16th International Conference on Energy and Climate Change

11-13 October 2023 - Athens, Greece

Total Harmonic Distortion of the Electrical Power Generated From PV Power Plant Online Measurement Virtual Instrument

Dr. Gentian DUME

Dr. Alfred PJETRI

Prof. Assoc. Astrit BARDHI

Dr. Marjola PUKA

Introduction

- Electricity demand has increased in recent years, while energy prices have increased dramatically.
- In Albania, electricity is mainly produced by hydroelectric plants. Solar energy conversion into electricity through photovoltaic panels (PV) is now more cost-effective and technologically advanced in terms of both cost and application.
- Nowadays, in Albania, several photovoltaic plants are in various stages of construction.
- In spite of the energy production, PV Power Plants inject into the electrical grid voltage harmonics because of the conversation for DC to AC through Power Electronic devices like inverters.
- In this work, we will present a virtual instrument built in the LabVIEW environment for the Total Harmonic Distortion (THD) measurement.

Introduction

- This is a custom-built device, which is customised to measure THD and to notify online for the voltage signal harmonics present besides the fundamental 50 Hz harmonic in the electrical grid, generated from a small-scale PV Plant in its AC side and to suggest in its front panel for the passive filter needed to be connected to reduce the THD to the allowed value by respective standard.
- This virtual instrument can be upgraded easily to automatically calculate and to select a passive filter and to connect it to the electrical grid to filter a specific harmonic of the voltage which is detected by the same instrument.
- This solution can be used to reduce the voltage THD generated from PV Plants and other electrical devices.

Harmonic distortion definition, sources and effects

- Harmonic distortion is a form of pollution in the electric plant that can cause problems if the voltage distribution caused by harmonic currents increases above certain limits. All power electronic converters used in different types of electronic systems can increase harmonic disturbances by injecting harmonic currents directly into the grid.

- Common non-linear loads include motor starters, variable speed drives, computers and other electronic devices, electronic lighting, welding supplies and uninterrupted power supplies. The effects of harmonics can include overheating of transformers, cables, motors, generators and capacitors connected to the same power supply with the devices generating the harmonics.

- Electronic displays and lighting may flicker, circuit breakers may trip, computers may fail, and metering may give false readings. If the cause of the above-mentioned symptoms is not known, then there is cause to investigate the harmonic distortion of the electricity distribution at the plant. The effects are likely to show up in the customer's plant before they show on the utility system.

Harmonic distortion definition, sources and effects

- In an ideal case the voltage and current in an AC grid is a pure sine wave and does not contain harmonics. In reality, voltage and current deviates from this pure sine wave and contains harmonics.

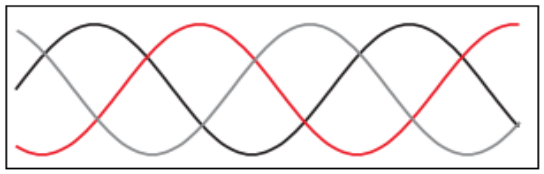


Fig. 1. A pure sinusoidal voltage and current does not contain any harmonics

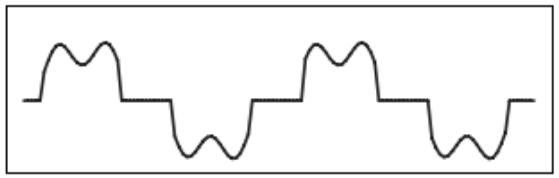
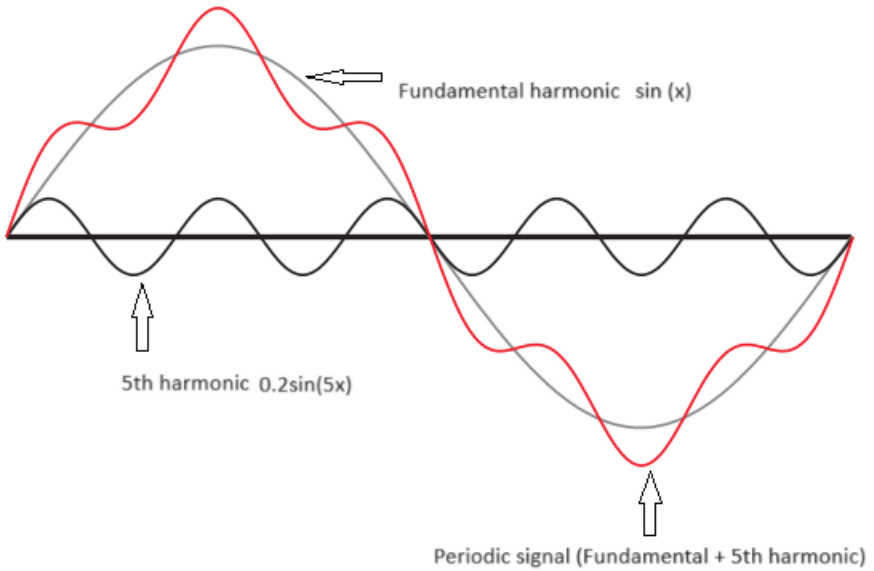


Fig. 2. Voltage and current that deviate from the sine form contain harmonics

- All continuous periodic signals can be presented as a sum of sinusoidal components: Fundamental + 3rd + 5th + 7th + …
- The principle of how the harmonic components are added to the fundamental current is shown in figure 1.3, where only the 5th harmonic is shown. Usually, harmonics are calculated up to the 40th or 50th order.



Harmonic distortion definition, sources and effects

- The amount of harmonic distortion is expressed as a THD % value:

$$THDi = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1}$$

-where I_1 is the rms value of the fundamental frequency current and In is the nth harmonic component.

$$THDv = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{V_1}$$

-where V_1 is the rms value of the fundamental frequency voltage and Vn is the nth harmonic component.

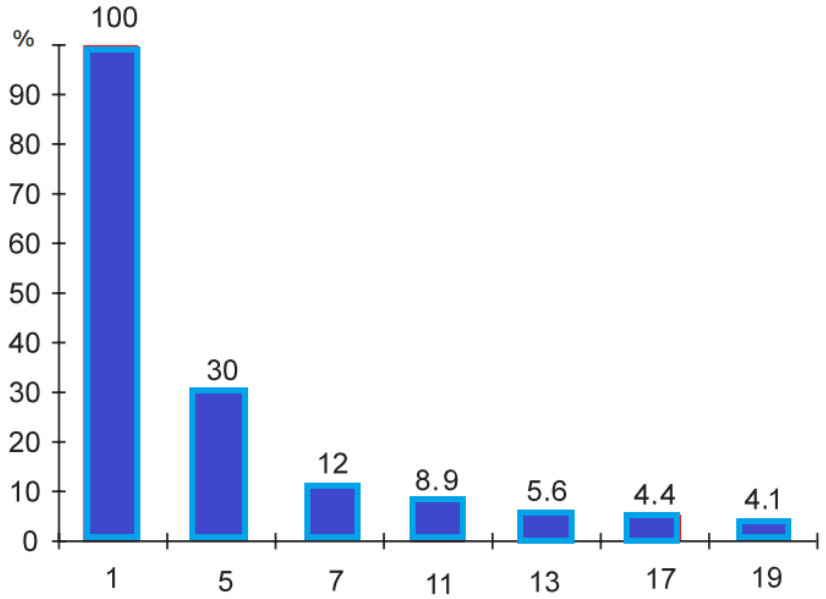


Fig. 4. Example of the harmonic content in a current of a 6-pulse rectifier (with coil).

