PRECISION CHECK OF ENERGY METERS UNDER NONSINUSOIDAL CONDITIONS

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ABSTRACT

The paper describes methods and results for precision testing of standard energy meters. Several meters were tested in different harmonic condition with various types of electronic load. Linear load, phase fired control load and switched-mode load were used. Results of testing were evaluated and displayed in graph and tables. The proposal of standard testing methodology is described in conclusion.

INTRODUCTION

Almost all mechanical (Ferraris) electricity meters had been replaced by static electricity meters nowadays. According to the international standards IEC 50470-1 [1] and IEC 50470-3 [2] focused on static meters has to be checked the precision of electricity meters during certain non-harmonic condition: one way certifier, phase fired control, sub-harmonics (current 2 periods ON, 2 periods OFF), voltage and current with content of harmonic 5th.

Still increasing content of electronic loads in industry and among home appliances produces distorted current. Most harmonic pollution nowadays is created as harmonic current produced by loads in individual installations. This harmonic current, injected into the network impedance transfers into harmonic voltage, (Ohm's law); which gets applied to all the loads within that user's installation.

The active power under non-sinusoidal conditions is sum of active powers on all harmonic. There is no active power on particular harmonic, when exists particular current harmonic without particular voltage harmonic. In real power network particular current harmonic causes voltage harmonic because of network impedance. If the power network impedance is low in certain location of power network, then the contribution of particular harmonic current to voltage distortion could be low. Anyway the voltage could already contain certain amount of harmonic voltage specified frequency.

EXPERIMENTS

Because of the available equipment, the programmable power supply Agilent HP6834B with arbitrary waveform output was used as the programmable power source. The generated voltage and load current was monitored by voltage and current input digitizer modules with 24-bit resolution (NI 9225 and NI 9227). The data was acquired by cDAQ chassis connected by USB to PC and analyzed by SW written in LabVIEW. The result of this measurement is information about basic electrical quantities and spectra of voltage, current and active power. As the reference electricity meter the YOKOGAWA W210 Power Meter was used.

Figure 1 Photo of practical experiment

Photo of practical experiment is shown in Fig.1. Following types of experiments were executed:

1. Ideal sinus 50Hz voltage with idealized linear load.
2. Ideal sinus 50Hz voltage with phase fired control load.
3. 50Hz fundamental harmonic voltage with 10% of 3rd phase shifted (45 degrees) harmonic, idealized linear load.
4. 50Hz fundamental harmonic voltage with 10% of 5th phase shifted (170 degrees) harmonic, idealized linear load.
5. 50Hz fundamental harmonic voltage with 10% of 7th phase shifted (160 degrees) harmonic, idealized linear load.
6. 50Hz fundamental harmonic voltage with 10% of 9th harmonic without phase shift, idealized linear load.
7. 50Hz fundamental harmonic voltage with mix of following harmonics: 6% of 3rd phase shifted (110 degrees), 5% of 5th phase shifted (200 degrees), 4% of 7th without phase shift and 1% of 15th phase shifted (60 degrees). 8 pieces of PC computers with LCD monitors were the load with power consumption of 695W.
8. 50Hz fundamental harmonic voltage with mix of following harmonics: 6% of 3rd, 5% of 5th, 4% of 7th, 3% of 9th and 10% of 15th harmonic. Load was linear.
9. 50Hz fundamental harmonic voltage with 20% 10th harmonic with idealized linear load.

10. 50Hz fundamental harmonic voltage with 10% 20th harmonic with idealized linear load.
11. 50Hz fundamental harmonic voltage with 10% 30th harmonic with idealized linear load.
12. 50Hz fundamental harmonic voltage with 10% 40th harmonic with idealized linear load.
13. 50Hz fundamental harmonic voltage with 10% 50th harmonic with idealized linear load.

