Precision Power Analyzers: A Designer's High-Performance Test Toolbox

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All the tools needed to study and optimize virtually any power project in a single instrument

Introduction

The design of any power conversion system requires the measurement of a large range of electrical parameters that could be made using a lab bench full of instruments. The precision power analyzer pulls all of these measurements into a single instrument replacing meters, oscilloscopes, chart recorders, harmonic analyzers and other devices.

This paper will provide a basic overview of the functions and capabilities of high-performance power analyzers. Examples of these functions and how to apply them will make use of details provided in the Operator's Manual for Vitrek's Model PA9xx Series of Precision Power Analyzers.

What is a Power Analyzer?

Power analyzers are a class of electronic instrumentation that combine the precision measurement and recording of a variety of parameters critical in designing and evaluating systems designed to generate, convert and consume electrical energy. Parameters include voltage, current, frequency, harmonics, RFI/EMI, power, efficiency and others. In addition to performing these measurements, power analyzers typically include the capabilities of saving setup data, producing reports, communicating via digital means with external devices and other PAs to perform and archive testing of complex systems. Some power analyzers have built-in functions to test equipment for compliance with efficiency and emissions standards.

In short, power analyzers are more than a mere collection of measurement and display functions. These instruments provide an integration of those functions into a cohesive tool required in the design and manufacturing of power electronics equipment.

Power Analyzer Capabilities

By combining the features and functions of a collection of instruments, power analyzers provide the ability to not only measure a wide range of parameters but also display the information in useful and effective ways, store the test setup information and data acquired and communicate/synchronize the information.

Figure 1 presents a sampling of the data that is typically available on a power analyzer screen. The image on the top displays the real-time data for the AC input of a power conversion device: input power (W, VA and VAR), power factor, voltage (V), current (A) and frequency. The left-hand screen display plots the harmonic content on the output of a converter plus the total harmonic distortion(THD) value. The right-hand screen is an oscilloscope display of the single-phase AC voltage and current of an adjustable-speed drive. Many other display options are typically available, including 3-phase vector display of voltage and current, historical data, bar graphs of harmonic content and other useful information.

Figure 1. *Power Analyzer screens are designed to display test setup, digital display of measurements as well as scope presentation of data*

Power Analyzer Applications

By combining the features and functions of a collection of instruments, power analyzers provide the ability to not only measure a wide range of parameters, but also display the information in useful and effective ways, store the test setup information and data acquired and communicate/synchronize the information. Applications where power analyzers are commonly used include:

- **AC to DC Power Supplies**
  Input power factor, inrush current, efficiency, harmonics, EMC emissions/compliance, current, power
- **DC-DC Converters**
  Power factor, efficiency, harmonics, EMC emissions / compliance, current, power, ripple
- **Motors**
  Inrush, efficiency, power, frequency, phase diagrams, speed/torque/direction transducers (analog and digital)
- **Adjustable Speed Motor Drives**
  Efficiency, harmonics, frequency, power, crest factor, compliance
- **LED Power Supplies**
  Power factor, ripple, power, efficiency
- **Solar Power Systems**
  Peak power point, voltage, efficiency
- **Uninterruptible Power Supplies**
  Power factor, efficiency, output voltage, output frequency, harmonics, phase to phase measurements and phase angles
- **Battery Chargers**
  Input power factor, efficiency, harmonics, EMC emissions compliance, current, power, ripple
- **Electric Vehicle Power Systems**
  Efficiency, power, voltage, charging current
- **Appliances / HVAC Systems**
  Standby power measurements and testing (for example to EN50564), power factor, efficiency, EMC emissions compliance

Scope capture and history are valuable tools for short term or long-term characterization during design and development. In addition to these product design, development and manufacturing applications, power analyzers in the field are also employed to troubleshoot problems and assess performance of systems in operation.

Power Analyzer Configurations

Many basic applications require the use of a single power analyzer. Most analyzers provide the capability of making multi-phase measurements. Here in this section, several applications requiring the application of one or more PAs will be described.

