Electromagnetic Interference in Smart Grids

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Abstract – The increasing conducted interference caused by modern electronic equipment is causing more problems for electronic, or static, energy meters. If equipped with a communication link they are called smart meter. Because the smart meter is a key device in smart grids, any deviation has huge impact on the reliability of any prediction of the energy consumption or production. It is known that conducted electromagnetic interference, for instance due to active infeed converters as used in photovoltaic systems, can cause a lower static energy meter reading. In a controlled environment it was found that three-phase meters can also give higher energy readings. These experiments were performed using an ideal sinusoidal voltage from a four-quadrant power amplifier with defined power supply impedance. Increased energy reading of +276 %, but also decreased energy meter reading of -46%, was observed. Measurements were repeated, with more meters, and supplied from a standard, low internal impedance, mains supply in the laboratory. Now positive reading up to +582%, and negative reading down with -32% were registered.

Keywords: Conducted interference, smart meter

I. INTRODUCTION

Conducted interference is one of the oldest types of electromagnetic interference (EMI), and covers also power quality effects between equipment, as also reflected in the title of IEC 61000-4-30 [1]. The quality of power supply is covered in EN 50160 [2]. We are observing a rapidly increasing number of serious EMI issues due to conducted interference effects. Especially in the frequency range 2-150 kHz, because only a few standards exists and nearly no requirements are taken into account [3]. The effects we have to consider should not be examined in the frequency domain but in the time domain, because modern equipment is non-linear, and non-stationary. Non-linear means that the impedance is dependant of the voltage supplied, and thus varies during the 20 ms (for 50 Hz) period. Non-stationary means that the impedance is dependant of time; In principle this is valid for any semiconductor load. Conventional equipment with linear (resistive) load impedance, which also act as a damper, is decreasing. That means that the mains impedance varies and interference effects become difficult to predict. The Smart Cities will result in many interconnected power electronic devices (loads, generators), as most loads ae not just a resistive load such as a light bulb, or inductive load as the washing machine motor. Modern devices have semiconductors to convert energy, for instance for light emitting diode (LED) or to control the speed of a motor using a power drive system in a washing machine. To communicate the control signals, the same Smart Cities need power line telecommunication (PLT) for, for instance, automatic meter reading, and control. When performing measurements in large installation, or even households, we observe huge non-intentional emission (disturbance) levels, as well as intentional emission levels which are higher than the test levels. Furthermore standard like the IEC 61000-4-19 [4] immunity test require levels for open circuit which will decrease when injecting. This standard has been rushed-through to deal with failing static energy meters due to interference caused by photovoltaic (PV) power electronics. The static energy meters gave a lower reading of the consumed or produced energy than actually was present. In Figure 1 the noise voltage between neutral and earth as measured in a PV installation is shown. This resulted in a lower energy reading than actually produced.

In recent years also higher static energy meter readings were observed. In [5] it was shown that a normal dimmer connected to modern lightning can cause a higher static energy meter reading upto 276%. These test were performed using a standardized power supply impedance and an ideal voltage waveform generated by a 4-quadrant amplifier. When the energy meter were connected to the mains supply in the university building the energy reading of the meter was increased upto 582% [6].

