Calibration system for voltage transformers under distorted waveforms

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Abstract: In this work, we describe a programmable high-voltage source to test the behavior of voltage transformers under distorted waveforms at nominal voltages, as well as the measurement system for computing their errors at each harmonic component.

Keywords: Harmonic, distortion, instrument transformer, power network, power quality, high voltage.

1. INTRODUCTION

Measurements of voltage harmonic distortion in power networks require of voltage transformers (VT). Their primary voltages are in the range of 6 kV to 500 kV, or even more. The errors they have under distorted waveform must be tested at nominal voltages [1]. For this reason, a programmable high voltage source was developed. It has the possibility to program any harmonic content, up to the 100th order of the power network frequency. Additionally, the same system allows to measure the errors of the VT under test, for each harmonic component. The following sections describe the developed system.

2. HIGH VOLTAGE SOURCE

2.1. Waveform generator

The waveform generator is based on a digital-to-analog converter, with a resolution of 16 bits, model DAQ 6211 from National Instrument [2], and a PC running a LABVIEW [3] based software developed for this application. The software has six screens: Generation, Measurements, Secondary, Primary, Ratio and Configuration. The first and the last ones are used to configure the waveform and generate it. In these screens (see figure 1), the fundamental frequency (50 Hz to 60 Hz) and the percentage and angle of each harmonic, up to the 100^{th} order, are entered. The software calculates the values of the data vector and finally loads this vector into the DAC. The output signal has a range of ±10 V. A voltage divider attenuates the signal to values compatibles with the input of the power amplifier (0.5 V). There are buttons to record and load distorted waves, buttons to load waveform into the card and to null the output voltage.

2.2 *Power voltage source*

The power voltage source has three main blocks. The first block is the dc power supply (see figure 2). It use a 20 kVA, 220 V /110 V, 50 Hz three-phase transformer with two secondary windings, one in delta and the other in star connections. A 12 pulse rectifier converts ac to dc. It has two three–phase full wave rectifiers each. At its output, there is a bank of capacitors (15 mF in total) for filtering.

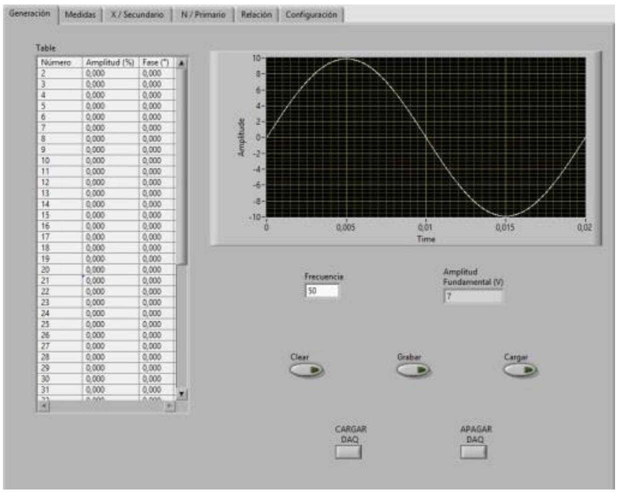

Fig 1. Waveform generation screen.

The second block is a 50-kW class-D audio power amplifier and auxiliary devices, as 13 V dc voltage source for the internal signal stage of the amplifier, multi-function meter for monitoring the power factor, current transformer, etc. The amplifier is energized with 300 V generated by the dc power supply. This amplifier can manage signals of 0.5 V, from 50 Hz to 3 kHz. These signals are amplified to values near 200 V rms, with currents of tens of amperes. Additionally, the system uses a series resistor at the output to increase the power factor (not shown in figure 2). Figure 3 and 4 show the arrangement of the different parts of the system in the rack.