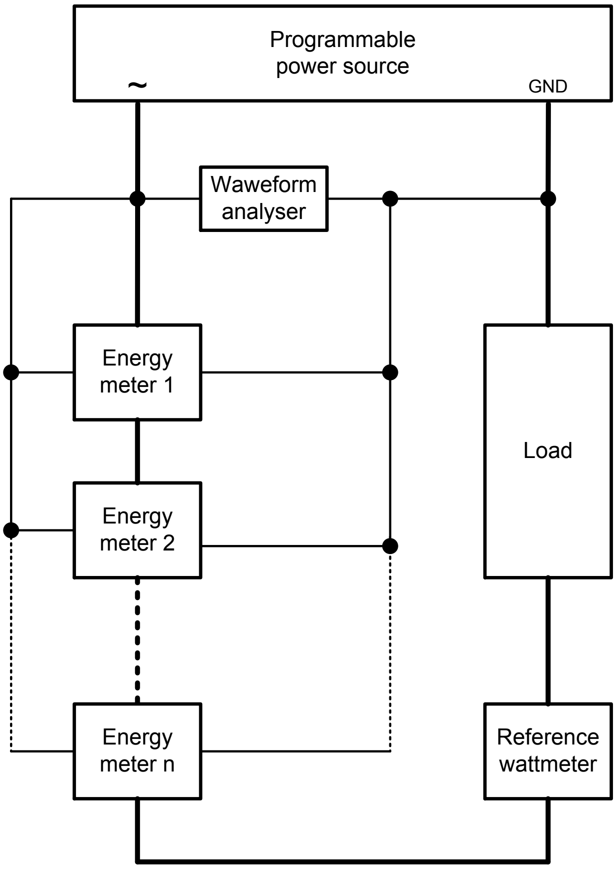

Figure 2 Block diagram of measurement

The block diagram is shown in Fig.2. There is programmable arbitrary function power source which can provide 1000Watt of maximum output power. The waveform analyzer samples voltage and current signals and calculates RMS voltage, RMS current, active power, reactive power and power spectra. Energy meters are connected in serial order. There is on reference wattmeter and load. Three types of load are used in experiments:

- Idealized linear load, it was made from combination of halogen lamps.
- Fired phase control load, it was made from fired phase control circuit and combination of halogen lamps.
- Electronic load, it was made from eight computers with LCD monitors. Total power consumption of this set was 695Watts.

Each one experiment takes from 1 to 2 hours. Total transferred energy in one experiment was about 1000Wh. In total 6 energy meters were tested. Following energy meters and their quantity were in tests:

- 3 pieces of KRIZIK E1S-12T, (meters Nr.1-3)
- 1 piece of LG ZMF120A, (meter Nr.4)
- 1 piece of LG ZMD410CT, (meter Nr.5)
- 1 piece of ITRON SL7000, (meter Nr.6)

Energy was measured by optoelectronic component which was placed on energy meter optical signalization. Pulses were counted by six 64-bit counters realized on National Instruments CompactRIO.

RESULTS

The result of experiment with idealized linear load is shown in Fig.3. Those graphs describe voltage and current waveforms and power spectra in experiment Nr.4. The current waveform has the same shape as voltage waveform. The power spectrum is shown as well. There are two harmonics in the power spectrum: 50Hz fundamental harmonic and 10% of harmonic 3rd.

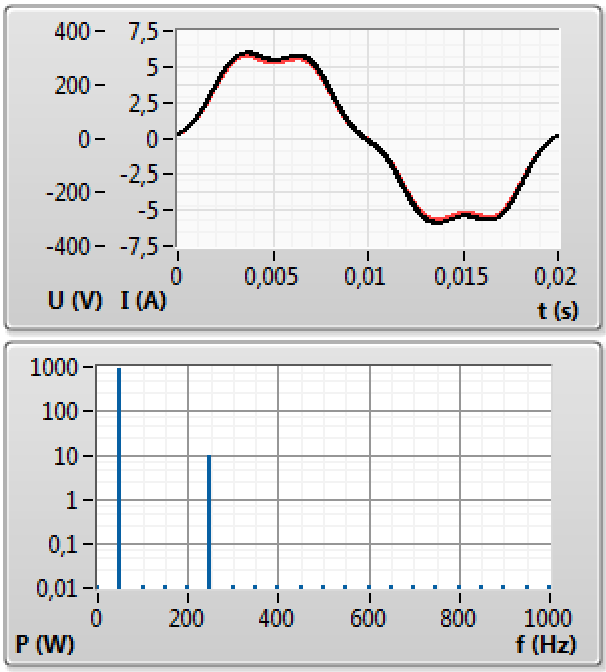

Figure 3 Experiment with idealized linear load

The different type of experiment is shown in Fig.4. There is presented measurement with fired phase control load. This is the result of experiment Nr.2. The voltage waveform is 50Hz sinus. Shape of the current waveform is distorted because the fired phase control was used. The power spectra components are shown in power spectra graph. The blue color displays positive power which is supplied to the load. The yellow color describes negative power which flows back from the load.

