Methods for the Calibration of Flickermeters

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1 Introduction

The variation in current supplied to appliances connected to the electricity supply causes local voltage drops across the impedance of the mains. This can manifest itself as a Flickering of the lights. The extent to which this is annoying to people is related to the magnitude of the light change and the rate at which it changes. In an attempt to reduce this phenomenon, an international standard IEC61000-3-3, imposes limits on the levels of Flicker which can be induced by a given electrical appliance.

The measurement of Flicker is embodied in the Flickermeter, the instrument which is used for product compliance type-testing. A key part of this regulatory framework is the calibration of Flickermeters. The paper will describe methods of calibration, both in use and under development at NPL.

2 What is Flicker and why is it Important?

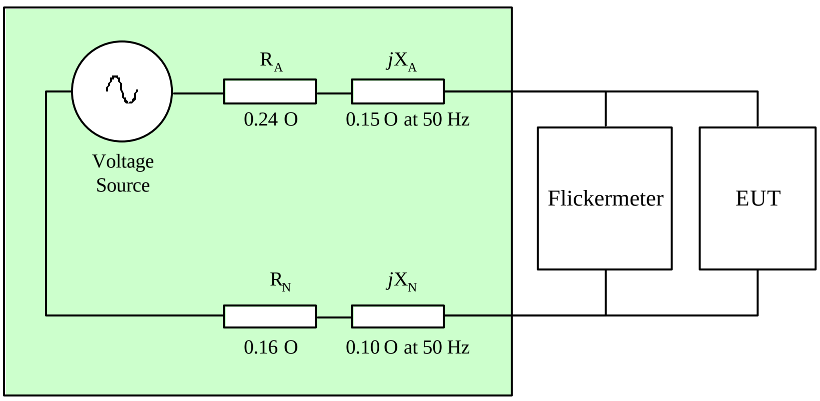
Since the inception of electric lighting, the dimming and flickering of lights has been a reality for most consumers. In general, the main cause of these effects is variable current drawn by switching operations of industrial processes and electrical appliances connected to the supply system. This fluctuating current flows through the network impedance and induces a voltage drop which changes at the same rate as the current.

At particular repeat rates, these changing voltage drops can be sufficiently large that people can be affected by a flickering of the electric lighting in the office or in the home. The effects of this can range from minor irritation to a health risk, particularly for those who are prone to epilepsy.

The present trend towards improving the quality of the power supply has led electricity supply companies and regulatory bodies to recognize the problem of Flicker and the proliferation of the type of equipment which causes these problems.

3 Regulating Flicker

An IEC standard 61000-3-3 [1] imposes limits on the voltage changes and fluctuations induced by a given appliance connected to the mains supply. This standard requires that electrical appliances be type-tested to ensure that they meet the requirements in the standard. A typical configuration for testing an appliance is shown in Figure 1. Testing is carried out by supplying the equipment under test (EUT) using a power amplifier with a defined [1] output 'reference' impedance which is representative of the mains impedance. The EUT is operated in its usual way and the indication of Flicker is recorded on the Flickermeter and compared to the limits as defined in the IEC standard.



Supply Source with Reference Impedance

Figure 1, the testing of an electrical appliance (EUT) using a Flickermeter and reference impedances

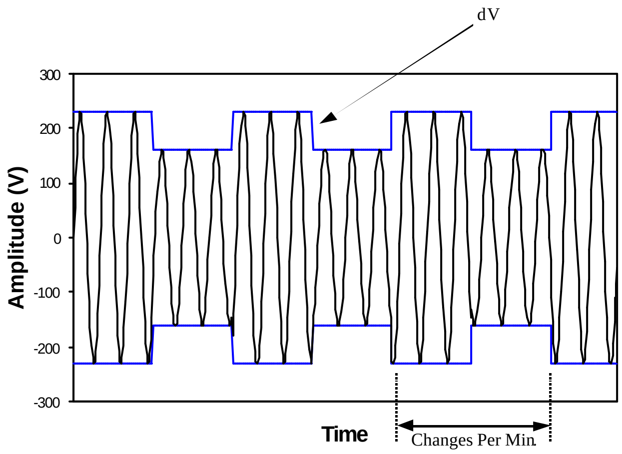
4 The Flickermeter

The measurement of Flicker induced by the EUT is made using a Flickermeter. The instrument output is given in units of Flicker severity (Pst), a value of one being the acceptable human tolerance limit. The workings of this instrument are a fascinating mimic of the way that a human perceives flicker. The instrument employs a series of electrical filters to model the response of the human eye and brain to light flicker. The design of Flickermeters is prescribed in EN60868 [2]. A useful article on the Flickermeter is given in [3].

Whilst the design of the Flickermeter is complex, there is a good choice of commercial meters which can be purchased that take care of the details. Despite the underlying complexities, from the point of view of the person carrying out the compliance tests on the EUT, the procedure boils down to a relatively simple electrical measurement using calibrated equipment.

