A comparative analysis of induction and electronic active energy meters

Annalisa Liccardo[1], Nicola Pasquino[1], Nello Polese

[1]*DIEL Dept. of Electrical Engineering, University of Naples Federico II,*
Via Claudio, 21 – 80125 Naples ITALY
Phone +39 08176.83630; Fax + 39 0812396897
{aliccard, npasquin, polese}@unina.it

Abstract- A comparative analysis of induction and electronic meters with regards to active energy measurements is presented, based on results obtained by application of a designed plan involving several input factors such as power voltage amplitude, power frequency, voltage total harmonic distortion (THD) and flicker severity.

I. INTRODUCTION

Issues related to active and reactive energy meters characterization is undergoing a renovated interest by the scientific community for the new scenario in billing rules which is arising in European countries and for the whole new kind of end user machinery which operates on the electrical power network.
On the one hand, in facts, industrial, commercial and residential customers of power electronic equipments, such as adjustable speed drives, controlled rectifiers, cycloconverters, electronically ballasted lamps, arc and induction furnaces and cluster of personal computer may cause disturbances to flow through the network and reach other equipments and interfere with their normal operation. On the other hand, if disturbances reach an active energy meter located at the end user side, it is important to determine at what level such disturbances cause malfunctioning or measurement errors of the meter, the latter of which may turn out to have even worse consequences because metering can be erroneous.
The standard 2004/22/CE [1], recently accepted in Italy, establishes the error limits of energy meters, according to their precision class; as an example, Fig. 1 shows the error upper limits for class A, B, and C energy meters operating within 5°C and 30°C.

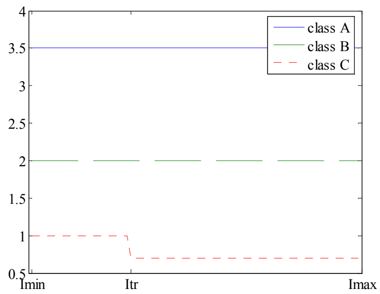

Figure 1 – Error limits in percent of energy meters according 2004/22/CE standard.

The manufacturer has to declare the current interval I_{min}-I_{tr} assuring that the error is lower than the declared limits, and the interval I_{tr}-I_{max} assuring that the error is lower than the lowest declared limits. The plotted errors have to be guaranteed also when the energy meter is reached by power quality disturbances. The standard establishes that the energy meter errors have to be maintained for disturbance level lower than the value reported in Tab. 1.

Disturbance	Percentage of disturbance limits		
	Class A	Class B	Class C
Voltage variation	$90\%V_n$-$110\%V_n$	$90\%V_n$-$110\%V_n$	$90\%V_n$-$110\%V_n$
Frequency variation	$\pm 2\%f_n$	$\pm 2\%f_n$	$\pm 2\%f_n$
Harmonic distortion	1%	0.8	0.5
Voltage unbalance	4%	2%	1%

Table 1 –Disturbance limits for energy meter classes

These limits, however, results lower than disturbance levels accepted on power lines by the standard EN 50160 [2]. It is thus important to verify that the rated errors remain into the limits shown in Fig. 1, when the meter is reached by every possible disturbance on the transmission network.

Therefore, a comparative analysis of active energy meters when subjected to distorted voltages and currents has been undertaken, following a research topic that the authors have already worked on and presented in previous papers [3-5].

II. EXPERIMENTAL SETUP

The experimental activity has been based on an appropriately designed experimental plan capable of highlighting the most important features of the chosen input factors, that could cause an error increasing of the energy meter. At this aim, the considered factors have been: power voltage amplitude, power frequency, and voltage total harmonic distortion (THD). The power voltage and current have been generated by a calibrated power source setup in a virtual load configuration so to obtain two independent waveforms for voltage and current signals. Variations of input factors have been applied following the designed plan shown in Table 2. They respect the largest variation allowed for power network quantities fixed by EN 50160.

Run	V [V]	f_0 [Hz]	THD [%]
1	230	50	0
2	230	49.5	4
3	230	50.5	8
4	207	50	4
5	207	49.5	8
6	207	50.5	0
7	253	50	8
8	253	49.5	0
9	253	50.5	4

Table 2 – Experimenal plan

A reduced factorial has been chosen for its properties of requiring a reduced set of experimental points yet allowing all main effects to be observed, i.e., the effects of each input factor. The plan inherently assumes that no interaction between factors exists so that a linear model is assumed for the behavior of the output quantity with respect to the inputs. The voltage signal in each run takes the general form:

$$v(t) = V\left\{\sin(2\pi f_0 t) + kv\left[\sum_{i=1}^{5}\frac{1}{hv_{2i+1}}\sin((2i+1)\pi f_0 t)\right]\right\} \tag{1}$$

where V is the *rms* voltage amplitude, hv_{2i+1} is the amplitude factor chosen according to the peculiar attenuation law of harmonic amplitudes and k is a constant factor adopted to obtain the required THD value. The terms hv_{2i+1} depend on the law at which harmonic frequencies are assumed to attenuate; authors are currently investigating the most common scenarios observed in power transmission network, in order to reproduce the same harmonics distribution.

