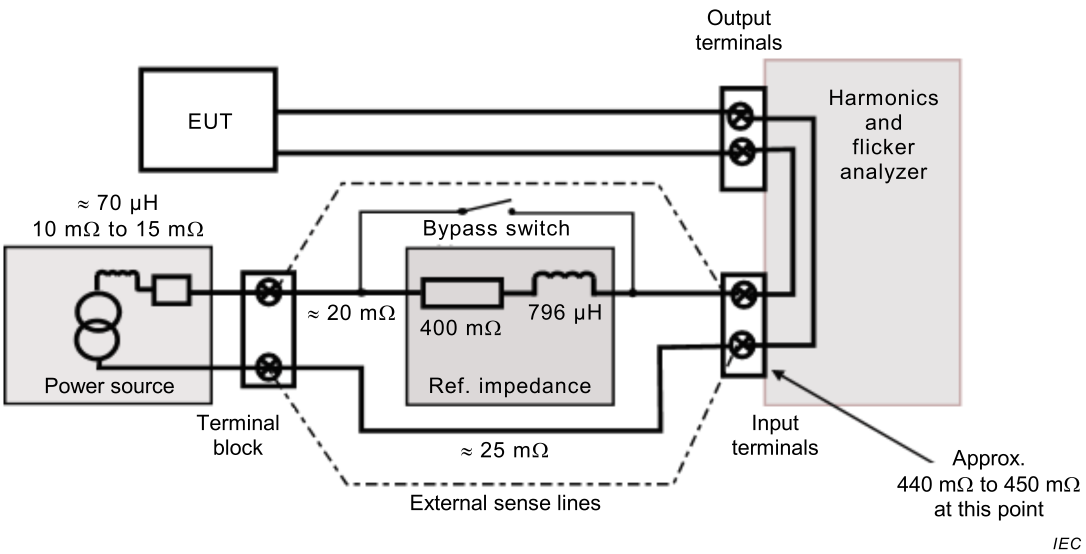

Figure C.1 – Single phase arrangement with excessive or near “zero” impedance

There are several integrated harmonics and flicker measurement systems that have a built-in reference impedance. For simplicity, the impedance is shown as a single phase arrangement, even though some systems may actually have the line and neutral values implemented separately. In those arrangements, the power source output is wired to the input terminals of the harmonics and flicker analyzer similarly to what is shown in Figure C.2.

It is not uncommon to see these systems without the external sense lines installed. In those cases, the flicker meter “sees” as much as 465 mΩ at its output terminals, and thus will have flicker readings that are grossly overstated. Note, however, that even with the external sense lines installed, there can still be an output impedance of 10 mΩ to 15 mΩ from the power source, i.e. there is still an error of 2 % to 4 % in the voltage fluctuations that the flicker meter “sees.”

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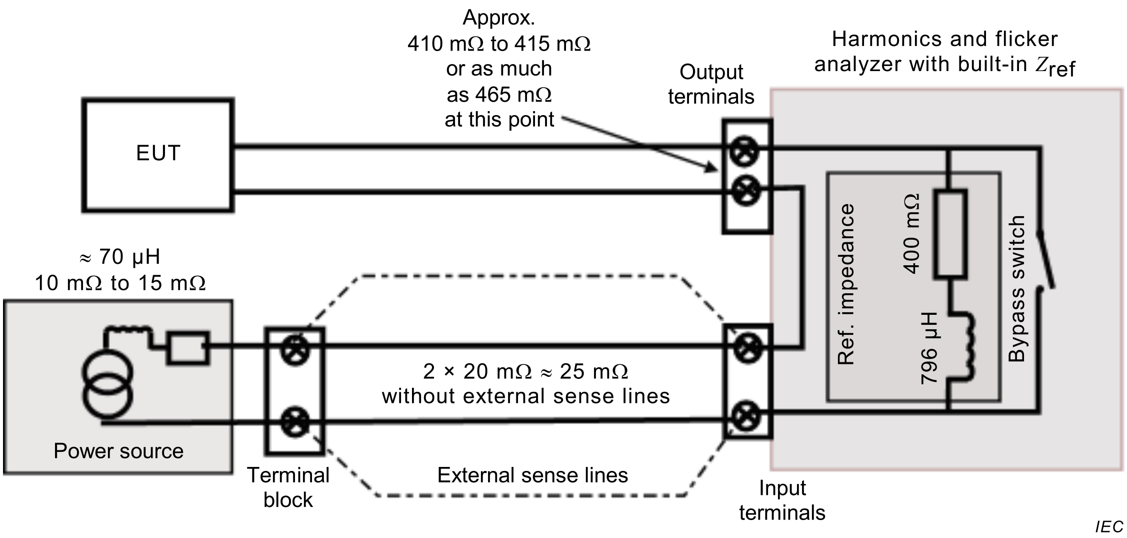

Figure C.2 – Single phase arrangement with sense lines present

Another common mistake that has been observed is where the user gets a power source and matched impedance from one supplier and a stand-alone power analyzer/flicker meter from another supplier. The user connects the flicker meter via good size wiring to the output connectors of the reference impedance and connects the EUT at the analyzer input. This arrangement easily adds 100 mΩ to the impedance "seen" by the flicker meter, and thus results in readings that are 25 % too high.

