Electromagnetic Compatibility – IEC61000-3-3:2013
A Technical Guide to Flicker Measurement

This technical article will discuss the Electromagnetic Compatibility (EMC) IEC61000-3-3:2013 testing standard, including relevant extracts from IEC61000-4-15(instrumentation oriented standard) and explanations relating to analysis of voltage fluctuations and flicker on public low voltage supply systems. We will also describe how N4L ensure full compliance to the standard, including our Harmonics and Flicker Analyzer (PPA5511/PPA5531), AC Power Source and Impedance Network (Z_{ref})

What is Flicker?

The formal definition of flicker is the "impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time" (IEC 60050-161, 1990)

Flicker can be considered as a symptom, resulting from the modulation of a load and its effect on its own terminal voltage. Whilst connected to a voltage source with finite impedance, any load modulation will cause voltage fluctuations on the supply line.

IEC61000-3-3:2013 is primarily concerned with the limitation of such fluctuations and subsequent flicker upon public low-voltage systems. IEC61000-3-3:2013 specifies the limits of voltage changes produced by electrical and electronic equipment when tested under these specified conditions.

IEC61000-3-3:2013

IEC61000-3-2:2013 is applicable to electrical and electronic equipment with an input current rating equal to or less than 16A per phase. Should a device fail the limits specified in IEC61000-3-3:2013 tested with the specified source impedance specified in section 6.4 (Z_{ref}), it may be retested to show conformity with IEC61000-3-11 (discussed in a separate article). Part 3-11 is applicable to all equipment with rated input ≤75A per phase and is subject to conditional connections.

What is Z_{ref}?

Z_{ref} is the internationally agreed reference source impedance for low-voltage supply networks, as illustrated in the diagram below.
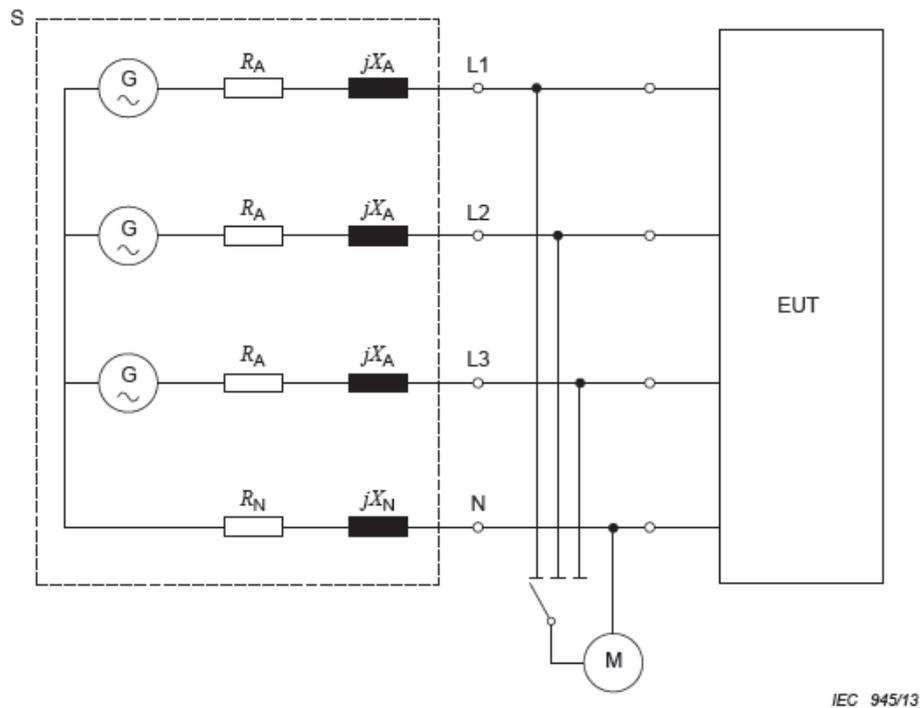
Figure 1. (IEC61000-3-3:2013,2013)

Key:

G – Voltage Source

EUT – Equipment Under Test

M – Measuring Equipment

S – Supply Source including reference impedance and voltage generator output impedance

R_A = 0.24Ω jX_A = 0.15Ω @ 50Hz

R_N = 0.16Ω jX_N = 0.10Ω @ 50Hz

Note: The reference impedance within the source (S) block includes both the output impedance of the AC Source (G) and the reference impedance network (R_A, jX_A, R_N, jX_N)

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Test Equipment Requirements

In real world compliant flicker testing, Z_{ref} is a physical impedance network consisting of a resistive element and an inductive element that is placed in between the AC Power Source and the equipment under test. N4L can provide the entire test system including Programmable AC Power source, Impedance Network and Flicker (+Harmonics +Power) Analyzer. We will discuss the different elements of the test system below;

1. **Programmable AC Power Source** - Section 6.3 of IEC61000-3-3:2013 describes the requirements for the AC Power Source for compliant Flicker Testing; this can be summarized in the table below.

IEC61000-3-3:2013 Test Supply Voltage (AC Power Source) Requirements	
Requirement	N4L N4Axx Programmable AC Power Source Performance
Open Circuit Voltage shall be the rated voltage of the equipment	0-300Vrms Single Phase, 520Vrms Three Phase
Test Voltage Maintained within ±2% of the nominal value	±0.1%
Frequency Stability ±0.25Hz	±0.01Hz
THD < 3%	Better than 0.3%

Table 1.

2. **Z_{ref} - Reference Source Impedance** - Section 6.4 of IEC61000-3-3:2013 describes the requirements for Z_{ref}

IEC61000-3-3:2013 refers to IEC/TR 60725 which specifies the in-phase and quadrature component of the reference impedance Zref. It is important to note that Z_{ref} includes the impedance of the reference network and the output impedance of the AC source, the output impedance of the N4A series AC Power Sources is very low and can be considered negligible for this application.

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3. **Flicker Analyzer** - Section 4.2.2 of IEC61000-3-3:2013 refers the reader to IEC61000-4-15:2010 which lays out the specification and signal processing requirements for compliant flicker measurements. All N4L PPA5511 and N4L PPA5531 Harmonics and Flicker Analyzers offer full compliance to IEC61000-4-15. Furthermore, N4L are able to offer IEC61000 Harmonics and Flicker calibration to ISO17025 from our in house UKAS Laboratory.