When the harmonics attenuation law is known, the fator k is obtained as:

$$kv = THD_v \Big/ \sqrt{\sum_{i=1}^{5}\frac{1}{hv_{2i+1}^2}} \tag{2}$$

The current presents essentially the same harmonic order as the voltage waveform but differs from it because the harmonic components have different amplitudes. Moreover, the current waveform shows a phase shift φ at the fundamental and harmonic frequencies, where φ is chosen so to obtain $\cos(\varphi)=\{1,0.3, 0.5\}$:

$$i(t) = I\left\{\sin(2\pi f_0 t + \varphi) + ki\left[\sum_{i=1}^{5}\frac{1}{hi_{2i+1}}\sin((2i+1)\pi f_0 t + \varphi)\right]\right\}, \tag{3}$$

where coefficients ki and hi_{2i+1} are evaluated as those obtained for the voltage.

III. EXPERIMENTAL RESULTS

In this section some preliminary results, which will be widely extended in the final version of the paper, are presented. They refer to the experimental plan shown in Table 2, with a linear harmonic amplitude attenuation law and with $\cos(\varphi) = 1$ and 0.5. Figure 2 presents the mean effects of each input factor at each level on the relative error of the induction meter with respect to a reference meter:

$$e = \frac{E_m - E_w}{E_w}, \tag{4}$$

where E_w is the energy obtained by the reference watthourmeter while E_m is the energy measured by the meter under test. . The measurement time has been fixed as the number of complete routes of the induction meter after a minute has been counted. $E_m = N/K$ where K is the calibration constant, i.e., 900 routes/kWh for the meter adopted. The reference energy has been evaluated by processing the voltage and current samples obtained from two Hall effect transducers (with 0.1% accuracy) and a data acquisition board (16 bits resolution).

It can be seen that the two scenarios differ by an order of magnitude in terms of relative error, and while $\cos(\varphi) = 1$ shows a mean error $e \approx 0$, $\cos(\varphi) = 0.5$ show an overall mean error at about 1.6%. Beside that, the dependence with the input factors seems to be quite the same: generally speaking, increasing values of the inputs determine a decrease in the error, even if the slope of such variations change in the two cases.

In the final version of the paper, the complete set of experiments will be presented, including those with the electronic meter and the third value of phase delay mentioned above.

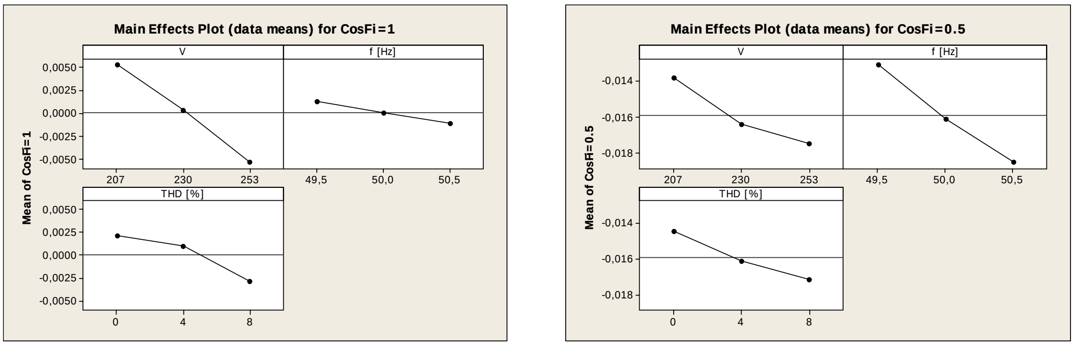

Figure 2 – Experimental results for induction meter

REFERENCES

[1] Measuring Instruments Directive (MID) 2004/22/EC.

[2] EN 50160, “Voltage characteristics of electricity supplied by public distribution systems”, CENELEC, 1999.

[3] D.Gallo, C.Landi, N.Pasquino, N. Polese “A New Methodological Approach to Quality Assurance of Energy Meters Under Non-Sinusoidal Conditions”, Instr. Measur. Techn. Conf. (IMTC/06), Sorrento, Italy, 24-27 April 2006.

[4] D. Gallo, C. Landi, N. Pasquino, N. Polese, A Methodology for Quality Assurance in Energy Measurements under non-sinusoidal Conditions, XVIII IMeKo World Congress,Rio de Janeiro, Brazil,September 17-22, 2006.

[5] D. Gallo, A. Liccardo, N. Pasquino, Performance Analysis of an Active Energy Induction Meter using an Innovative Approach, XVIII IMeKo World Congress, Rio de Janeiro, Brazil, September 17-22, 2006.