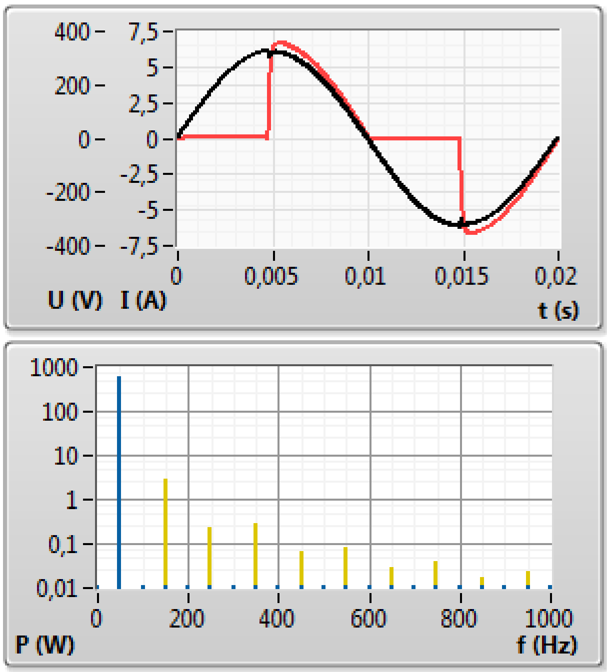

Figure 4 Experiment with fired phase control load

The voltage and current spectra in experiment with fired phase control load is shown in figure 5.

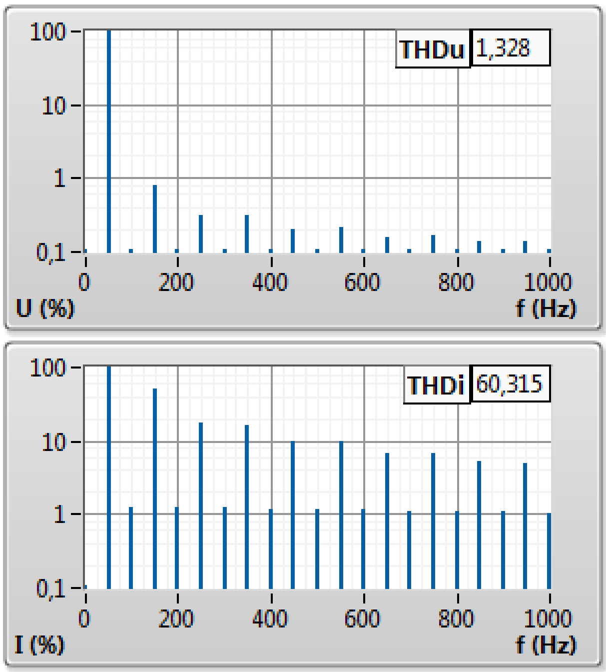

Figure 5 Spectra with fired phase control load

The last type of experiment is shown in Fig.6. There is presented experiment Nr.7 with electronic load (8xPC). The voltage waveform is distorted to maximum value limits described in international standards. This simulation shows the worst real condition in power net. The current waveform is distorted because the load is nonlinear.

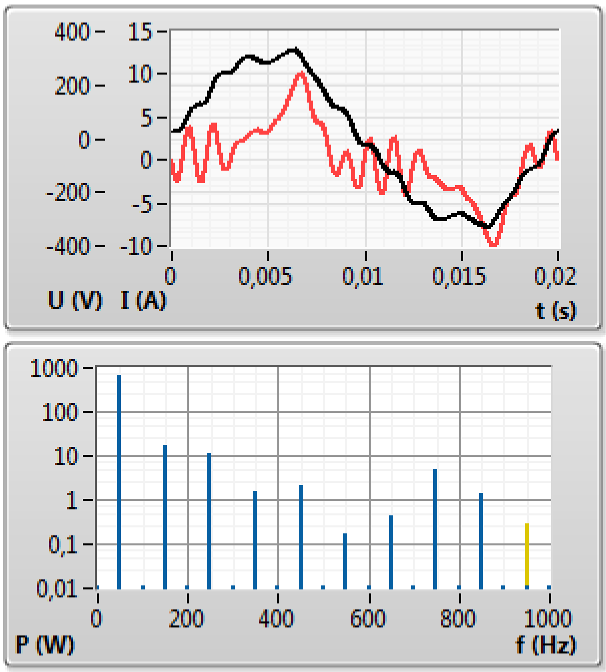

Figure 6 Experiment with electronic load

Voltage spectrum in experiment number 7 is shown in figure 7. The current spectrum is shown here as well. The figure shows influence of every even harmonic components.