Single Power Analyzer Applications

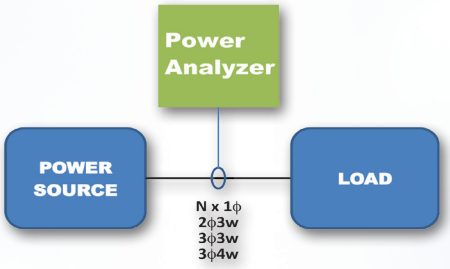

Figure 2. *Advanced PAs offer versions to accommodate a selection of single-phase and multi-phase measurements.*

Power Analyzers are connected between the source and load, as shown in ***Figure 2***. All of the measurements described earlier in this article are possible with a single analyzer, with the exception of efficiency which must calculate this value based on measurements of input power and power output.

Dual Power Analyzer Applications

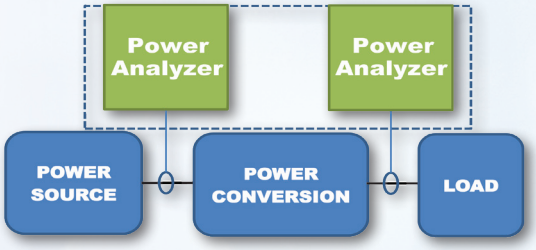

Figure 3. *Two PAs are needed in applications where both input and output measurements are required.*

In applications where both input and output measurements must be conducted simultaneously, it is frequently necessary to utilize two PAs, as shown in ***Figure 3***. (Later in this article, Vitrek's proprietary Virtual Power Analyzer (VPA) will be described that, in many cases can eliminate the need for a second instrument.)

A list of typical applications requiring dual power analyzers would include the following:

- AC to DC Power Supplies (single or multiple outputs)
- DC to DC Power Supplies (single or multiple outputs)
- DC or fixed frequency AC supplied variable or fixed speed motor drives Power Transformers (single or multi-phase)
- Lighting Ballasts (most types)
- Standby or Backup Power Supplies (AC or DC)
- Photovoltaic Power Generators (DC in; DC or AC out)
- Electric Vehicle Traction Motor / Generator Drive Systems

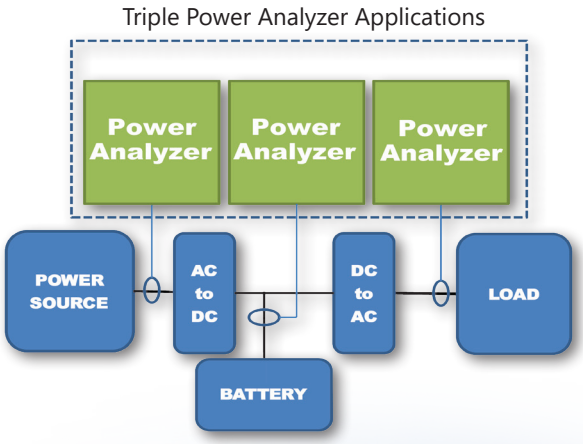

Figure 4. *Double-conversion systems, like the UPS shown here would require three PAs to completely characterize performance.*

Examples of electronic systems requiring three PAs to fully characterize performance include:

- Emergency Lighting Ballasts (most types)
- Standby or Backup Power Supplies (AC or DC)
- Solar Systems with Auxiliary Battery Backup

Note that in large systems, e.g., distributed power networks, the input power analyzer can be placed literally miles away from the output PA. In addition, there are very intricate applications, like inductive wireless charging of EV batteries that would require four geographically-distributed power analyzers.

The Virtual Power Analyzer – A Better Solution

The information presented in this article is intended to provide a basic understanding of the utility and effectiveness of power analyzers in the design, development and analysis of power conversion systems. In many cases, the application requires the use of multiple PAs to accomplish the task at hand. While nearly all power analyzers provide versions that can handle either single phase or multiple phase inputs, only Vitrek provides the ability to integrate separate PAs into the same instrument. Vitrek has taken this concept further by essentially making each channel in the device into an individual PA channel. Channels can be combined into Virtual Power Analyzers (VPAs) enabling a single device in some applications to perform the work of multiple instruments.