Voltage Change Characteristics

Commonly known as "d" values, voltage change characteristics constitute three separate parameters – $d_{(t)}$, d_c, d_{max} and T_{max}.

- $d_{(t)}$ – Time function of the relative rms half period voltage change for each half period between zero-crossings of the voltage source, expected during steady state voltage conditions.
- d_c – Maximum steady state voltage change during an observation period
- d_{max} – Maximum absolute voltage change during observation period
- T_{max} – Maximum time that the half period rms voltage exceeds the limit for dc. During a voltage change event the T_{max} value is accumulated until a new steady state condition is established.

P_{st}

P_{st}, or "short term flicker severity" is the calculated short term flicker as per IEC61000-4-15, unless otherwise specified the P_{st} evaluation period is 10 minutes.

P_{lt}

Long term flicker sensitivity (perceptibility long term) is calculated as follows;

$$P_{lt} = \sqrt[3]{\frac{\left(\sum_{i=1}^{N} P_{st}^3, i\right)}{N}}$$

Where P_{st}, i (i = 1,2,3…) are consecutive readings of short term flicker severity P_{st}

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Conditional Connection

Should the device under test fail the limits specified in IEC61000-3-3 when tested with Z_{ref}, it is permitted for a manufacturer to specify that the equipment must be connected to a supply interface point which exhibits an impedance lower than that of Z_{ref} (the terminal/socket at which the device will be connected to the mains supply). This does make sense as basic electronic theory teaches us that voltage drop across any impedance (whether it is real or complex) is proportional to that impedance. If the source impedance at the connection point of the supply is lower (for the same load modulation) you will experience lower voltage fluctuations at the connection point, thus lower flicker readings.

Assessment of Flicker

Assessment of relative Voltage change:

The basis of flicker measurement centers around the voltage change characteristics when measured at the terminals of the equipment under test. N4L use the "Flickermeter" method for assessment of P_{st}. Other methods exist and are specified in section 4.2.1 of IEC61000-3-3, these methods are however accompanied by caveats such as that the nominal voltage ($U_{(t)}$) must be known to use the simulation method.

It can be considered as the difference between the line and neutral U_{hp} values, remembering that U_{hp} is the half period RMS value between consecutive zero crossings.

If:

$U_{hp}(t1)$ is the half period Vrms at time = t1

$U_{hp}(t2)$ is the half period Vrms at time = t2

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Then:

$$\Delta U_{hp}(t) = U_{hp}(t1) - U_{hp}(t2)$$

This voltage change at the equipment under test's terminals (or the difference between $U_{hp}(t1)$ and $U_{hp}(t2)$), is a result of a change in voltage drop across the complex reference impedance (Z_{ref}) caused by a chang in the complex fundamental current IEC61000-3-3 describes the complex current as;

ΔI_p = Active current change

ΔI_q = Reactive current change

If the equipment under test exhibits an inductive load to the generating equipment, for single phase and symmetrical three phase equipment the voltage change can be approximated to;

$$\Delta U_{hp} = | \Delta I_p R + \Delta I_q X |$$

Where ΔI_p and ΔI_q are the in phase and quadrature parts of the current change respectively. R and X are the in-phase and quadrature elements of the complex impedance.

Relative Voltage Change

Relative voltage change is given by the following formula;

$$d = \Delta U_{hp}/U_n$$

As we have already stated, d_{max} is the maximum absolute voltage change, therefore the $d_{max,i}$ evaluation ends as soon as a new steady state voltage condition is established. Alternatively the evaluation of $d_{max,i}$ will end when the measurement period finishes.

Positive $d_{max,i}$ is recorded when the maximum voltage change is a result of a reduction in voltage since the previous $d_{end,i}$

Negative $d_{max,i}$ is recorded when the maximum voltage change is a result of an increase in voltage $d_{end,i}$

Using the P_{st} = 1 Curve

The P_{st} = 1 curve is a well known concept, it is however rarely understood. The graph below (taken from IEC61000-3-3:2013) illustrates the overall concept, we must remember that if the performance of the equipment under tests lies under the P_{st} = 1 curve then the disturbance to the supply network is deemed to be acceptable in the short term (we will distinguish between short term and long term later in this article).
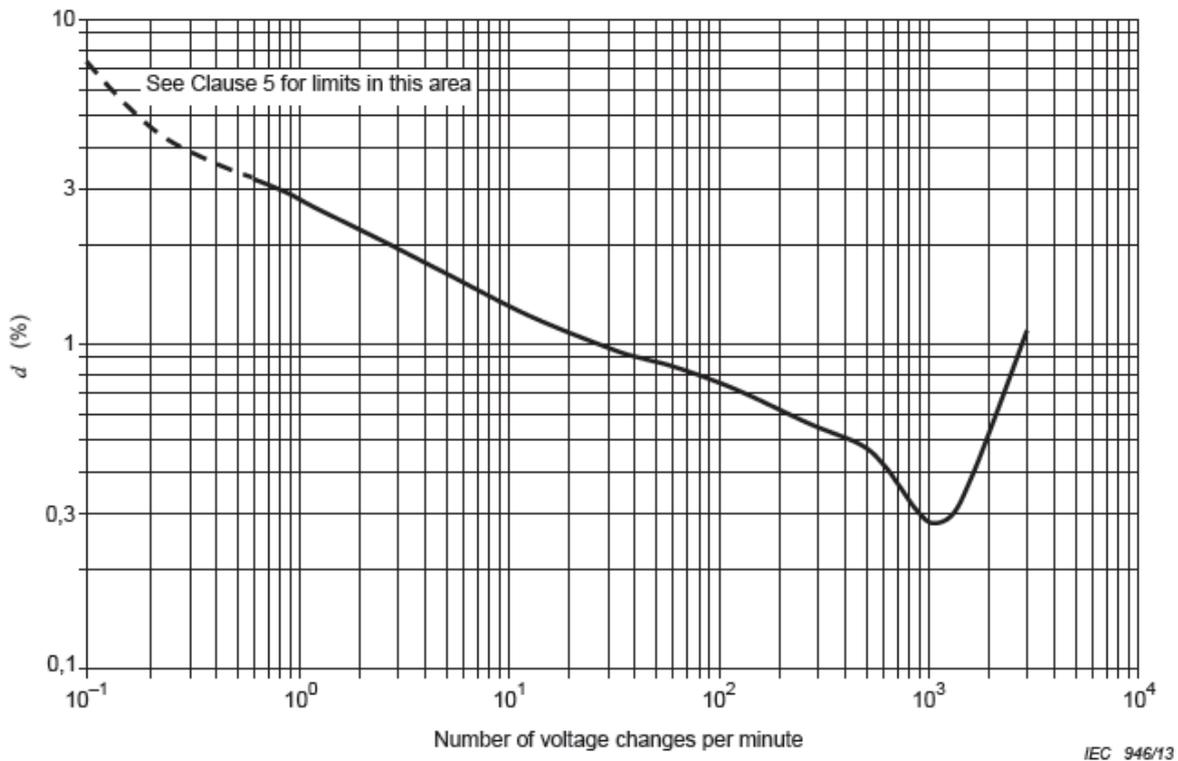