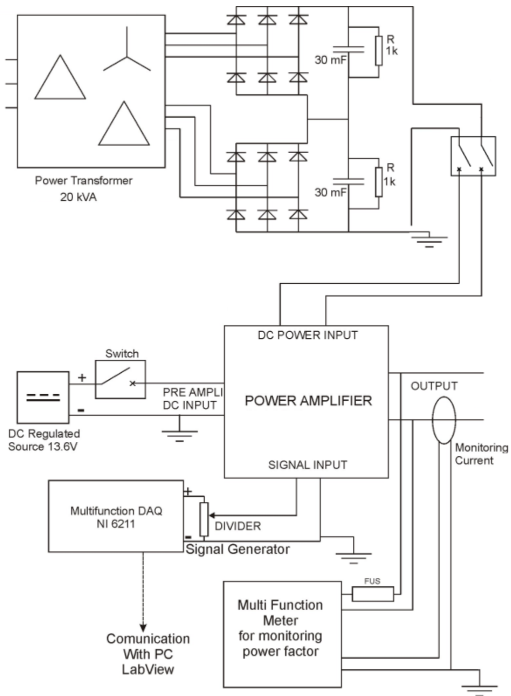

Fig 2. Power voltage source block diagram.

The third block is a step-up voltage-transformer, with bandwidth in the range 50 Hz to 3 kHz, to get tens of kilovolt, according to the nominal voltage of the device under test. Different transformers were used. As the nominal voltage increases, the bandwidth decreases. To get the required harmonic amplitude at the VT under test, higher values must be generated.

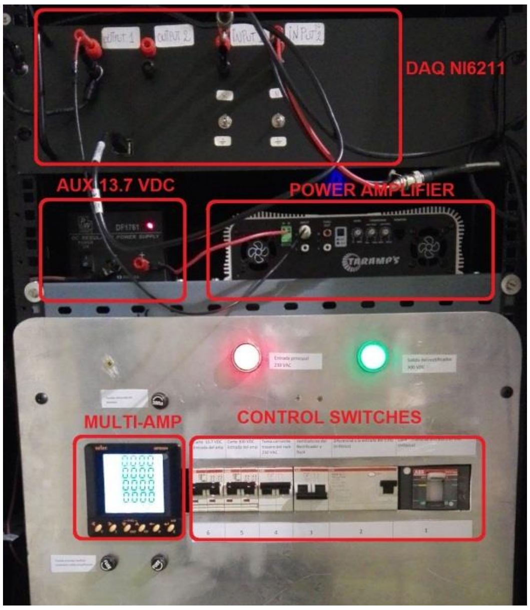

Fig 3. Power voltage source panel.

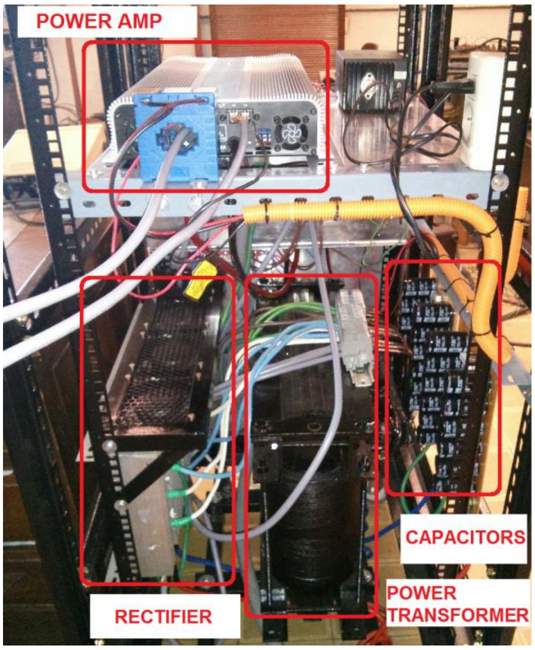

Fig 4. Internal view of the power voltage source.

2.3 Measurement system

The primary and secondary voltages of the transformer under test are scaled by voltage dividers. The primary voltage is scaled down by a capacitive type divider made by a 100-pF-SF6 high voltage capacitor in series with an array of low voltage capacitors. The divider constant has a value of 20071. The secondary voltage is scaled down by a resistive type divider made by a set of high thermal stable resistors (Vishay). The arrangement of these resistors has been constructed in such a way that it is possible to obtain two output values. The first one has a divider constant value of 21 and the second one, a divider constant value of 42. With these two ratios and the ranges of the harmonic meter, it is possible to feet a large range of VTs. Figure 5 shows the general diagram.