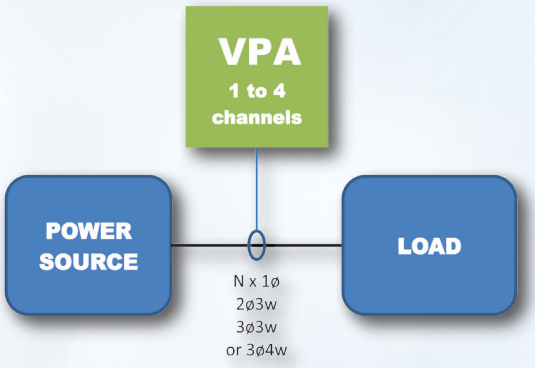

Figure 5. *The Vitrek PA9xx can be equipped with up to four independent channels that can be configured into up three separate PAs.*

Here is a short list of the performance features of Vitrek PA9xx Series, 4-channel Power Analyzers

- Supply frequency measurements DC and 0.01Hz to over 1MHz (W channels) or 100kHz (L, A or S channels) supply frequencies
- N x 1ø can be up to 4 AC or DC supplies
- 2ø3w and 3ø4w measures neutral current from phase currents
- 3ø3w can use either 2 or 3-wattmeter methods
- 2ø3w, 3ø3w (3ch) and 3ø4w measures phase-to-phase voltages in addition to the individual phase voltages
- Wye (3ø4w) and Delta (3ø3w) voltage conversions for 3ø3w and 3ø4w resp.
- Power can flow in either direction, separately integrates power in each direction (per phase and total) as well as the total
- Total power (W, VA, VAR and PF) measured in addition to the individual phases
- Max. hold maintained for voltage, current and power measurements
- Harmonic analysis of every signal up to the 500th harmonic, <435kHz (W channels) or <115kHz (L, A or S channels)

One special feature, worthy of note in this paper, is the built-in compliance test for various industry leading environmental performance standards. These compliance tests are integrated into the PA9xx Series and are selectable from the touch-screen. The test results can also be displayed on the touch-screen with no requirement for PC-based software. This display feature significantly improves the user interface and efficiency when performing these critical tests. Engineers and technicians enjoy the flexibility of using the touch-screen at the test station with software available if required. Vitrek power analyzers' built-in compliance testing support environmental / performance standards including:

- EN60034-2-1:2014 (motor drives)
- EN50564:2011 (standby power)
- EN61000-3-2 and 3-12 and 4-7 (harmonics emissions)
- RTCA DO-160E/F/G (avionics)
- Boeing 787B3-0147
- Airbus ABD0100.1.8 (A380) and ABD0100.1.8.1 (A350)

It is beyond the scope of this paper to detail all of the features of these instruments. For a detailed review of features and specification visit www.vitrek.com

VPA Application Examples

A few examples of the Vitrek VPA architecture will illustrate the convenience and economy of this approach:

Power Supplies

AC-DC power supply with a three-phase AC input and a DC output could be analyzed with a single 4-channel PA9xx power analyzer. Three channels would be combined as one VPA to measure and record the 3-phase input. The fourth channel would then measure the DC output. All input/output measurements, including efficiency, are contained within one device without any external synchronization.

EV Drive Systems

The analysis of the performance of an Electric Vehicle drive system can be accomplished by assigning two channels each to the interface between the battery and two channels as a second analyzer between the power converter and the motor. Bi-directional energy flow, efficiency and a full range of performance features can be handled with a single instrument.

Photo Voltaic (PV) Inverters

The output of the PV cell (DC) can be monitored on one of the four available channels, while the 3 phase AC output (output of the power conditioner inverter and converter) can be monitored using the remaining 3 channels. From this, efficiency studies can be performed using the built in VPA's of the power analyzer.

Motor Efficiency Calculations

Motor manufacturers and users can easily perform efficiency studies to IEC 60034-2-1:2014 (built in to Vitrek PA) which classifies the levels of motor efficiency.

Important VPA Features

A few examples of the Vitrek VPA architecture will illustrate the convenience and economy of this approach:

Oscilloscope Measurements

Many applications require oscilloscope measurements of voltage, current and power. The PA9xx integrated oscilloscope hi-resolution oscilloscope function provides up to 24-bit resolution. Most oscilloscopes only have eight bits of resolution. This means they only have 256 vertical digitizing levels. The PA9xx has 65,536 times better vertical resolution! Typical oscilloscopes are either two or four channels (there are specialized oscilloscopes with more channels). The PA9xx integrated oscilloscope can display up to 12 channels (any six at a time). Any measurement parameter can be plotted as a channel. So, for instance the instrument can display input voltage, current and power and the output voltage, current and power, simultaneously.