Figure 2. (IEC 61000-3-3:2013,2013)

If we analyze various working points on the P_{st} = 1 curve it is possible to determine the relative voltage change (d value) and the number of voltage changes per minute at that perturbation level.

Example:

For a 230V system a relative voltage change of 1% resulting in a Pst of 1 would require 25 voltage changes per minute. Figure 3 below is annotated at the 1% voltage change point and we can follow the graph across to the intersecting value on the y-axis at approximately 25 voltage changes per minute.
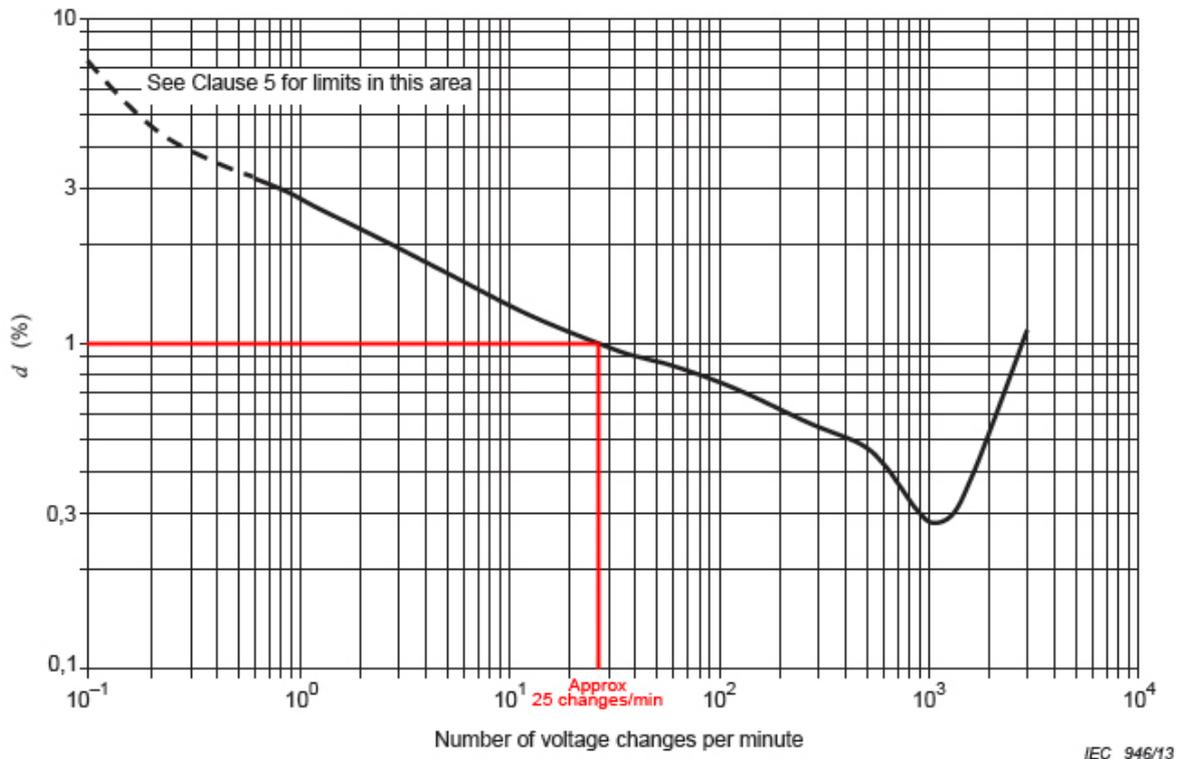

Figure 3. (IEC 61000-3-3:2013,2013)

We can state that for a voltage change of 1% at a frequency of 25 changes per minute, we would achieve a P_{st} equal to 1.

If we cross refer to table D1, found in Annex D of IEC61000-3-3 we discover that the findings above correlate to the test protocol table.

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Annex D
(informative)

Input relative voltage fluctuation ΔV/V for P_{st} = 1,0 at output
[IEC/TR 61000-3-7:2008]

Table D.1 – Input relative voltage fluctuation ΔV/V for P_{st} = 1,0 at output

Fluctuation rate (r) changes/min	Voltage fluctuation %		Fluctuation rate (r) changes/min	Voltage fluctuation %	
	120 V lamp 60 Hz system	230 V lamp 50 Hz System		120 V lamp 60 Hz system	230 V lamp 50 Hz system
0,1	8,202	7,4	176	0,739	0,64
0,2	5,232	4,58	273	0,65	0,56
0,4	4,062	3,54	375	0,594	0,5
0,6	3,645	3,2	480	0,559	0,48
1	3,166	2,724	585	0,501	0,42
2	2,568	2,211	682	0,445	0,37
3	2,25	1,95	796	0,393	0,32
5	1,899	1,64	1 020	0,35	0,28
7	1,695	1,459	1 055	0,351	0,28
10	1,499	1,29	1 200	0,371	0,29
22	1,186	1,02	1 390	0,438	0,34
39	1,044	0,906	1 620	0,547	0,402
48	1	0,87	2 400	1,051	0,77
68	0,939	0,81	2 875	1,498	1,04
110	0,841	0,725			

NOTE 1   Two consecutive voltage changes (one positive and one negative) constitute one "cycle", i.e. two voltage changes per second correspond to a 1 Hz fluctuation.