Related work

“Electricity Generation Using Solar Power in Industrial Application – Case Study”

15th International Conference on Energy and Climate Change

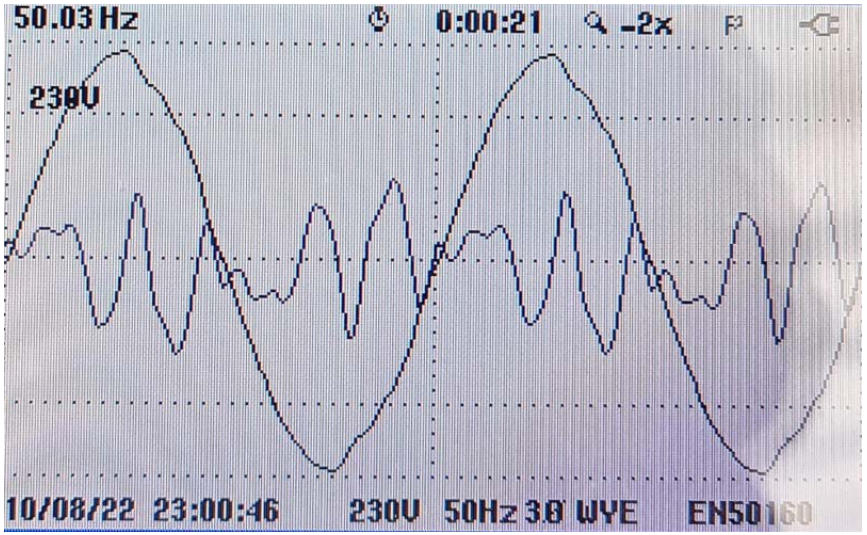


Fig. 5. Voltage and current waveform of the inverter

- The main problem encountered is the power quality.
- Except for the fundamental harmonic, the voltage and current spectrum of the inverter output contain high-order harmonics

- There are some problems in the power system with the increase of solar plants installed.

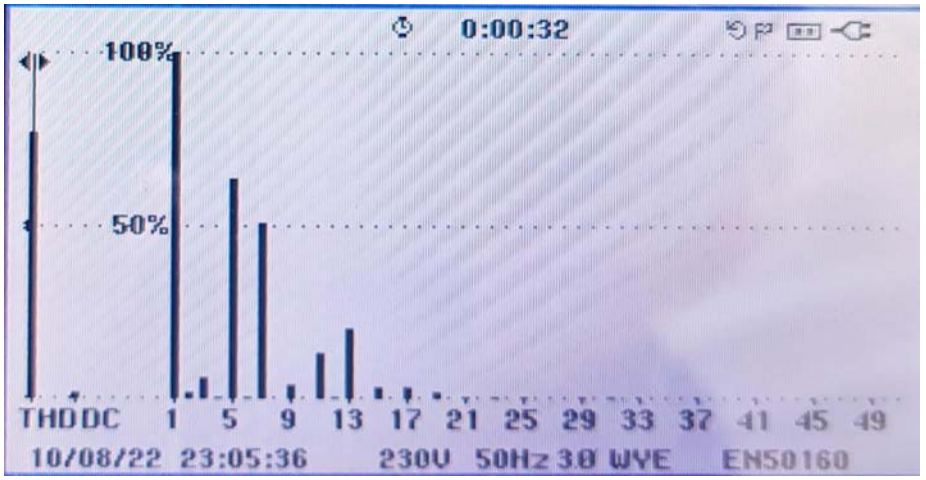


Fig. 6. Current spectrum.

- In this paper, we will present you a Virtual Instrument which was built with the help of one of the most popular engineering software among the engineering disciplines of many developed countries, called LabVIEW.

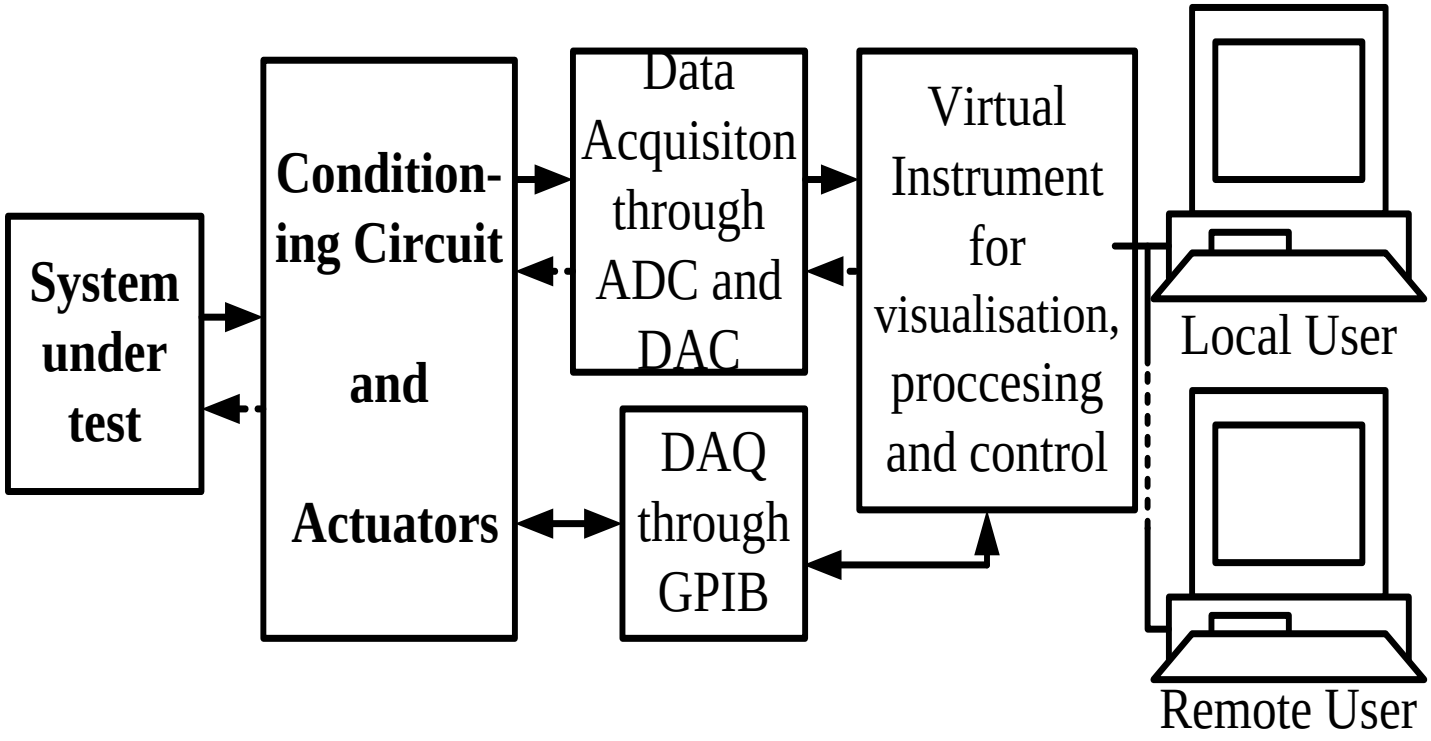


Fig. 7. Block diagram of a laboratory test bench based on PC

What are Virtual Instruments?

- The Virtual Instrument is defined as the combination of hardware and software in order to imitate the traditional measuring instrument.
- Traditional measuring instruments are built from predetermined physical parts that cannot be changed and are specific to the measurement they will perform.
- The main difference between physical and virtual instruments is that in virtual instruments the physical hardware is replaced by software, which is easily changeable and at no additional cost.
- The software allows complex and expensive measuring devices to be replaced by a computer that can serve many other functions.