5 Calibration of Flickermeters

If the EUT fails to meet the flicker requirements of the standard, this will prevent the appliance from gaining access to important markets. This can lead to costly redesign and delays in marketing a new product. In such cases, in particular if the failure is 'borderline', attention is given to the accuracy of the Flickermeter. This need has led NPL to develop and offer a calibration service for Flickermeters which is the subject of the remainder of this paper.



The Flickermeter output depends on the depth of modulation and rate of change of the mains type signal applied to its input. In order to calibrate the Flickermeter it is necessary to characterize such a signal and compare the theoretical response of an ideal Flickermeter to the response of the device being calibrated.

A simple fluctuating mains-level voltage waveform can be obtained by amplitude modulating using a squarewave as shown in Figure 2. This gives rise to two distinct RMS levels which occur at a given repetition rate (changes per minute).

Figure 2, The Squarewave modulation of the mains voltage as used to calibrate a Flickermeter

For the special case of squarewave modulation, IEC61000-3-3 [1] contains a graph to relate the changes per minute, to the depth of variation in voltage (dV), such that the value of Flicker severity is unity. By choosing points from this theoretical response graph, the Flickermeter can be calibrated over a range of modulation rates and depth. EN60868 Part 0 [4] tabulates six points from the graph for assessment purposes.

6 Generation and Analysis of the Calibration Signal

The modulated calibration signal can be produced by a commercially available waveform synthesizer with an amplitude modulation (AM) input. A second waveform generator is then used to produce a square wave which is applied to the AM input. The system is shown in Figure 3.

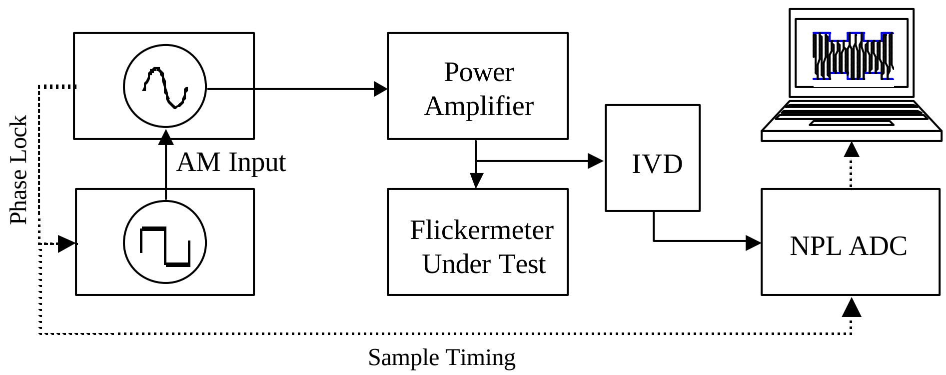


Figure 3, System for the Calibration of Flickermeters

Having chosen a point on the Flickermeter curve and set the required repeat rate on the squarewave generator, the calibration signal amplitude is then independently measured and adjusted to the required voltage depth by changing the amplitude on the squarewave generator.

Having set-up the calibration signal to the required depth and rate, the Flickermeter is used to make a 10 minute Pst measurement. For the points used on the theoretical curve, this result should give a value of one. The allowed tolerance for Flickermeters as defined in EN80868 is ± 5 % of reading.

In order to measure the calibration signal the voltage is stepped down to 1 V rms using an inductive voltage divider (IVD). This signal is applied to the input of a calibrated analogue to digital converter (ADC) of NPL design and the sampled data is then analyzed. The type-b uncertainty on the measured value of Pst is typically 0.01 Pst units. The data analysis method used depends on the repeat rate of the modulation.

6.1 Time Domain Analysis of the Flicker Calibration Signal

In the case of slow modulations of a few changes per minute, time domain analysis is used. This involves calculating regular RMS values from the samples obtained by the ADC. For example, a RMS value can be found once per mains frequency cycle, hence building-up sets of measurements at the modulation levels. Further processing on these measurements can be carried-out and the results used to find the modulation depth.

For faster modulation rates, a time domain approach is not practical as there are fewer full mains cycles at each level available for analysis. In this case a frequency domain approach is used which makes use of AM theory to find the modulation depth.

6.2 Frequency Domain Analysis of the Flicker Calibration Signal

AM theory predicts sideband frequency components at the sum and difference of the modulating and carrier frequencies. Squarewave AM gives rise to many sideband components, but it is only necessary to pick one of the sidebands, together with the carrier frequency component. Using these two values, the depth of modulation can be found in a similar way to the sinewave case. It is a useful check to perform the calculation on some of the other available sidebands and compare the results.