NOTE 2   These curves are based on 60 W incandescent lighting. While other lighting equipment can give different results, these curves are adopted as reference to allow consistent evaluations across a wide variety of situations.

NOTE 3   Different versions of this table exist in the literature with very minor differences.

Assessment of P_{lt} (Long term flicker)

Long term flicker P_{lt} shall be calculated with a value of N = 12 (see formula below)

$$P_{lt} = \sqrt[3]{\frac{(\sum_{i=1}^{N} P_{st}^{3}, i)}{N}}$$

The standard states that it is only necessary to assess P_{lt} for devices that are to be operated for longer than 30 minutes at a time.

Limits

The limits specified in IEC61000-3-3:2013 are applicable to voltage fluctuations and flicker measured at the supply terminals of the device under test. This is an important point, as any current carrying component with measurable impedance; there will be a voltage drop across it. A current carrying cable connecting the AC Source to the equipment under test is no different and if the Flickermeter is placed at the output terminals it is important to remember that the overall impedance of the test circuit will include the interconnecting cabling. N4L have characterized this additional impedance and supply known value interconnecting cables with our IEC61000 test systems and compensated Z_{ref} networks accordingly.

Voltage Fluctuation and Flicker Limits	
Parameter	Limit
P_{st}	Less than or equal to 1.0
P_{lt}	Less than or equal to 0.65
T_{max}	Accumulated time of d(t) with a deviation exceeding 3.3% during a single voltage change at the equipment under test terminals must not exceed 500ms
d_c	The maximum relative steady state voltage change must not exceed 3.3%
d_{max}	Maximum relative voltage change (between two half periods) shall not exceed: 4% without additional conditions 6% for equipment that is; - switched manually - switched automatically more than twice a day and is also fitted with a delayed restart not less than a few tens of seconds. Alternatively a manual restart after a power supply interruption. 7% for equipment that is; - attended whilst in use - switched on automatically or intended to be switched on automatically no more than twice per day. Must also be fitted with a delayed restart of not less than a few tens of seconds (or manual restart) after a power supply interruption.

P_{st} and P_{lt} limits need not be applied to voltage changes caused by manual switching.

Nor do the limits need to be applied to voltage changes associated with emergency switching or emergency conditions, this is sensible as such occurrences will be very rare.

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Test Conditions

For voltage changes caused by manual switching, equipment is deemed to comply without further testing providing the maximum input current (including inrush current) evaluated over each 10ms window between zero crossings does not exceed 20A. Further to this, the supply current after inrush must be within 1.5A. If the maximum relative voltage change $d_{(max)}$ caused by manual switching is determined via measurement methods (such as the N4L PPA5511 and PPA5531) shall be measured as per the "Inrush Test Caused by Manual Switching" section below. The test procedure described is detailed in Annex B of IEC61000-3-3:2013.

Measurement Uncertainty

IEC61000-3-3:2013 describes various uncertainty requirements ranging from the flickermeter(PPA5511/PPA5531) to the impedance network(IMP161,IMP163,IMP323,IMP753).

The accuracy requirements are detailed in section 6.2 of IEC61000-3-3 and are tabulated below for your reference;

Flickermeter Accuracy Requirements		
Parameter	**Limit**	**N4L PPA55x1 Performance**
Current	±(1% + 10mA)	0.01% Reading + 0.038% Range
Total Measurement Uncertainty, including tolerance of Impedance Network and Impedance of AC Power Source	±8%	<1%

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Reference Impedance

The reference impedance is a conventional impedance and consists of a resistance and inductance in each phase. The values specified in IEC61000-3-3 are detailed in figure 4 below;
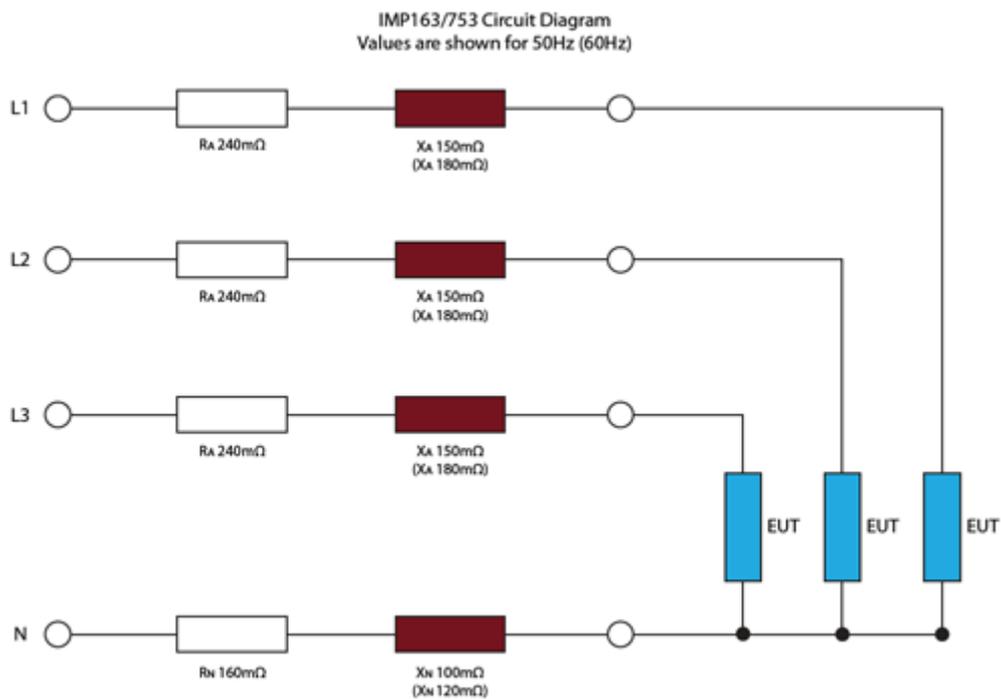
IMP163/753 Circuit Diagram
Values are shown for 50Hz (60Hz)

L1 — R_A 240mΩ — X_A 150mΩ (X_A 180mΩ)

L2 — R_A 240mΩ — X_A 150mΩ (X_A 180mΩ)

L3 — R_A 240mΩ — X_A 150mΩ (X_A 180mΩ)

EUT   EUT   EUT

N — R_N 160mΩ — X_N 100mΩ (X_N 120mΩ)

Figure 4.