Fig. 8. Analog Oscilloscope

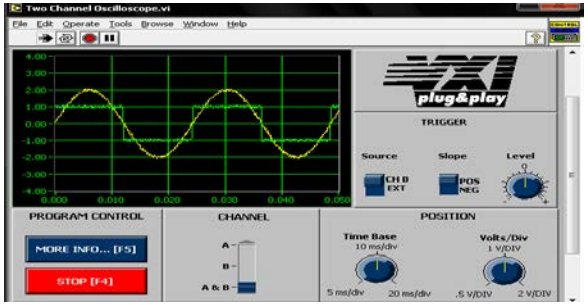


Fig. 9. Virtual Oscilloscope

LabVIEW

- LabVIEW is short for: Laboratory Virtual Instrument Engineering Workbench. It is a programming language in which the program is created using graphical symbols (connecting functional nodes with threads through which information flows).
- In this context it differs from traditional programming languages such as C, C++, Java, in which the program is written in the form of text.However, LabVIEW is more than a programming language.
- It is an interactive program especially for scientists and engineers, who need to program because they need it in the work they do.
- The LabVIEW programming environment is compatible with Windows, Mac OS X and Linux operating systems.
- LabVIEW can create programs that run on platforms such as Microsoft Pocket PC, Microsoft windows CE, Palm OS and a variety of special platforms such as FPGA (Field Programmable Gate Arrays), DSP (Digital Signal Processors), etc.

THD monitoring and improving

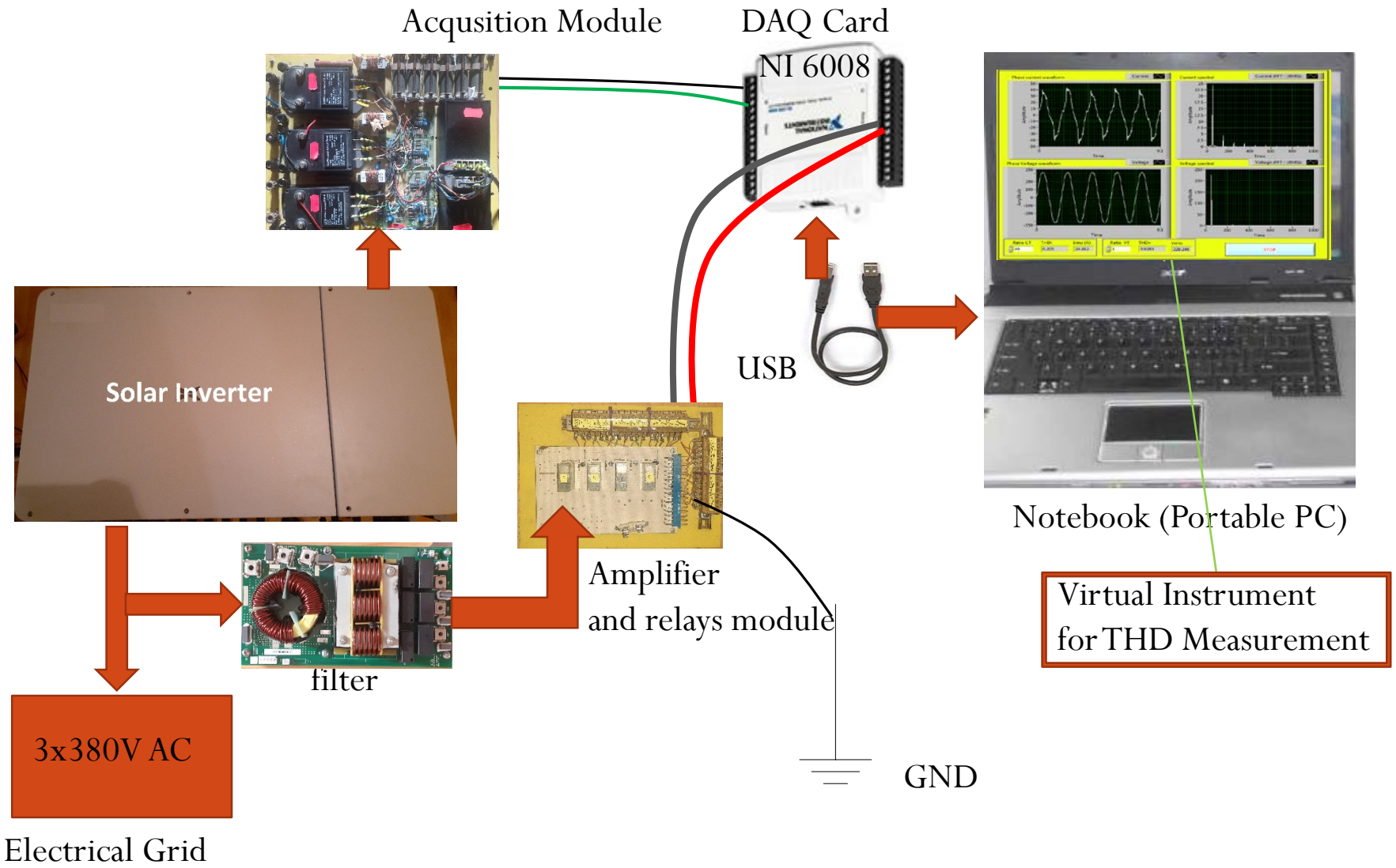


Fig. 10. THD measuring and lowering

THD proposed virtual instrument

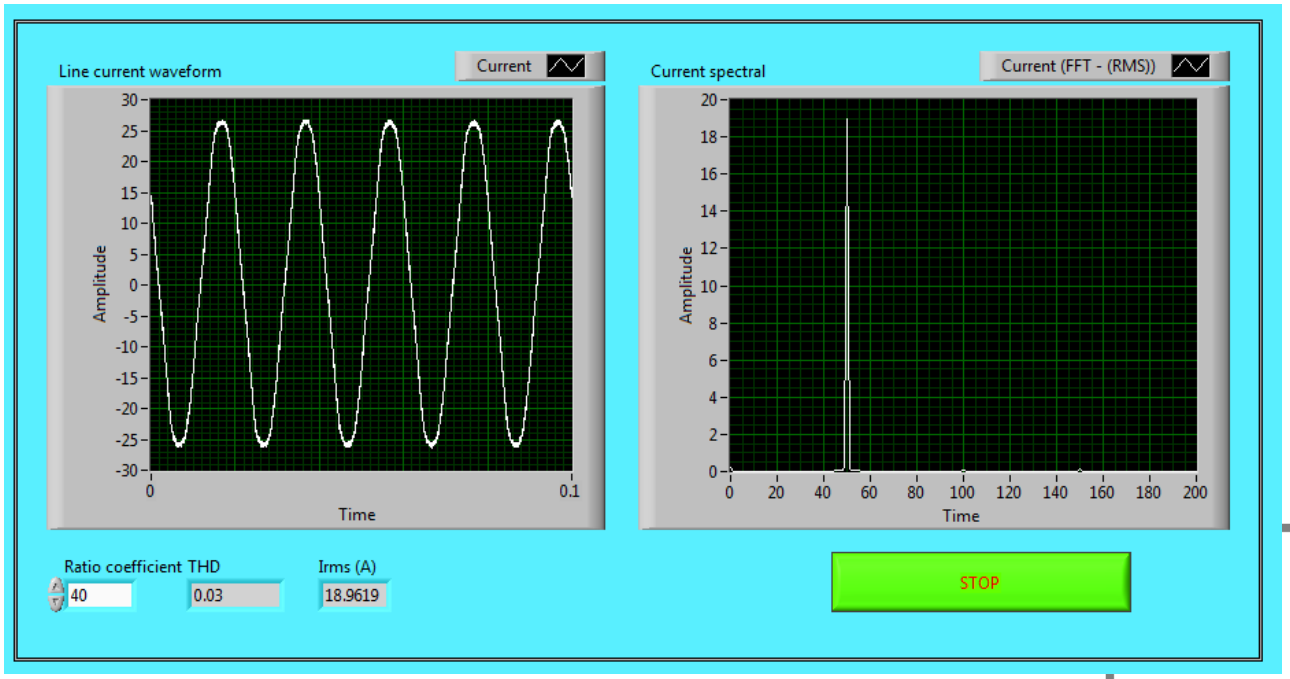
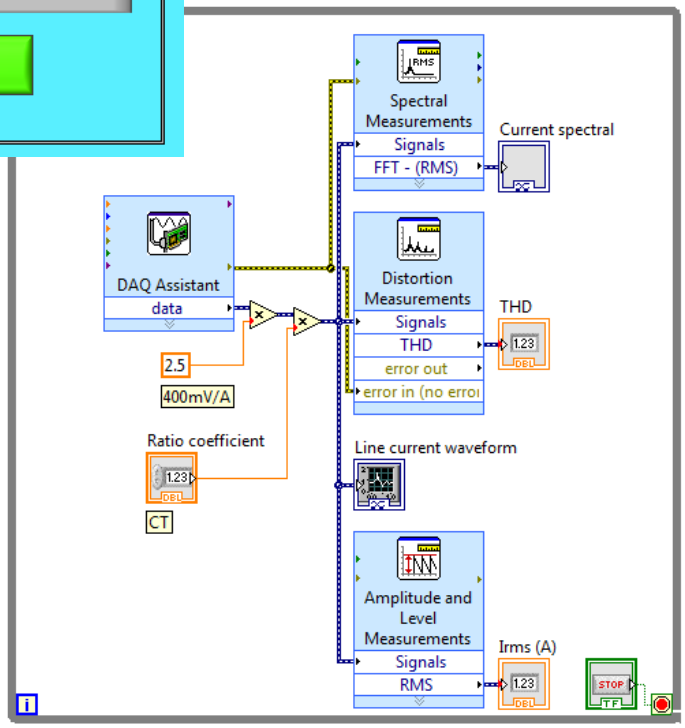