Harmonics

Normal harmonics analyzers measure the harmonics up to 10x or 50x the fundamental frequency. However, some of the new requirements ask for more. The PA9xx Harmonics Analyzer function can measure up to the 500th harmonic of the fundamental! Again, because of the instrument's up to 24-bit digitizing, it performs better than many dedicated spectrum analyzers. This is needed for looking at small signal content in the presence of large signals.

Distributed Analyzers

With the PA9xx, up to three separate power analyzers can be combined to get up to twelve time-synchronized, distributed channels. For example, channels of one analyzer can be assigned to the input, and channels of another analyzer to the output, enabling measurement of the efficiency of the system, even if the input and output are geographically separated by miles!

Extended Measurement Capabilities

The PA9xx is also capable of measuring rectified data and signals with crest factors as high as 100. The instrument can also measure load impedance - series inductance and resistance; parallel capacitance and resistance, energy consumption (KWH), average power (W), and calculate energy bought or sold.

Datalogging

The PA9xx datalogger function timebase rescales automatically over the length of the test. So, for a 1-hour test, the display will be for 24 hours. For a ten-day test, it will display over ten days. However, the data logged for any specific moment over the test period can be retrieved as well as the min and max peaks between datapoints. Datalogging

(collection is automatically stopped after this time has elapsed. This is not fully tested at the time of writing!). Any measurable parameter can be displayed on the screen as a trace and logged data can be saved to an external USB drive.

Reporting

The PA9xx provides the capabilities to clearly document and produce reports of the results of the tests performed. As with other power analyzers, data can be exported via Ethernet or RS-232. The PA9xx also features front-panel USB drive access. The USB drive can be used to save and recall configurations, harmonic limits, measurements, spectrum analyzer data, scope data, cycle data, history data and harmonics data. Easiest of all, screen shots can be captured of anything data selected, such as this:

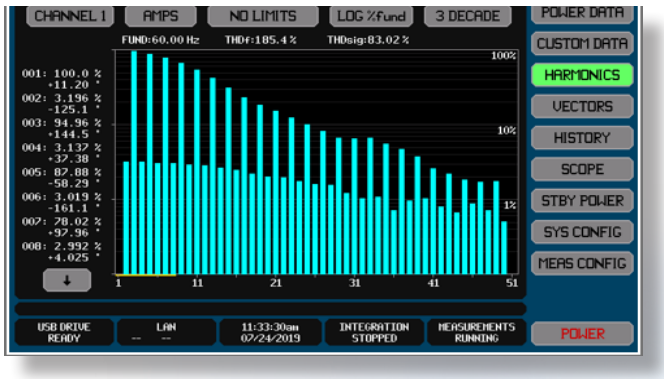

Figure 6. *Data selected for display on the PA9xx can be easily exported via the front-panel USB access port.*

Conclusion

The precision power analyzer combines into a single instrument that functions and features of several bench-top instruments. The PA9xx's Virtual Power Analyzer simplifies setup and synchronization of input and output test data, enabling the ability to perform intricate and accurate tests with few instruments.

The following is a useful checklist that may be helpful:

- Simple setup and operation via a touchscreen display
- High-resolution digital display
- Supply frequency measurements DC and 0.01Hz to over 1MHz supply frequencies
- Multiple accuracies and frequencies based on your specific application
- Single phase and multi-phase inputs (including all common types)
- VPA (Virtual Power Analyzer) features extending the testing capabilities of the Power Analyzer
- Input voltages up to 600VAC
- Bi-Directional power flow (per phase and total)
- Total power (W, VA, VAR and PF) measured in addition to the individual phases
- Max. hold maintained for voltage, current and power measurements
- Harmonic analysis of every signal up to the 500th harmonic
- Datalogging capabilities with scalable timebase
- Report generation capabilities
- Built-in programming to testing to selected safety and emission standards.