Reference Impedance 50Hz (60Hz)	
Parameter	Value
R_a	240mΩ
X_a	150mΩ (180mΩ)
R_n	160mΩ
X_n	100mΩ (120mΩ)

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Observation Period

The observation period is indicated in section 6.5 of IEC61000-3-3, the recommended period T_p for measurement of flicker is shown in the table below;

Observation Period	
Parameter	**Time**
P_st	10 minutes
P_{lt}	2 hours

The standard recommends that the observation period should cover the part of the operation cycle that includes the most "unfavorable sequence of voltage changes".

Assessing P_{st} requires the cycle of operation to be repeated continuously unless otherwise specified in Annex A of IEC61000-3-3. The minimum time it takes to restart the equipment, for equipment that automatically stops shall be included in the observation period if the cycle of operation is shorter than the observation period.

The assessment of P_{lt} does not require the cycle of operation to be repeated unless otherwise stated in Annex A, when the cycle of operation is less than 2hrs and the equipment is not used continuously.

Example:

Cycle of operation: 35 minutes

Four consecutive P_{st} values are measured during an initial period of 40 minutes.

Remaining eight P_{st} values in the 2Hr test period are deemed to be zero.

General test conditions

The standard provides guidance on general test conditions for devices not mentioned in Annex A, advising that the equipment should be set up to produce the most unfavorable conditions with respect to voltage fluctuations at the input terminals of the equipment when connected to the power source and reference network.

The equipment should only use settings and programmable modes that are mentioned by the manufacturer in the instruction manual or that are otherwise likely to be used.

The underlying message of the standard is one that the equipment must be working in a similar manner to that which it would be in normal day to day use when in the field. The standard concentrates on simulation of the equipment when connected to a real power grid, therefore it makes sense to ensure that the equipment being tested is being used in a realistic manner.

Guidance for Motors

When a motor is first started, the back emf created by a rotating rotor across the static motor windings is zero, therefore when the rotor mechanical frequency is zero the supply current will be maximum. It is sensible to conclude that a locked rotor test (in which the rotors mechanical frequency is zero) could be used to determine the maximum inrush current. A secondary effect of maximum inrush current is a large d_{max} measurement, in fact the maximum d_{max} will occur during a locked rotor test and this approach is acceptable for d_{max} assessment.

Separately Controlled Circuits

For equipment consisting of separately controlled circuits, each system should be considered as an entirely separate item of equipment. This is providing that each sub circuit is not designed to be switched at exactly the same moment.

If several sub circuits are designed to be switched simultaneously then each group of circuits should be considered a separate item of equipment.

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Example:

A system contains 14 sub circuits

Circuits 1,3,5 and 7 all switch simultaneously (System A)

Circuits 2, 4, 6 and 8 ~ 14 all switch simultaneously (System B)

Therefore, two "Items of equipment" are separately tested for the 14 sub circuits.

If a control system regulates only part of a load, the fluctuations in the supply voltage produced by each variable part should be separately considered.

Annex A

IEC61000-3-3 Annex A	
Product Type	**Type Test Conditions**
Cookers	No requirement to test P_{lt} for domestic cookers P_{st} performed at steady state, unless specified **Hotplates** - Tested using standard saucepans with water quantity specified in table A.1 of IEC61000-3-3:2013 Boiling – Perform 5 tests at boiling point and take the mean to calculate final result Frying – Fill pan to 1.5 times quantity in table A.1, set temperature to 180 deg C, confirm temperature with thermocouple Power Settings – Test all discrete power stages up to a maximum of 10. If non discrete stages are available separate range into 10 discrete steps. **Baking Ovens** - Test empty with door closed Place thermocouple in center of oven Set temperature to 220 deg C (conventional ovens), 200 deg C (hot air ovens)

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	Grills - Test with doors closed, unless otherwise stated If settings are available - set to lowest, middle and highest settings and record worst result. **Baking Oven/Grill Combinations** - Test with door closed Place thermocouple in the center of the oven Set temperature to 250 deg C (or closest available temperature to this value) **Microwave Ovens** - Use a 1000g glass bowl of water as a load Test at low, medium and third power stage (less than or equal to 90% maximum power) Worst result recorded
Lighting	Use lamp rated at power rating of equipment P_{lt} and P_{st} evaluation only required for equipment likely to produce flicker, such as disco equipment No limits apply to individual lamps, such as fluorescent tubes Incandescent Lamps ($\leq$1000W), Discharge Lamps ($\leq$600W), LED Lamps ($\leq$200W) are deemed to pass d_{max} without the requirement for testing. Luminaries with higher ratings that do not comply to the limits specified in IEC61000-3-3 shall be subject to conditional connection in accordance with IEC61000-3-11
Washing Machines	Complete laundry program, normal wash cycle, 60deg C cotton without pre wash program if available Rated load of double hemmed press washed cotton cloths (70x70cm, 140g/m² ~ 175g/m²) Water temperature 65degC (heater element), 15degC (other) Heating elements not controlled by programmer – preheat to 65degC Heating elements with no programmer – preheat to 90degC or lower if steady state is reached Ignore simultaneous switching of motor and heater for assessment of d_c, d_{max} and

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	T_{max} Evaluate P_{st} and P_{lt}
Tumble Dryers	Fill with textiles, 50% dry load double hemmed press washed cotton cloths (70x70cm, $140g/m^2$ ~ $175g/m^2$) Soak with 25degC water, adding 60% of original mass Where possible, perform test at maximum and minimum heat settings Evaluate P_{st} and P_{lt}
Refrigerators	Operate continuously with the door closed Adjust thermostat to the mid value Empty the cabinet, no heat required Do not evaluate P_{st} and P_{lt}
Copying Machines, Laser Printers and Similar	Test for P_{st} at the maximum rate of copying Copy medium is white blank paper, $80g/m^2$ if not otherwise stated Evaluate P_{lt} in standby mode
Vacuum Cleaners	Do not evaluate P_{st} and P_{lt}
Food Mixers	Do not evaluate P_{st} and P_{lt}
Portable Tools	Do not evaluate P_{lt} For portable tools without heating elements fitted do not evaluate P_{st} Switch on for 10 minutes
Hairdryers	For hand held dryers P_{lt} shall not be evaluated Evaluate P_{lt} by switching on for 10 minutes If power ranges are available, test complete range up to a maximum of 20 stages (for discrete steps)
Television, Audio, Computer, DVD and similar equipment	Refer to Annex A, if no special test conditions are appropriate, only compliance to d_{max} is required.