Fig. 11. THD virtual instrument front panel

Fig. 12. VI Block diagram



THD proposed virtual instrument

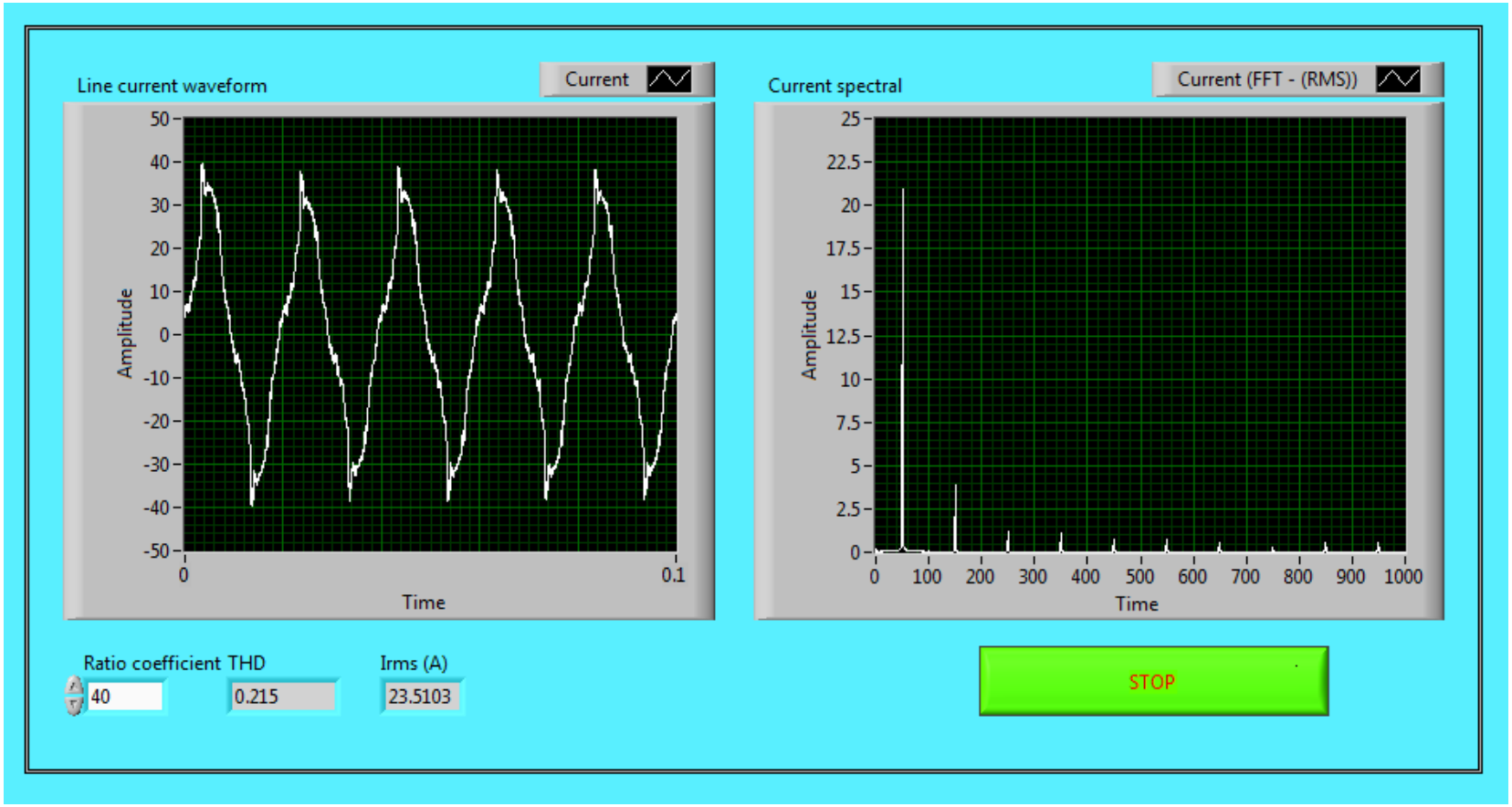


Fig. 13. Switch mode power sources detection in the electrical grid

THD proposed virtual instrument

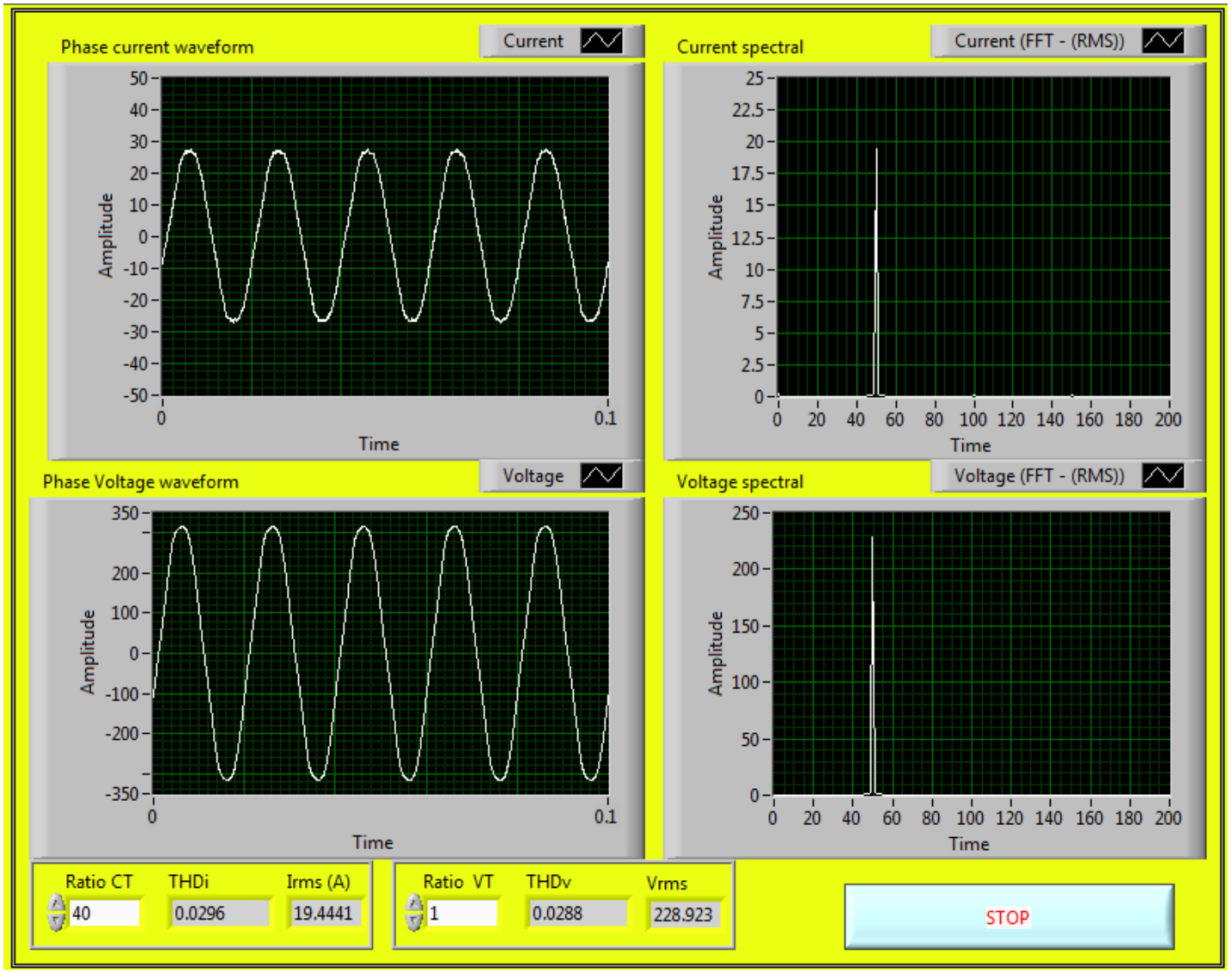


Fig. 14. Improving the virtual instrument to measure simultaneously voltage and current