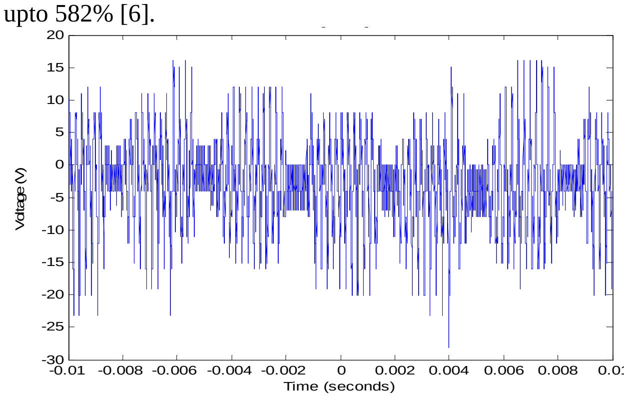

Figure 1 Neutral-earth voltage PV

II. STANDARD POWER SUPPLY

A single-phase ideal power supply was generated by a four-quadrant amplifier from Spitzenberger & Spies (S&S) PAS 5000. The S&S SyCore generator and the PAS 5000 are used to generate a controlled distortion-free ideal sinusoidal voltage waveform. The internal impedance of this source is less that 0.4+j0.25 Ω, as defined in the standard IEC 61000-4-11 [7]. Four different three-phase static energy meters have been tested in series with an electromechanical meter and a Dranetz PowerXplorer PX5-400, and an oscilloscope. These were used for reference energy measurements. Measurements with ideal sinusoidal, and with distorted voltage waveform have been performed. The loads used during the tests were power resistors, strings of CFL and LED lamps, a power drive system, and a dimmer driving these lamps. The dimmer creating a chopped part of a sinusoidal waveform, in case a resistive load would be used. Tests were performed during at least 24 hours, and sometimes over the weekend, over a 48 hour period. The registered energy of the static meters was measured using an Arduino microprocessor and optical sensors for detecting the pulses from the LED on the static meter fronts. The readings were verified using the liquid crystal display (LCD) reading on the meter. A recently calibrated conventional electromechanical meter based on the Ferraris principle was used as reference, because consumers are also using this as reference. Most experiments have been repeated to confirm the conclusions, and repeated again, and again, because some of the static energy meters gave large differences upto 276% [5]. To confirm and to further investigate the effects, a series of experiments have been performed over a period of 6 months, with tests lasting at least 1 week, sometimes several weeks. The reason for these long tests are the low energy consumption of the connected devices. The tests have been performed using standard mains supply. In this series, 10 static meters were connected in series with 1 electromechanical energy meter, and 1 phase was used, because some of the meters are single-phase types. The details setup is described in [6]. One static meter is using a shunt, others are using a Rogowski and Hall sensors. The deviations for the experiment with the dimmer and LED+CFL are shown in Table I. SM8 is a meter using the shunt principle. We could not confirm, without breaking the seals, if SM5 is also using the shunt, but it is likely. SM1, SM2, SM6, SM7 and SM9 are using the Rogowski coil and SM4, and we expect also SM10, are using the Hall principle.

Table I: Deviation of energy meters

Meter	Year of production	Dimmer 90^o	Dimmer 135^o	Dimmer 135^o, repeated
SM1	2013	60%	559%	566%
SM2	2007	64%	574%	581%
SM4	2014	-28%	-32%	-32%
SM5	2004	0%	-5%	-6%
SM6	2007	60%	563%	569%
SM7	2009	61%	575%	582%
SM8	2011	1%	0%	0%
SM9	2013	28%	480%	475%
SM10	2014	-25%	-31%	-31%

III. DISCUSSION

Many experiments were performed to find out if static energy meters can provide higher energy readings due to conducted interference caused by other equipment. We observed lower energy readings, and these effects have also been confirmed in research results of others in publications and standards. The lower energy readings were caused by power drive systems or active infeed converters, as well as the high PLT levels. The higher readings were caused mainly by dimmers driving LED and CFL. The reason for faulty readings appears to be the current sensor, and the associated circuitry. As a Rogowski coil results in a time-derivative of the measured current, the measured voltage has to be integrated. Probably active integration is used instead of passive integration, and the input electronics are pushed in saturation caused by the high rise-time of the current. Although the peak current level is below the maximum level stated for the meters.

Using the readings of smart energy meters in any smart grid optimization algorithm poses a risk for the stability of the grid. Therefore conducted interference effects shall be taken into account, and preferably be reduced. In [8] a long list of cases of severe pollution of the mains supply is described. Also the PLT signals are a risk for misreading of energy meters. On the other hand, any reduction of interference in power lines is also reducing the wanted PLT signal.

IV. CONCLUSION

The effect of poor power quality, or conducted electromagnetic interference, on static electronic energy meters causing a lower reading was known. A well- known cause of misreading is the interfering currents caused by active infeed converters for renewable energy. Recently it has been shown that modern static or smart meters can present also substantial higher readings. Using these excessive readings in any smart grid optimization algorithm poses a risk for the stability of the grid. Reducing conducted interference levels is one possibility, but will also hamper the quality of PLT signals.

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