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The table is not exhaustive and reference to Annex A in IEC61000-3-3 is recommended, further test conditions recommendations are made for other equipment such as water heaters, audio-frequency amplifiers, air conditioners, heat pumps, commercial refrigeration equipment and arc welding equipment.

Annex B

Annex B describes test conditions for measuring d_{max}, also known as voltage changes at the terminals of the equipment under test caused by manual switching.

When an item of equipment is manually switched on or off, current inrush to the EUT causes voltage changes over the supply network. A statistical method is used in order to achieve a repeatable measurement of d_{max}.

The procedure includes 24 separate measurements, described below;

1. Start measurement
2. Switch on EUT
3. Operate EUT for as long as possible during a 1 minute period
4. Switch off EUT before the end of 1 minute period
5. Ensure all moving parts inside the EUT have come to a standstill before the end of the 1 minute period.
6. Ensure devices affecting d_{max} have had time to cool to the ambient temperature before the next measurement interval has started.
7. Start the next measurement

The highest and lowest recorded d_{max} values are deleted and the arithmetical average of the remaining 22 values is taken.

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Annex C

Annex C describes determination of steady state voltage and voltage change characteristics.

This section of the standard is a modified version extracted from IEC61000-4-15:2010, we should remember that the two standards would not exist without the other. IEC61000-4-15 sets out requirements of the measurement system whereas IEC61000-3-3 describes the pass/fail limits and practical implementation of a flicker test.

There are two distinct conditions that should be considered, one is where the voltage half period RMS remains in a steady state, the other is a period of "change". This change can be a rise or fall of the half period RMS magnitude.

Definitions

In order for us to understand the terminology and descriptions within annex C, it is important for us to define the parameters related to steady state and changing voltages.

Half period RMS Voltage (U_{hp}) -

This is the half period RMS (root mean square) value of the test waveform, taken from 0~180° and 180~360°, you will notice that the "half wave" is windowed with respect to zero crossing.

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Half Period RMS as specified in IEC61000-3-3 (U_{hp})
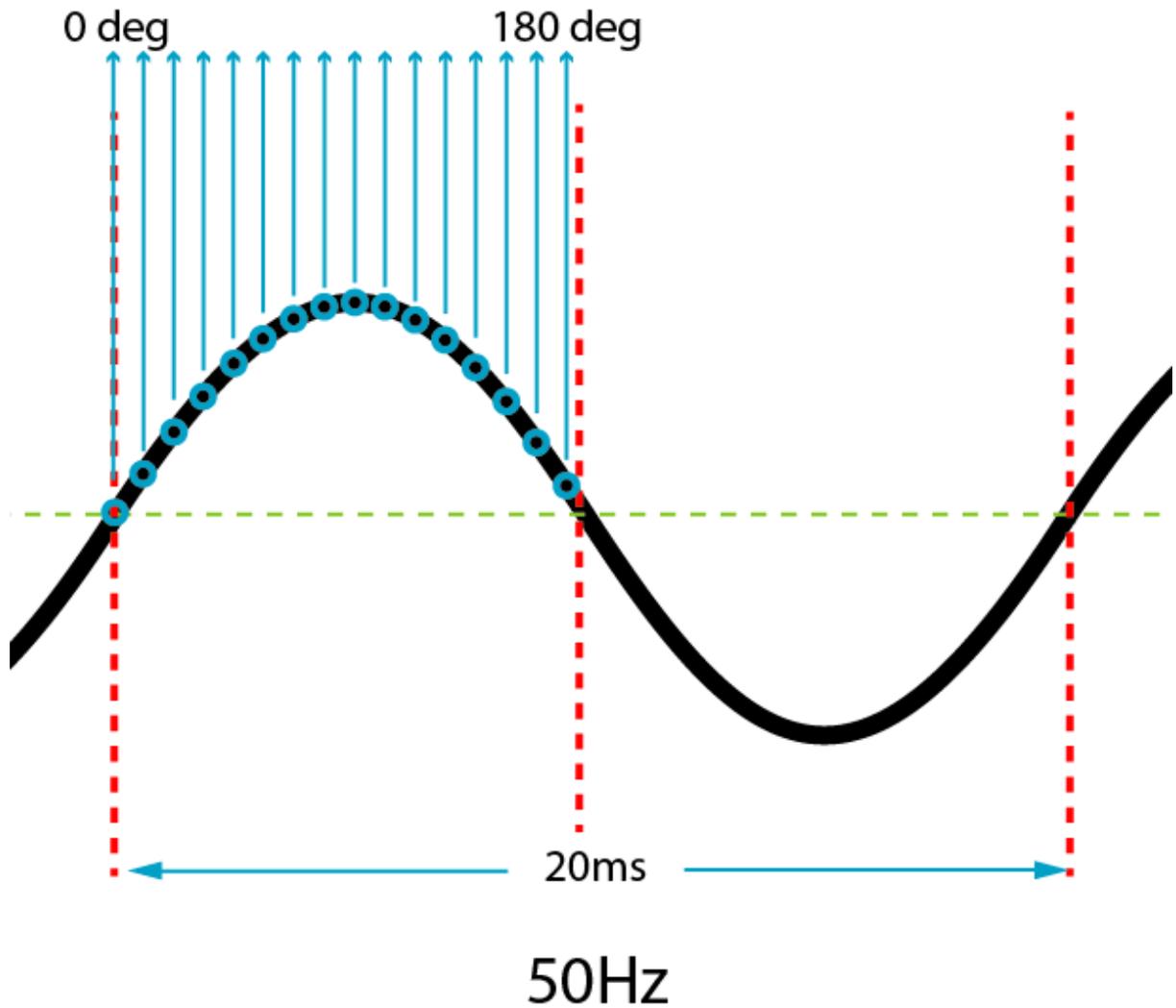

0 deg   180 deg

20ms

50Hz

Figure 5.