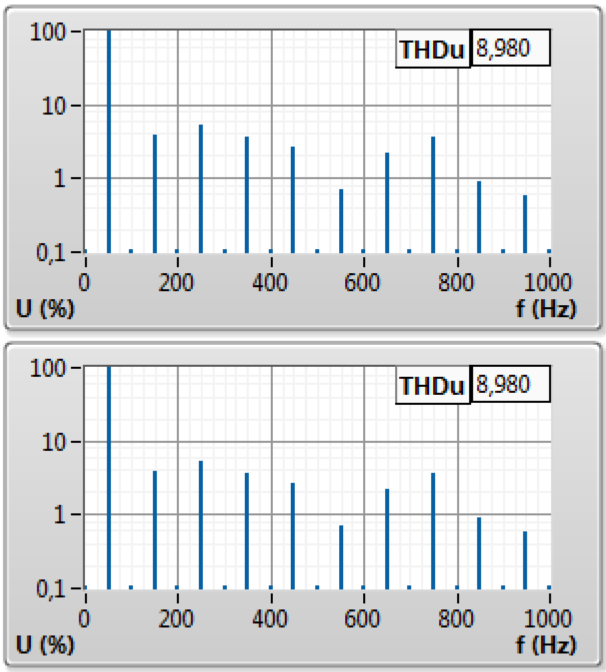

Figure 7 Spectra with electronic load

Frequency components in current spectra are caused by electronic load. The power source Agilent HP6834B has low internal impedance and this causes very small harmonic components on voltage when pure sinusoidal waveform is generated. To simulate the real power network with distorted voltage, appropriate harmonics were generated on voltage with such phase shift to get maximal active power on each particular harmonic of power spectra.

RESULTS

Results of all testing cases described in chapter "EXPERIMENTS" are summarized in Tab.1.

Table 1 Results – List of Meters Errors

METER:	1	2	3	4	5	6
Experiment 1	-0,22%	0,81%	-0,05%	0,46%	0,09%	0,00%
Experiment 2	-0,12%	0,65%	-0,21%	0,60%	0,16%	0,00%
Experiment 3	-0,83%	0,24%	-0,56%	0,51%	0,13%	0,21%
Experiment 4	-0,13%	0,98%	0,24%	0,67%	0,15%	0,27%
Experiment 5	-0,89%	0,59%	-0,71%	0,53%	0,11%	0,22%
Experiment 6	-0,53%	0,73%	-0,53%	0,60%	0,13%	0,25%
Experiment 7	6,60%	6,78%	6,23%	3,34%	0,33%	0,43%
Experiment 8	-0,12%	0,73%	0,19%	0,50%	0,12%	0,29%
Experiment 9	-0,48%	1,35%	-0,32%	0,46%	0,11%	0,26%
Experiment 10	-0,92%	0,37%	-1,24%	-0,86%	-0,04%	-0,89%
Experiment 11	-1,49%	0,45%	-2,50%	-2,48%	-0,28%	-4,01%
Experiment 12	-1,72%	0,69%	-3,24%	-3,68%	-0,62%	-4,21%
Experiment 13	-0,97%	2,24%	-3,25%	-4,29%	-1,04%	-4,55%

For some signal shapes and different types of electronic load all the electricity meters provide result with significantly increased error. The error was calculated as ratio between measured value by energy meter under the test and value of reference wattmeter. The worst cases are highlighted. It has to be admitted, that conditions of experiments Nr.10-12 are improbable in real distribution network.

CONCLUSION AND DISSCUSION

The 4 types of energy meters were tested in this work. The significant error is shown in simulated real load condition. The most interesting result was experiment Nr.7 with electronic load. The error has positive character that means the energy meters integrated more energy than real state is. In general the cheapest energy meters measured with worse error than expensive ones. The error rises to more than 6 %. For idealized linear load the error is less than 1% in experiment Nr.1 to 6. The error in experiment Nr.8 to 13 was up to 4% and it was mostly negative that means the meter measured less energy than was transferred.
The work can be used to propose new methods for standard testing of energy meters.

ACKNOWLEDGMENTS

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