Evaluation of EMI Effects on Static Electricity Meters

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***Abstract* — Recent studies involving large errors in static electricity meters when exposed to step changes in the current waveform are reviewed. Triggered by these findings, a joint European research project has recently started to further evaluate these effects. A description is given of this pre-normative research programme which aims to provide evidence and techniques to resolve this unsatisfactory meter error situation. The need or otherwise for a regulatory and standardisation response to these large meter errors is discussed.**

***Index Terms* — Electromagnetic Compatibility, EMC immunity testing, energy measurement, static meters, standards, watthour meters.**

I. Introduction and Background

Throughout the world traditional electro-mechanical electricity revenue meters are being replaced with static meters with data communication capabilities as part of smart meter programmes, which in the EU alone involves some 200 million meters. European regulations require all meters to be type-approved; this involves *inter alia,* accuracy testing, the limited testing of the effects of the 5th harmonic and a swept frequency test using a single tone up to 150 kHz.

A recent study by University of Twente [1] compared the readings of a range of type-approved static meters against a traditional electro-mechanical meter, when metring electricity into non-linear loads drawing highly impulsive currents. These loads consisted of heaters and non-dimmable energy-saving lamps and LED-lamps, both with and without an additional dimmer. When using dimmed lamps, three out of four static meters showed deviations in their energy readings, with up to three times more energy consumption registered. Following the UTwente findings, the Dutch utility association, Netbeheer Nederland, asked VSL to verify the results which duly confirmed the findings of the UTwente study and extended the work to investigate the majority of meter types installed in the country [2].

These findings are particularly worrying as all the meter evaluated are EU type-approved according to the present standards [3] – [5], indicating possible deficiencies in the testing regime and associated normative standards. Critics of the UTwente study point out that the use of dimmers on non-dimmable energy-saving and LED lamps is not a realistic or typical of the situation that occurs in practice. However, in the VSL follow-up study, meter error readings for dimmable versions of these lamps were also found [2]. An important remaining criticism is the question to what extent the waveforms of the UTwente study occur in real life, in the present electricity networks.

Given the serious nature of the Dutch study findings and the still many open issues, there is a clear need to do further research to understand the response of static meters in particular to types of fast step change (chopped) current waveforms, similar to those caused by dimmed lamps, but induced by typical electrical appliances employing power electronics.

To this end, a new EU funded project starting in May 2018 which will investigate these issues further, with the ultimate aim of developing new type-testing procedures to resolve this unsatisfactory situation to the benefit of consumers, utilities and meter manufactures. In this paper, we summarise the research programme of this new EU project.

II. Proposed Pre-Normative Investigations

The UTwente and VSL findings has opened a debate as to the extent and seriousness of the static meter errors. Whilst the Dutch findings potentially undermine customer and industry confidence in static meters, any updating of testing regimes, redesigning meters and ultimately retrofitting or replacing considerable numbers of meters, will have significant costs to industry and consumers. The extent of the regulatory and standardisation response must be evidence and risk based and carefully weighed between confidence and cost.

In order to address these complex issues and provide a sound metrological base for any new normative standards, the new project will develop methods and apparatus to capture, analyse and accurately reproduce real-world waveforms to determine the extent of the problem by testing the ensemble of EU static electricity meters. The six main technical activities of the project are described in the following sections.

A. Isolate the offending interference waveforms.

Currently, electricity meter type-approval tests use simple signals which contain a fixed amount of interference at the 5th harmonic and a recently introduced single-tone frequency sweep up to 150 kHz. However, this is not representative of household appliances currents which are highly complex and subject to switching and variation, causing wide-band current signals. At the same time, it is justifiably questioned whether the very-high bandwidth signals of the recent Dutch meter studies [1] – [2] are not highly exaggerated with respect to the actual current distortion levels occurring in our electricity networks. To answer these critical questions, and to provide the basis for more realistically testing static meters, the current and voltage waveforms typically occurring at the metered supply points (MSP) will be accurately captured using high-bandwidth sampling instruments and transducers. In addition, waveforms of some typical household appliances with significant (switching) power electronics will be recorded.

