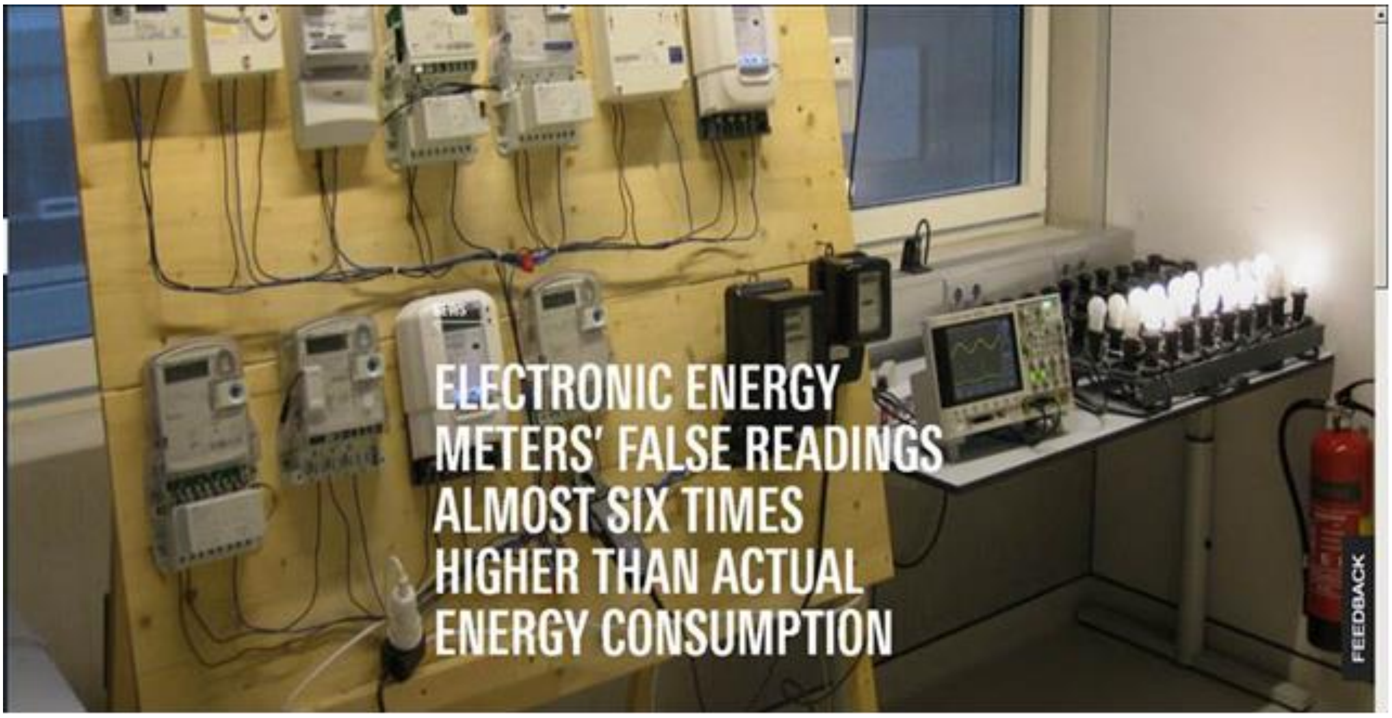
This document is based on work done at the University of Twente in Holland - see Meter False Readings – as reported on the BBC's "Money Box" programme on Saturday 4th March — to listen to this try Money Box, about 17 minutes into the programme. In preparing this document, the opinion of various metering experts was sought.



Summary

Recent press reports suggest that some types of electricity meter (including so-called 'smart' meters) are susceptible to gross errors when feeding low-energy lamps, variable-speed drives and other equipment that generates electromagnetic interference. This review concludes that measurement errors do occur; that their magnitude depends upon the current-sensing technology used by the meter; and that the effect may be negligible in normal situations in the domestic market. However, potential for gross error remains in unfavourable circumstances, particularly in industrial or commercial installations or where there is deliberate intent to fool the meter."