THD proposed virtual instrument

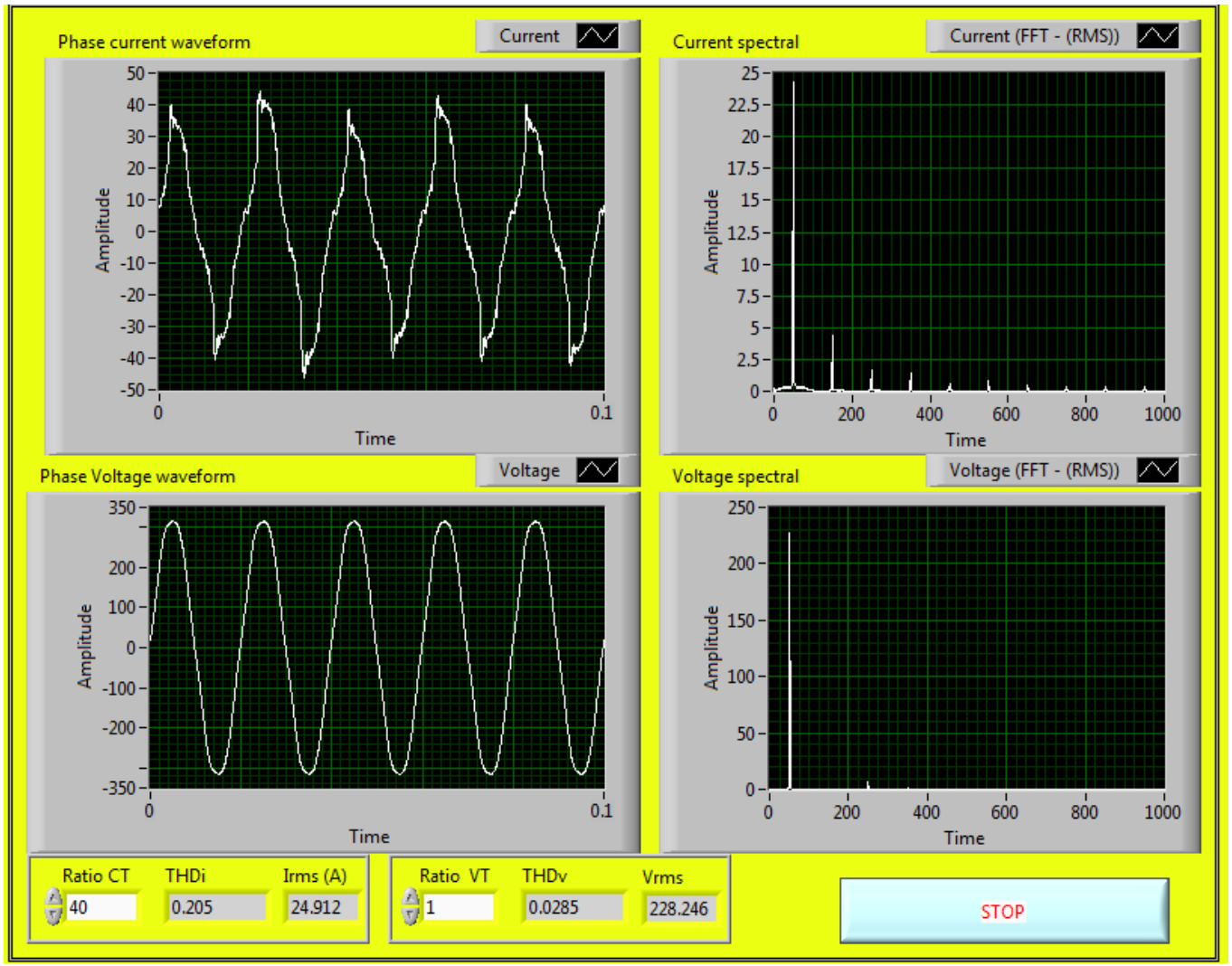


Fig. 15. Switch mode sources detection through voltage and current

THD proposed virtual instrument

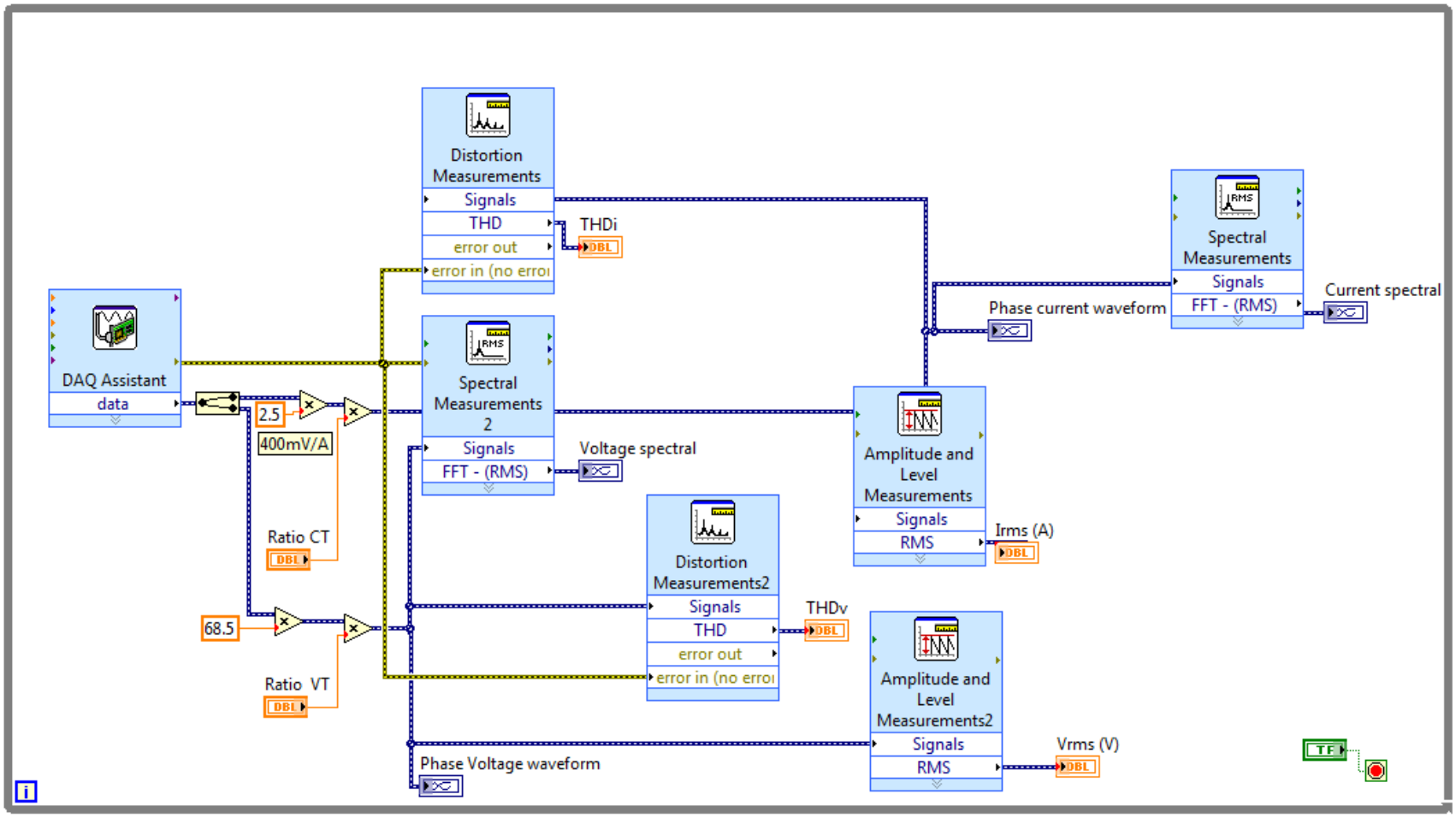


Fig. 16. Virtual instrument block diagram to measure simultaneously voltage and current