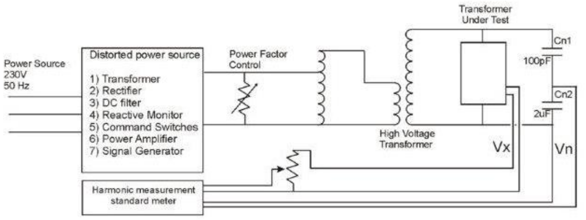

Fig 5. General diagram of the measurement system.

The outputs of the voltage dividers are sent to the analogue-to-digital converters (ADC) of the DAQ 6211. This ADC has a resolution of 16 bits in 8 differential inputs with ranges: 0.2 V, 1 V, 5 V and 10 V. Our system only uses two of those inputs. Both input channels are digitized synchronously, to allow the phase measurement between them, and the data is sent to the PC.

An Interpolated Fast Fourier Transform algorithm reconstructs the two signals obtaining information about the harmonic content of each one. It includes the amplitude and the phase for each harmonic component. There is a screen of the software for entering the values of the voltage dividers (module and phase), and the nominal ratio of the transformer to be tested.

The resulting ratio and phase shifts errors for each harmonic are computed and shown in the Ratio screen (figure 6). It includes type-A uncertainties.

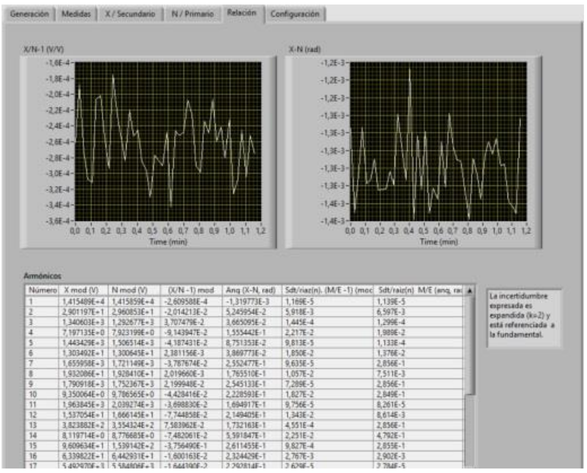

Fig 6. Ratio screen.

Figure 7 reproduces the Primary screen that shows the measured waveform of the primary voltage and its harmonic content (bar graph and table) of the transformer under test. A similar screen exists for the secondary voltage.

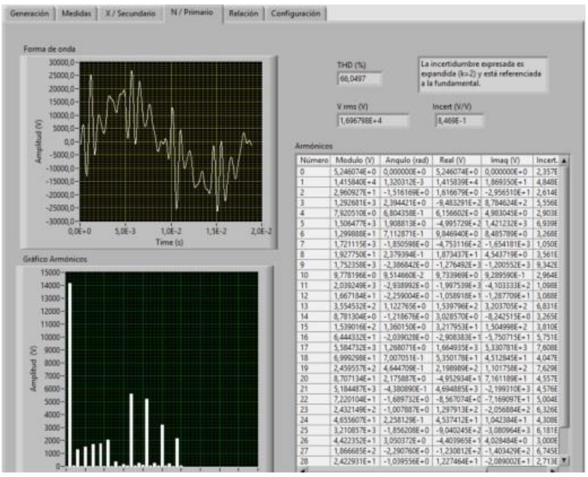

Fig 7. Primary waveform screen.

3. CONCLUSIONS

A system that generates and measures distorted voltage waveforms was described. It can calibrate voltage transformers determining the errors in amplitude and phase for each harmonic, up to the 100^{th} component. It was used for transformers up to 500 kV.

Discussion on the uncertainty of the calibrations will be presented at the conference.

6. REFERENCES

[1] Daniel Slomovitz, Gonzalo Aristoy, Alejandro Santos1, Marcelo Brehm, Leonardo Trigo, “Behavior of voltage transformers under distorted waveforms,” this issue.

[2] www.ni.com/pdf/manuals/371931f.pdf

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ACKNOWLEDGMENTS

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