Background

For quite some time now, rumours have been rife about electronic energy meters giving incorrect readings, usually excessively high readings; in Holland, Germany, Sweden & other countries. In some cases, it appears that legal action is even being considered. Prof. Leferink of the University of Twente in Holland decided to investigate whether such meters can indeed give false readings. Tests were carried using various loads such as CFL lamps, heaters, LED lamps & dimmers.

Nine different Static Meters, manufactured between 2004 and 2014, were used. As I understand, some were purchased in the UK and some were MID approved. Five of these meters gave readings that were much higher than the actual consumption, up to 582% high ! However, two of the meters read 30% low. All the readings were reproducible.

The greatest errors were seen with energy saving light bulbs and LED bulbs controlled by a dimmer. The errors resulted from the meter's design. If a Rogowski sensor (air cored coil) was used to measure the current, the meters read high; Hall Effect sensors caused the meter sensors to read low.

Another example was where a VSD controlled fan was being used; the VSD generated a fast common mode voltage and current which lead to a 60% reduction in the reading of an adjacent meter. Replacing the VSD by another make solved the problem !

The errors were caused by conducted and radiated emissions in the range below 150KHz. There are several different factors behind this problem; the use of electronic equipment directed connected to the mains, mains communications and a discrepancy between standards.

Discrepancy between Standards

Permissible EMC levels vary between standards, depending on the industry promoting the standard. Manufacturers of VSD would prefer for a relatively high emissions levels to be acceptable; manufacturers of PLC equipment would like the mains environment to be as quite as possible — apart from their signals. Other manufacturers of electronic equipment that connect to the mains, particularly measuring equipment, would prefer that EMC levels — both conducted and radiated — were kept to a minimum.

IEC TC77 (and CENELEC SC205A) are responsible for 'Basic and Generic Standards for Electromagnetic Compatibility'. These are numbered "IEC 61xxx". Rather than using the generic 61xxx series of standards, IEC product committees can write their own EMC standards which will apply to their products; any such standard needs to be reviewed by TC77. IEC TC22, which develops standards covering 'Power Electronic Systems and Equipment', decided to develop an EMC standard for their industry; (IEC 61800-3:2017 'Adjustable Speed Electrical Power Drive Systems – Part 3: EMC Requirements and Specific Test Methods'). However, they did not properly consult with other committees. Without this full consultation, lack of compatibility has led to problems for other users.

For electronic energy meters, IEC 62053-22 does not have any accuracy requirements for radiated RF fields below 30kHz and for conducted emissions below 150kHz. EN 50470-3, for MID Meters, has the same limits. In both cases, there is a test for accuracy in the presence of imported 5th harmonics. All accuracy tests only apply to true energy measurement (kWh); no other parameters are covered.

Where utilities are purchasing meters, or specifying meters to be used, they may require additional performance requirements. I understand that the UK utilities are fully aware of these potential errors. Thus smart meters installed in the UK should not be affected.

Mains Communications (PLC)

PLC uses a frequency uses frequencies in the range from 110Hz to 148.5kHz. This frequency band is currently not fully covered by product EMC standards (such as for meters). Several product committees are investigating EMC problems in the range between 2kHz and 150kHz and we can expect amendments to be published.

Electronic Equipment and Metering

The major source of EMC is electronic equipment power supplies. These require a large inrush current and have a high Crest Factor. (Crest Factor is the ratio of peak to rms value of a current waveform. The crest factor for a sinusoidal current waveform is 1.414.). For dimmable LED lights, the Crest Factor can be as high 25 or 50, depending on the method of dimming and the quality of the LED lamp. The dimming process, combined with the electronic power supplies in each LED or CFL lamp, results in high levels of harmonics and fast transients