B. Algorithms to trigger capture and visualise events.

Capturing sporadic events of interest at MSPs will require the collection and the time-consuming analysis of large data sets. This makes site measurements difficult, as the investigator is not sure whether any signals of interest have been captured until off-line analysis has been completed. To avoid this, triggering algorithms will be developed to detect, capture and visualise each event. These algorithms will be used together with the hardware developed in *A* to capture the right MSP events in the on-site measurement campaigns.

C. Algorithms for the parsimonious specification of waveforms.

Fourier transform methods are normally used to decompose waveforms into their different frequency components, however these transforms give errors when the waveforms are subject to the sporadic switching and variation as seen at real MSPs. Transforms based on wavelets and time-frequency distributions will be optimised building on work in other fields of applied mathematics.

All waveforms captured in *A* will be analysed using the new transforms. Once the key characteristics of the waveforms are clear, decompositions using these transforms will give parsimonious yet accurate representations of long captured time series, suitable for accurate regeneration and publication in normative standards.

D. New testbeds for meter type approval.

Currently electricity meter testbeds sweep a single frequency tone to 150 kHz to test a meter response [5]. New testbeds will be developed, capable of accurately and repeatably reproducing fast-switching real-world signals with a target uncertainty of 0.1 %. Two parallel routes will be followed. First, existing meter testbeds will be modified to allow for mixing interference with the mains frequency waveform. This approach requires critical alignment of the interfering and mains signals to avoid distortion of fast edges. The second approach will employ an arbitrary waveform method as an alternative testbed. After a final evaluation of both approaches via a comparison between the two, these new testbeds are available as the basis for future testbeds to be used in EU meter approvals.

E. Testing smart meters with real world waveforms, leading to new type-approval protocols.

Once the testbeds have been developed and a series of representative waveforms have been determined, the testbeds will be used to test a representative selection of EU smart static meters using regenerated versions of the captured waveforms. The testing will effectively prototype new normative procedures for the future routine type-approval testing of meters in the presence of realistic interference. The results will reveal the extent of metering errors and determine the scope and degree of the standardisation response.

F. Bench mark meters to settle customer billing disputes.

Utilities need suitable meters that are sufficiently insensitive to the types of disturbance occurring on the grid so that they can be deployed to settle billing disputes, especially where interference is a suspected cause. Having tested the EU installed meters with realistic waveforms, a selection of interference immune meters will become bench mark meters.

III. CONCLUSION

The Dutch studies have shown that rapidly changing current waveforms can cause some static meters to have gross errors in their energy readings. New pre-normative research will inform regulators and standards bodies, providing evidence for a proportionate regulatory response to this unsatisfactory situation. Key elements of the research are the development of equipment for on-site waveform capturing, of waveform analysis algorithms, and of new testbeds for meter testing together with the appropriate testing procedures.

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REFERENCES

[1] F. Leferink, C. Keyer, A. Melentjev, “Static Energy Meter Errors Caused by Conducted Electromagnetic Interference,” *IEEE Electromagnetic Compatibility Magazine,* vol. 5, Issue 4, pp 49-55, Fourth Quarter 2016.

[2] G. Rietveld, D. Hoogenboom, and M. Acanski, “Error readings of Static Electricity Meters caused by EMI,” CPEM 2018 Conf. Digest, July 2018.

[3] EN 50470-1, Electricity metering equipment (a.c.), Part 1: General requirements, tests and test conditions – Metering equipment (class indexes A, B and C), 2006.

[4] EN 50470-3, Electricity metering equipment (a.c.), Part 3: Particular requirements – Static meters for active energy (class indexes A, B, and C), 2006.

[5] IEC 61000-4-19: Electromagnetic Compatibility (EMC) - Part 4-19: Testing and measurement techniques - Test for immunity to conducted, differential mode disturbances and signalling in the frequency range from 2 kHz to 150 kHz, at a.c. power port, 2014.