THD proposed virtual instrument

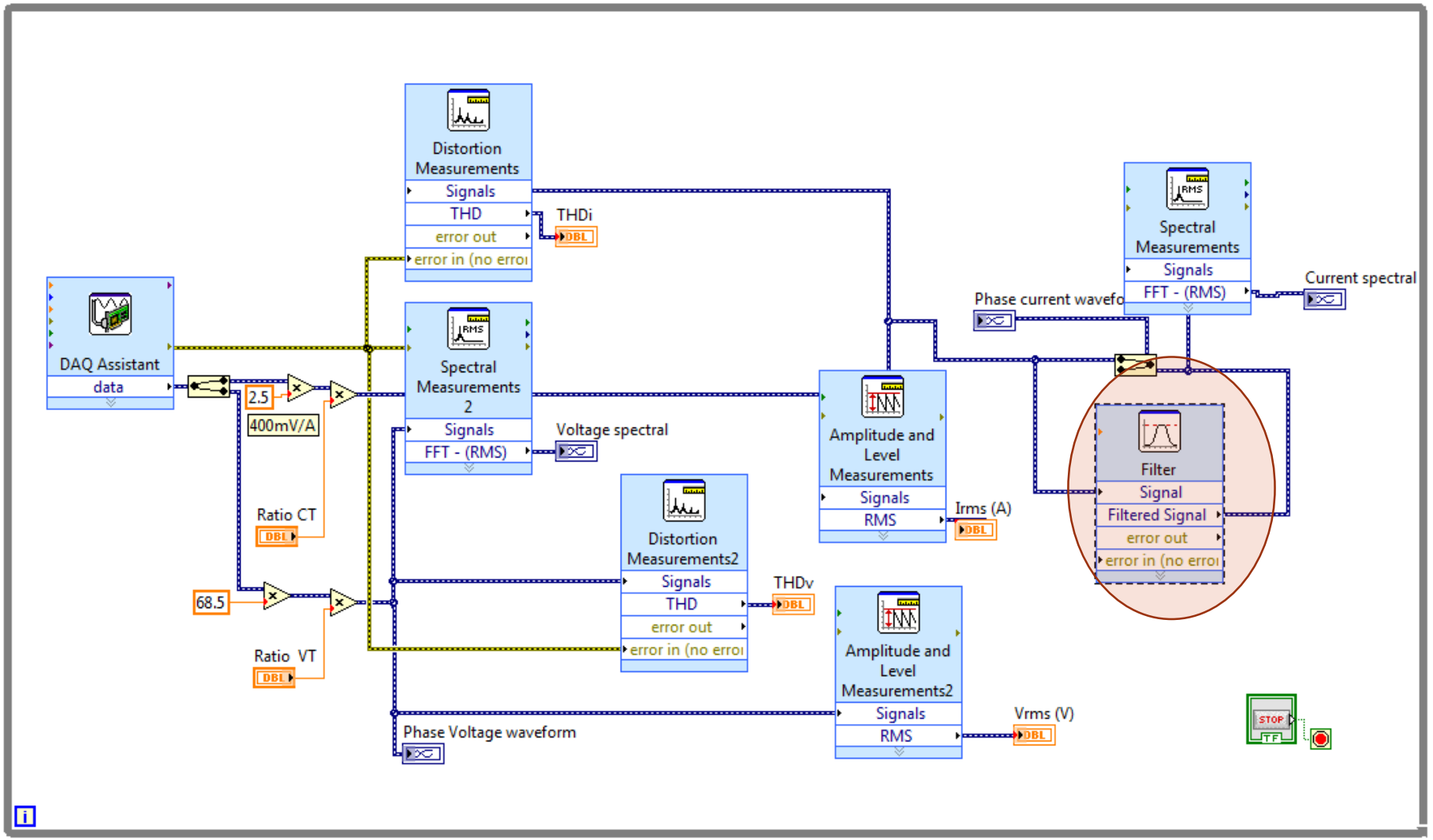


Fig. 17. Inserting filter in the THD virtual instrument block diagram

THD proposed virtual instrument

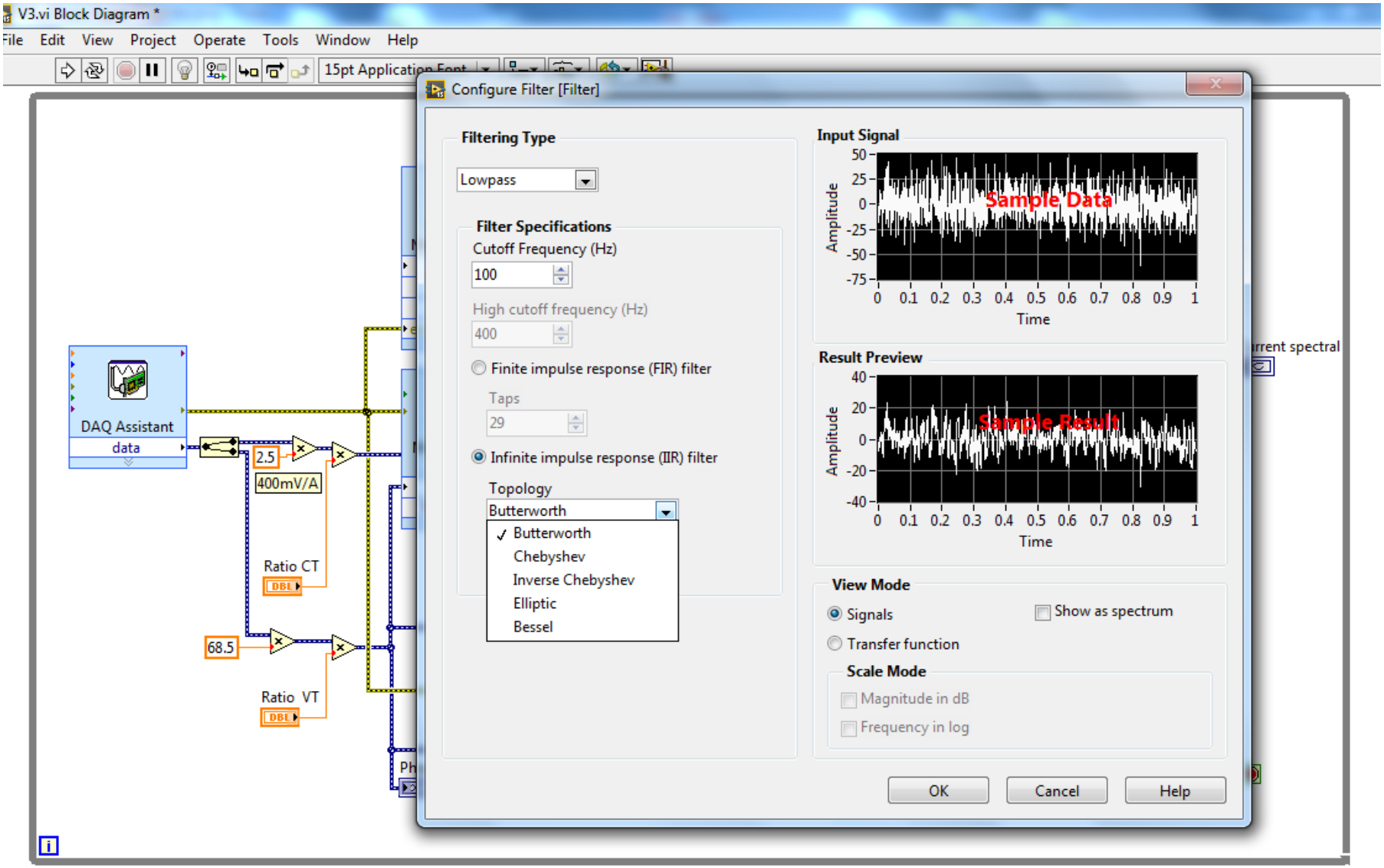


Fig. 18. Selecting the filter order and type

THD proposed virtual instrument

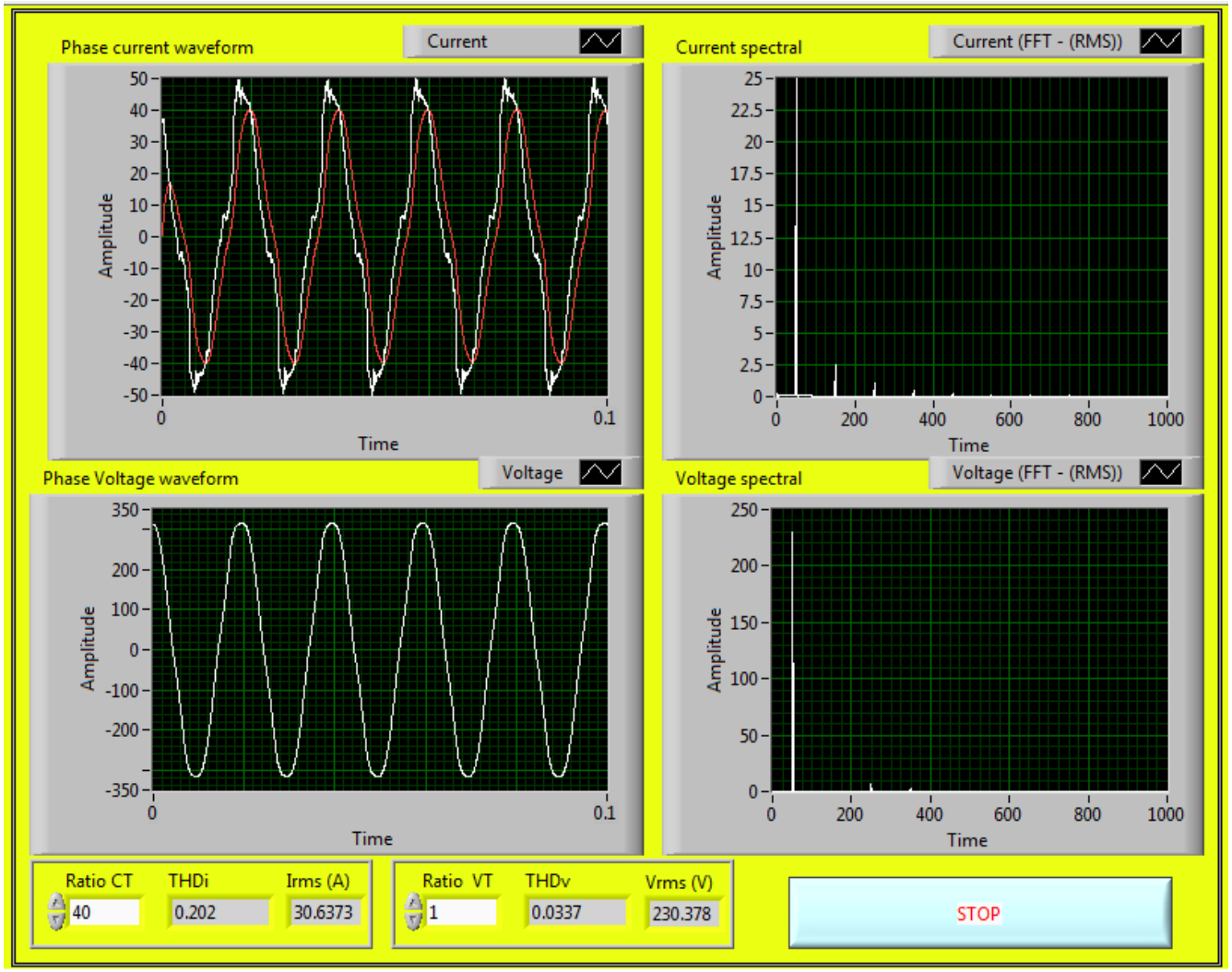


Fig. 19. Switch mode sources with first order filter

THD proposed virtual instrument

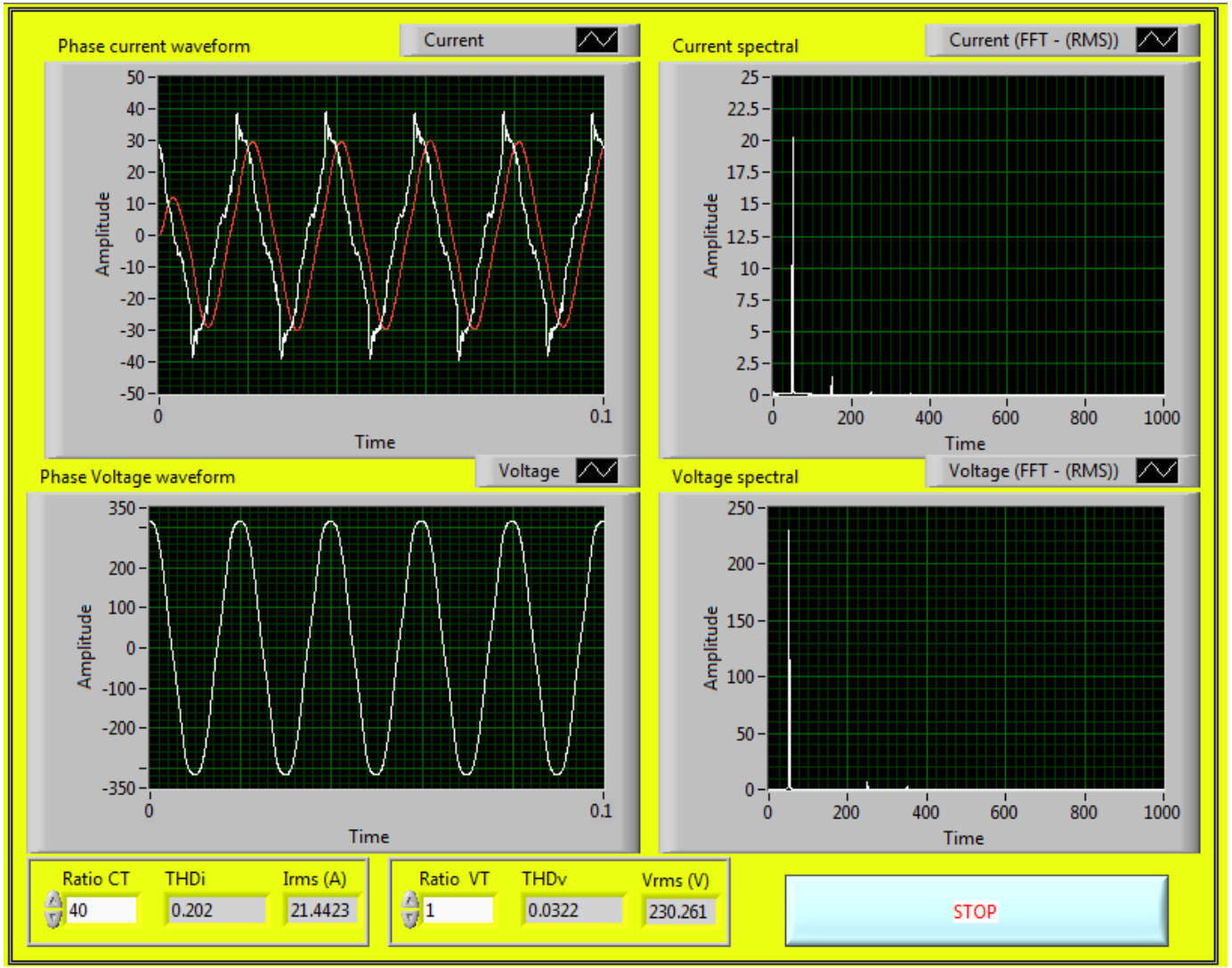


Fig. 20. Switch mode sources with second order filter

THD proposed virtual instrument

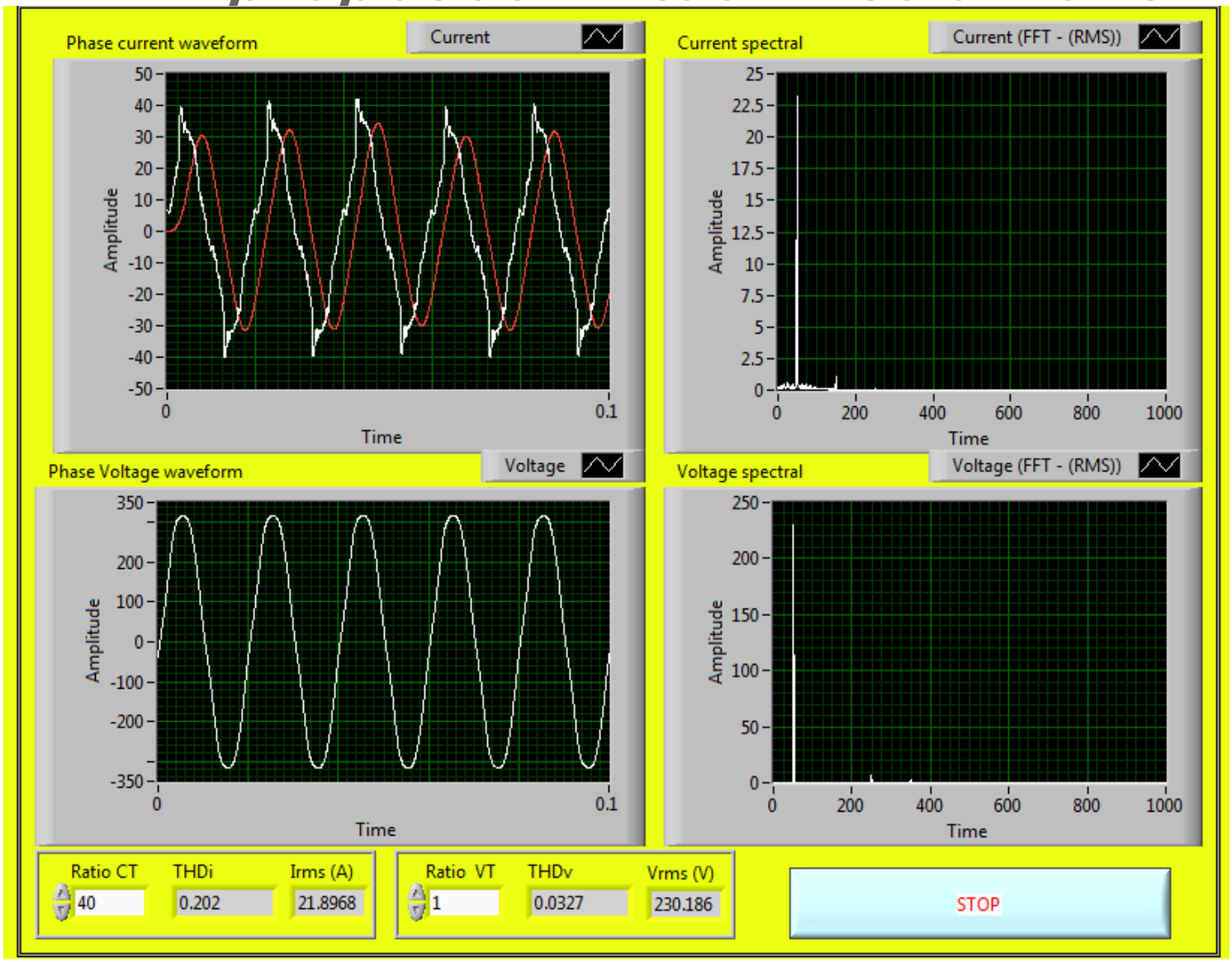


Fig. 22. Switch mode sources with third order filter

Conslusion

- Using virtual instrumentation for the THD measurement can be used to detect sources which inject high-order harmonics of the voltage and current causing problems in the power system.
- Online THD monitoring and improving via the Internet is another option, which makes this Virtual System a competitive alternative to devices that perform the same task, but have a fairly high maintenance cost. This can be achieved with the help of NI-PSP protocol of LabVIEW software.
- Since this instrument is based on programming it is very flexible to add other functionality on it. For example it can be used to alert the electrical grid utility if the THD of the voltage or the current pass a preset threshold value in the point where the instrument interface is connected.
- Using digital outputs of the DAQ card used to acquire signals with this instrument we can customize this instrument to select a desired physical filter or also to interrupt any load or sources which inject high harmonics and pollute the electrical grid.

Thank you

October 12th 2023

NATIONAL INSTRUMENTS
LabVIEW