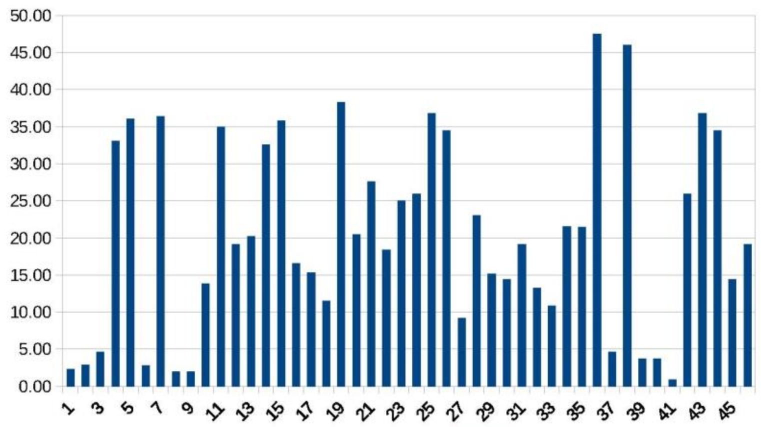


Figure 1 Measured Crest Factor of 46 LED's with leading edge dimming. From Shutle Lighting [7]

In pure measurement terms and assuming that the meter design allows for such operation, errors are likely to be small & immaterial; the meter will need to be over-rated to cope with such high current levels. This approach has cost implications and could limit the minimum current at which the meter can measure accurately.

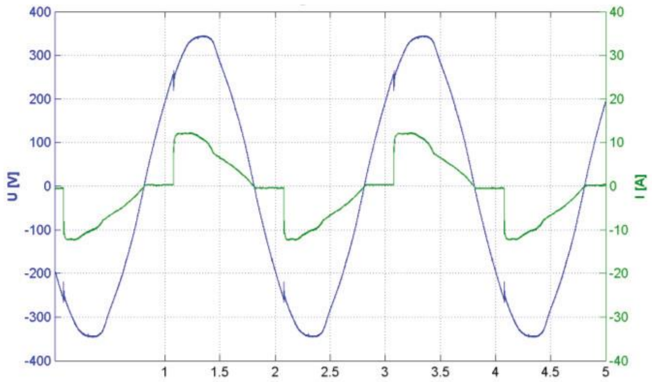


Figure 2 Voltage and current, for heater, CFL and LED load, dimmer at 45^0 (From Frank Leferink [3])

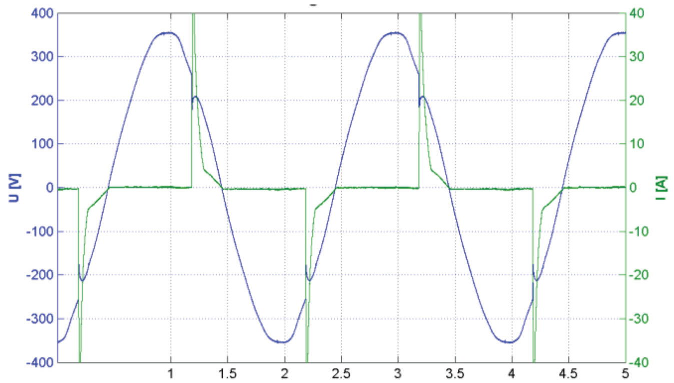


Figure 3 Voltage and current, for heater, CFL and LED as load, dimmer at 135^0 (From Frank Leferink [3])

In practice, the Crest Factor limit of meters is likely to be in the order of 2 at maximum current (and rising as the current reduces). However, since the energy content of these peaks is small, the effect on the accuracy of kWh Meters of not measuring the energy in such peaks is likely to be minimal. This presumes good design and the use of correctly designed anti-alias filters.