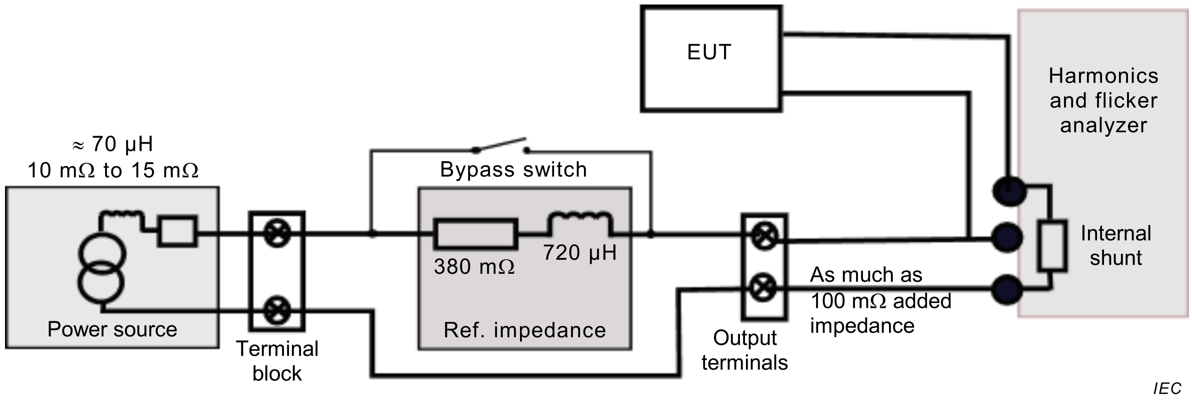

Figure C.3 – Single phase arrangement with connecting lines to power analyzer

It will be obvious that if we replace the EUT by a very well defined load that produces a precisely measured current level, the user can determine what the flicker meter should read.

A somewhat more complicated problem is presented in Figure C.4. This example actually concerns a system that had been calibrated successfully in previous years. It is a bigger system with a 45 kVA 3-phase power source and a 3-phase impedance, plus a 3-phase measurement system in an adjacent 19 inch rack. In the illustration for Figure C.4, only a single phase of the 3-phase system is shown for simplicity.

The system owner had several new bus-bars installed to distribute power to other locations in the laboratory. The electrical contractor followed good practices and installed a heavy duty connection from neutral to ground at the power source, as well as grounding the neutral in the measurement cabinet where the flicker meter is located. The net effect was that the neutral part of the Z_{ref} (as well as the Z_{test}) impedance was bypassed with a very low impedance line. Thus, all the single phase flicker readings were about 40 % too low, while the 3-phase arrangement was fine. These types of configuration errors can only be identified with a real

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load being connected to the system, just like an EUT presents a real load. Shortly after this case was encountered in the USA, a similar case was found in Asia.

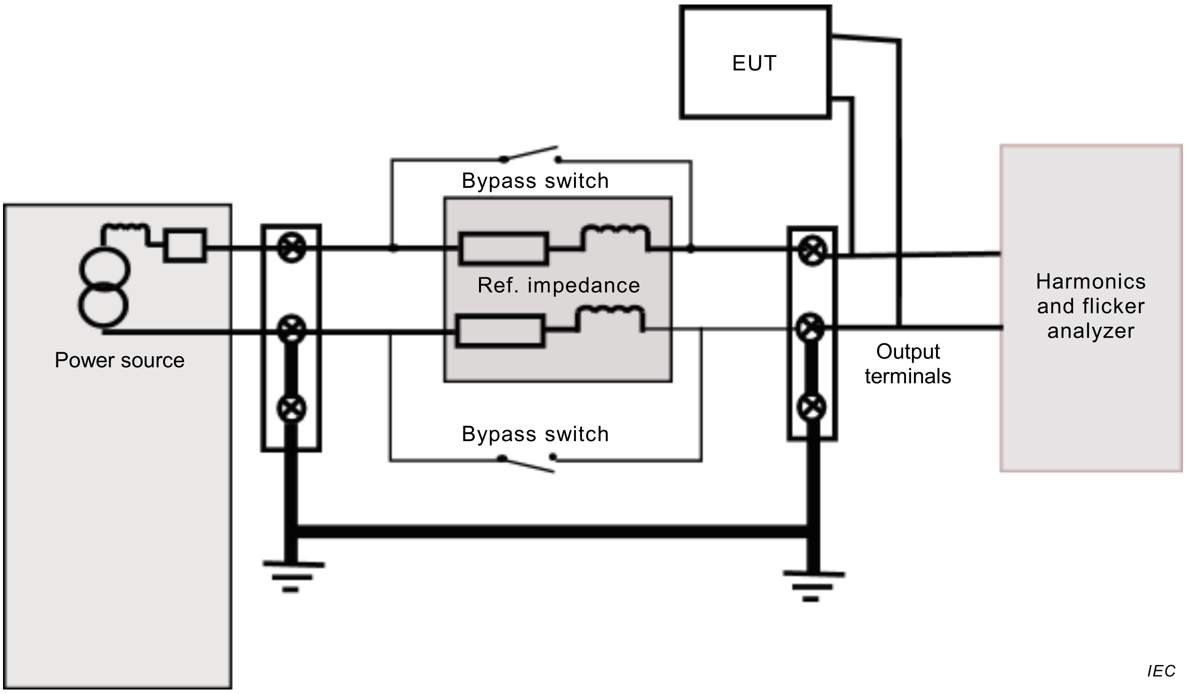

Figure C.4 – Neutral impedance bypassed externally

In all cases, the application of a real load with defined d_c, P_{st}, and d_{max} characteristics allowed these issues to be recognized and corrected. In particular, the case illustrated in Figure C.4 could not have been found otherwise. When one wants to measure the reference impedance or Z_{test}, it is common practice to remove all input/output wiring and then measure the impedance. This would obviously “mask” the neutral bypass connection. Similarly, with the case presented in Figure C.2 and Figure C.3 , the individual system components would likely check out fine, but the completed system would still have issues. Thus, the application of a real load as presented in this technical report permits the complete system verification and calibration.

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IEC 61000-4-7, *Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

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ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch

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