One of the advantages of having two separate methods for the measurement of the modulation depth, i.e. time domain and frequency domain, is that the results can be compared at suitable intermediate frequencies where both methods are applicable. When comparing results in this way it is found that the results agree within the noise of the measurement.

7 Calibration of Flickermeters Using More Complex Modulation Signals

In practice, the nature of the Flicker modulating signal is essentially arbitrary and the Flickermeter must give the required results for whatever signal is produced by the EUT. This leads to a desire to calibrate the Flickermeter with synthesized waveforms similar to those induced by real appliances.

Assuming that it is possible to generate more complex modulation functions, it is necessary to:

1. Have a method of accurately measuring the modulation function.
2. Find the theoretical response of an ideal Flickermeter with which to compare the meter being calibrated.

Work at NPL on waveform transforms allows for the accurate demodulation of fluctuating signals and it is envisaged that these techniques can be applied to characterize the more complex calibration signals. Having found the applied signal characteristics, the results can be used in a computer model of an ideal Flickermeter to obtain the theoretical Pst reading with which to compare the Flickermeter being calibrated.

8 Remote Calibration of Flickermeters

The method described above requires separate calibration of the Flickermeter and the Reference Impedance. It is desirable to have a system which can calibrate the full Flicker Tests System in the configuration in which it is used in day-to-day measurements. This has led to the development of a transportable Flickermeter calibrator, an example of which has been developed by California Instruments Inc. The calibration configuration is shown in Figure 4, the calibrator taking the place of the EUT in Figure 1. The calibrator consists of a set of 'non-inductive' high current resistors. The values of the resistors are arranged that the current drawn will induce a known voltage drop. The extent of the voltage drop corresponds to a pre-selected point on the Flickermeter response curve for squarewave modulation.

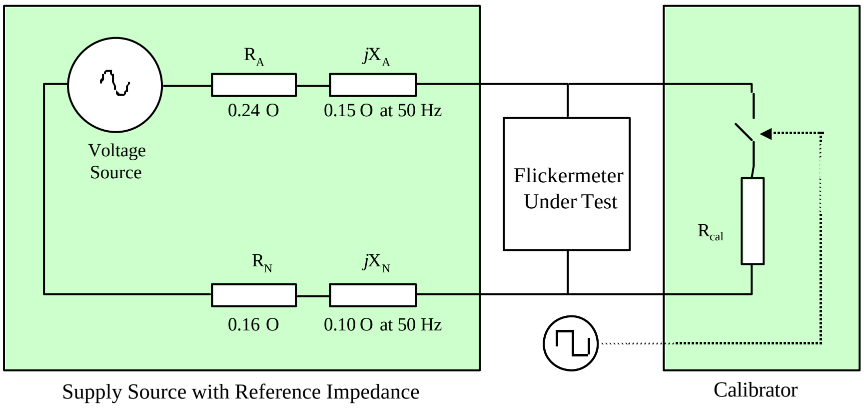


Figure 4, Calibration of a Flicker Test System Using a Calibrator

To give squarewave modulation, the resistor is switched in and out of the circuit using a solid-state relay. The relay is driven by a square wave generator at a rate corresponding to the point on the IEC curve for the drop induced by the resistor. Five different resistors are available in the calibrator allowing the flicker test system to be calibrated at five different amplitudes for all frequency points on the IEC curve.

The calibrator itself needs to be calibrated and its performance assessed which has led NPL to develop a calibration procedure for this system. Tests were carried-out to assess the performance of the calibrator, including the behavior of the resistors under load. An obvious concern is whether the resistor values undergo any change due to self-heating when under-load. Using a computer model of the Flickermeter, it was concluded that the relatively small amount of resistor variation had a negligible effect on the performance of the system.

In the near future, it is hoped that the calibrator can be used to calibrate Flicker test systems on-site. Such a calibrator would be in effect a traveling standard which would be delivered to a customer's premises. Using a relatively simple procedure, the customer should be able to calibrate the complete Flicker system under the same conditions, with the same wiring configuration, that it uses to make its 'every-day' compliance measurements. Using a before and after calibration methodology for the calibrator, it should be possible to issue calibration certificates for the full flicker test system, remotely.

9 Conclusion

This paper has introduced the causes and problems associated with Flicker. These problems have led to the regulation of loading characteristics of electrical appliances connected to the mains supply. This type-testing regime and the Flickermeter which is used for making these compliance measurements, was described.
Central to the regulation and compliance system is the calibration of the Flicker systems. The paper described the NPL calibration procedure for these systems and discussed some of the on-going development in this area.

10 Acknowledgements

The development of calibration services for Flickermeters as described in this paper was supported by the DTI National Measurement System Policy Unit's Programme for Electrical Metrology. The authors wish to express their thanks to Mathieu van den Bergh and California Instruments Inc. for discussions regarding the remote flicker calibrator.

11 References

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