Cause of Errors

The cause of these large errors arises from the choice of the sensor used to measure the current and its associated electronics. There are 4 options for sensors:

- A shunt (or resistor) in the current path. The voltage drop across the shunt is measured.
  The sensor itself is unlikely to be affected by high crest factors;
- A Current Transformer (CT).
  Short term transients with a frequency up to about 10kHz will be accurately passed through the CT; higher frequencies will be subject to errors. Additional errors can be added by the electronics if not designed to fully deal with the amplitude & frequency components of the transients.
- A Hall-Effect sensor.
  From the tests carried out, this type of sensor will give a low reading. At this stage, I have not identified any explanation for the errors
- A Rogowski device.
  This is an air cored coil which surrounds the current carrying cable.
  These devices can be used to accurately measure high frequency transients, but the associated circuitry must be suitably designed. As the output from a Rogowski sensor is proportional to the rate of change of the current, namely $^{di}/_{dt}$, this signal has to be integrated to provide a signal proportional to the current.
  Where this integrator is designed for power frequency signals and the lower harmonics, fast transients saturate the integrator causing errors. If the integrator is designed for such transients, the output will be a much reduced signal level. This can be amplified, but the increased noise levels will affect accuracy, particularly where the measured current is small.

Other Problems

Extensive use of electronic equipment such as VFDs, LED lights, etc. can be a problem where standby generators are used or new buildings are designed for maximum energy efficiency. Standby generators need to be overrated to allow for the initial surge (say 50% instead of 44%). For new buildings, to prevent overheating and distorted voltages, supply transformers need a MVA rating possibly twice the power rating.

Conclusions

ESMIG in their position paper state that the Smart Meters being installed in the UK & Europe will be unaffected by such signals [6]. They confidently say that:

- The electromagnetic interference phenomena created in the tests of the University of Twente grossly exceed emissions limits allowable under EU regulation for equipment typically used in households.
- These conditions would not be found in any imaginable normal household scenario.
- There is no reason to question smart metering technology

ESMIG may be right, but it is rare for a householder to be aware of EMC regulations. I can also well imagine a situation where 10 or more LED lamps may be connected to a dimmer to create the right ambience. As to dimmable or otherwise, ESMIG assure us that non-dimmable lamps were used in the tests – and they dimmed ! Clearly if Electrical Engineers try to dim non dimmable LED lamps, what is to stop a householder doing the same ? I agree that the emissions generated in the tests are higher than normally found, but such cases may well occur.

If such interference affects certified Smart Meters, it will ultimately be a problem for the utilities and further reduce public confidence. As to sub metering, there is no such fall-back. As a manufacturer, ND is replicating the test system used in Holland to check the effect of such transients on its meters.

However, since all Meters manufactured by ND use current transformers as sensors; the tests so far have shewn that, with this type of sensor, errors are relatively small. As to other manufacturers, it is a case of "*Caveat Emptor*".

References & Source Material

Kris Szajdzicki is the founder (and now a director) of ND Metering Solutions. He has been designing & manufacturing kWh Meters for about 40 years, specifically for Energy Management applications. He has also represented the Energy Management Industry on numerous standards committees such as IEC TC/13 dealing with electricity metering, IEC TC/66 on product safety, ISO TC/301 on Energy Management, etc.

[1] Frank Leferink
https://www.utwente.nl/en/news/!/2017/3/313543/electronic-energy-meters-false-readings-almost-six-times-higher-than-actual-energy-consumption

[2] Frank Leferink
Runaway Energy Meters due to Conducted Electromagnetic Interference
Proc. of the 2016 International Symposium on Electromagnetic Compatibility - EMC EUROPE 2016, Wroclaw, Poland, September 5-9, 2016

[3] Frank Leferink
Static Energy Meter Errors Caused by Conducted Electromagnetic Interference
IEEE Electromagnetic Compatibility Magazine – Volume 5 – Quarter 4

[4] Frank Leferink
Conducted Interference, Challenges and Interference Cases
I EEE Electromagnetic Compatibility Magazine - Volume 4 - Quarter 1

[5] Dimensioning a UPS/Inverter for LED crest factor

[6] ESMIG Position paper
Static energy meter errors caused by Electro Magnetic Interference, March 2017

[7] Shuttle Lighting
Dimensioning a UPS/Inverter for LED crest factor