Figure 5 illustrates the data points used (the PPA5511/PPA5531 sample rate is much faster, at 2Ms/s) to calculate the half period Voltage RMS between 0~180°, this process is then repeated for the second half of the cycle (180~360°). It is clear that U_{hp} becomes a function of time which leads us on to our second definition.

Half period RMS Voltage characteristics $U_{hp(t)}$

The behavior of successive half period Vrms values is a function of time, therefore U_{hp} is used.

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Relative Half period RMS Voltage d_{hp}

Expressed as a ratio in comparison to to nominal voltage, this compares the most recently measured U_{hp} value to the nominal voltage (U_n) as follows.

$$d_{hp(t)} = U_{hp(t)} / U_n$$

Steady State Voltage Change $d_{c,i}$

Value of the difference between two consecutive steady state voltage changes, normally expressed as a percentage of the nominal voltage U_n.

$$d_{c,i} = [d_{end,i-1} - d_{start,i}]/U_n$$

d_c Measurement Example:
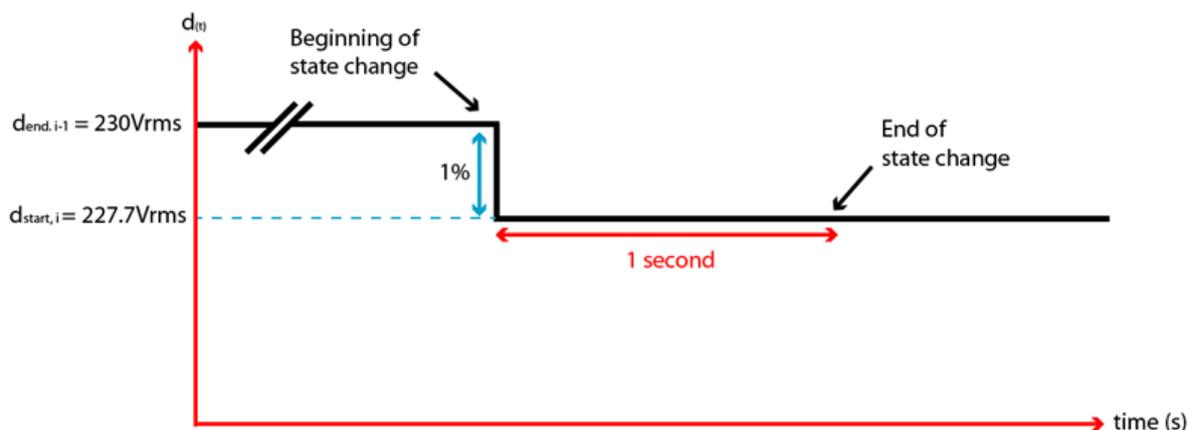
Steady State Voltage Change Example

Figure 6.

Figure 6 illustrates the behavior of the half period RMS over time when a "steady state change" occurs as per the IEC61000-3-3 standard.

$$d_{c,i} = [d_{end,i-1} - d_{start,i}]/U_n$$

$$d_{c,i} = [230-227.7]/230 = 0.01 = 1\%$$

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This is an example of a steady state voltage calculation, you will notice that the next steady state occurs after 1 second at the 227.7Vrms half period value.

Maximum Voltage Change $d_{max,i}$

This is the maximum recorded voltage difference between a steady state condition and a following half period Vrms ($d_{hp(t)}$) during the test period.

$$d_{max,i} = \max [d_{end,i-1} - d_{hp(t)}]$$

Polarity is indicated, the direction of polarity is dependent upon the direction of the voltage change in comparison to the $d_{end,i-1}$ value.

If:

The d_{max} value is a result of a reduction in voltage then the value of d_{max} is positive.

The d_{max} value is a result of an increase in voltage then the value of d_{max} is negative

Maximum steady state Voltage change during observation period d_c

d_c is the highest absolute value of all $d_{c,i}$ values recorded during a test.

$$d_c = \max i \, [|d_{c,i}|]$$

Maximum absolute Voltage change during test period d_{max}

Highest absolute value of all $d_{max,i}$ values during the test period.

$$d_{max} = \max i \, [|d_{max,i}|]$$

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Voltage deviation d$_{(t)}$

d$_{(t)}$ is the deviation of the current half period Vrms(d$_{hp(t)}$) to the previous d$_{end,i-1}$ inside a voltage change characteristic. Polarity is optional for this parameter and a voltage drop is considered positive.

d$_{(t)}$ = d$_{end,i-1}$ - d$_{hp(t)}$

Steady State Voltage Change and Voltage Change Characteristics

A steady state condition is defined as when the half period r.m.s. voltage U$_{hp}$ remains within a tolerance band of ±0.2% for a minimum of 100 half cycles of the fundamental frequency (50Hz), this clearly equates to a steady state for 2 seconds.

At the beginning of a flicker test, the initial reference voltage is defined to be the average r.m.s. voltage acquired during the preceding second to the commencement of the test period. This is the starting reference value for d$_c$ and d$_{hp(t)}$ calculations and well as for the calculation of d$_{max}$ and d$_{(t)}$ measurements.

If a steady state condition cannot be established during the test, d$_c$ shall be reported as zero.

As the test progresses, an average U$_{hp,avg}$ is calculated from the last 100 (50Hz) U$_{hp}$ values. The U$_{hp,avg}$ value is used to determine whether or not the steady state condition continues, it is also used as the reference for d$_c$, d$_{max}$ and T$_{max}$ in the event voltage changes occur.

What this essentially means is that a 100 sample average, U$_{hp,avg}$ of the half period r.m.s. voltage is continually taken, this average value is then compared to the last half period r.m.s. voltage U$_{hp}$. If the last half period r.m.s. voltage is within 0.2% of the U$_{hp,avg}$ value then the steady state condition continues.

A new steady state condition d$_{c,i}$ is determined after a voltage change has occurred by calculating an initial value – dstart,i = dhp(t=tstart) is used. A tolerance value of 0.2% is set and a steady state condition is detected if 100 half period r.m.s. values are within the 0.2% band.

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The reason $U_{hp,avg}$ is used is to prevent slowly changing line voltages triggering a d_c or d_{max} indication.

The last value of U_{hp} that lies within the 0.2% tolerance is denoted as $d_{end,i}$. The new half period r.m.s. value following this final value within the 0.2% limit is denoted as d_{hp}. This value is used as the starting value for determining the value of the next steady state condition, known as $d_{c,i+1}$.

Once a new $U_{hp,avg}$ is present (after 100 half cycles), a new steady state condition is measurement is taken. If any value falls outside the tolerance band for the 100 half periods, then this new value is used as the starting point for the steady state condition, until a period of 100 consecutive half cycles fall within the tolerance band of 0.2%.

Verifying D Values

N4L's flicker meter verification tests are performed as per "Determination of steady state voltage and voltage change characteristics, as defined in IEC61000-4-15:2010", specifically referring to Annex C.

Both reference voltage change characteristic patterns are generated which are described in table C.1 and C.2 of IEC61000-3-3:2013.

N4L have developed an AC Power source capable of generating the required Vrms change characteristics to simulate the waveforms described in C.1 and C.2, other waveforms can be generated as per customer requirements with the generator of the N4A06 6KVA AC Power source.

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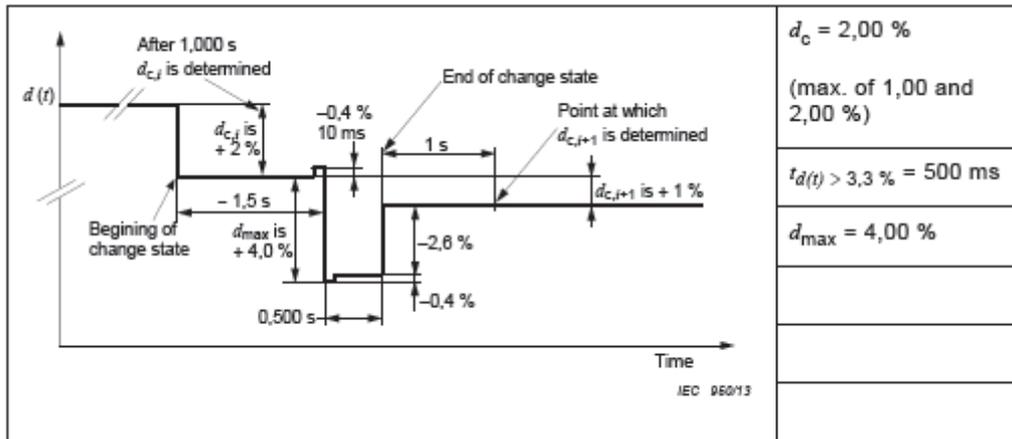Table C.1 – Test Specification for $d_c - d_{max} - t_{d(t)}$

Figure 7.

The waveform is generated using "SEQUENCE" mode in the N4A06 AC Power Source, utilizing highly accurate timing algorithms.

The waveform is then measured with the PPA5511 flicker meter, with "normal" d(t) measurement settings.

PPA5511 Verification: $t_{d(t)}$ = 500ms

Figure 8.

The waveform in table C.2 is then generated and verified, a $t_{d(t)}$ value of 600ms is expected. Note that $t_{d(t)}$ is displayed as Tmax on the PPA5511.

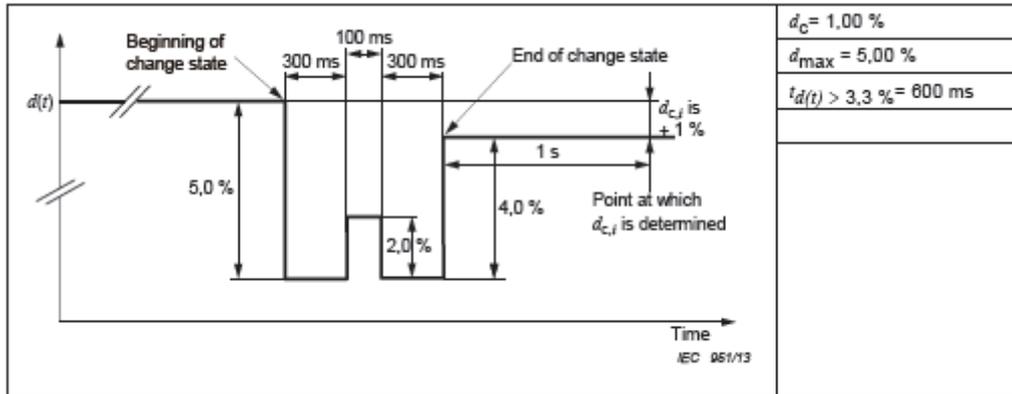Table C.2 – Test Specification for $d_c - d_{max} - t_{d(t)}$

Figure 9.

PPA5511 Verification: $t_{d(t)}$ = 600ms

Figure 10.

It should be noted that in figures 8 and 10 the values for $d_{(t)}$, d_c and T_{max} are all well within the accuracy limits of the IEC61000 standards.

Conclusion

Flicker analysis is a complex subject, procedures must be in place in order to perform thorough verification of the analyzer. Newtyons4th are an accredited ISO17025 Calibration Laboratory (UKAS) and our scope includes testing of Harmonics and Flicker to IEC61000-3-3 (IEC61000-4-7), ISO17025 calibration is available directly from Newtons4th.

References:

- International Electrotechnical Vocabulary. (1990). Electromagnetic Compatibility – Chapter 161, IEC 60050-161:1990. International Electrotechnical Vocabulary
- International Electrotechnical Commission. (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. International Electrotechnical Commission.