Choosing a power measurement instrument that is right for you

Power efficiency concerns both product development and manufacture. Selection of an appropriate power analyzer plays a key role for these activities; proper selection can enhance productivity, reduce production costs, achieve quality and reduce time to market. This article helps you identify the technologies available and navigate some of the factors that influence your choice of power analyzer.

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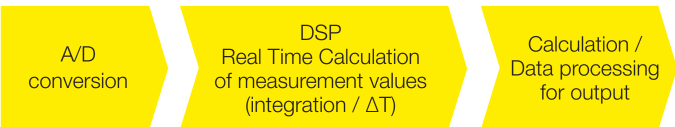
Measurement technology -What's out there?

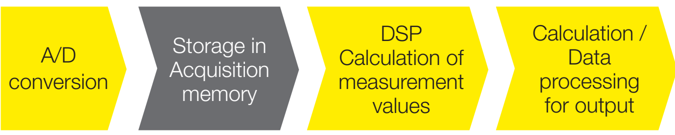
There are a variety of instruments in the market that can potentially serve your power measurement needs. Depending on your circumstances, you may need the waveform analysis of an oscilloscope, the high accuracy of a power analyzer or a hybrid combination of the two with flexible data acquisition added into the mix. But the underlying power measurement principle behind each of these instruments is essentially the same - sampling the voltage and current waveforms simultaneously, multiplying them together after acquisition, integrating the resultant instantaneous power readings over a whole number of fundamental waveform cycles and then dividing by the time. Depending on the resolution of the A/D converter and the sampling rate however, there are two broad categories that power measurement instruments fall under.

Streaming or averaging type instruments



These include the traditional power meters and power analysers.Streaming instruments use high resolution on the analog to digital conversion stage and instantaneously compute/integrate the voltage, current and power values in order to achieve continuous measurements and high accuracies.

Digital storage type instruments



A digital storage type instrument such as an oscilloscope, ScopeCorder or Power Scope acquires data at high sampling rate, stores it in acquisition memory and then processes it for output. During processing of the sampled data however, there is 'dead time' when the instrument is not reading the input waveform thus missing the data points for continuous measurements.

The high sampling rates in digital storage type instruments allows for a better representation of the input waveform making them ideal for analyzing single shot events. However oscilloscopes are not designed for stability and do not specify AC uncertainty. Therefore when high accuracy is needed particularly in compliance testing, a streaming or averaging type power analyzer is usually the better choice as they can achieve accuracies up to 0.01% of reading. Hybrid instruments like the Power Scope however can combine waveform analysis together with high accuracy measurement.

Questions to ask

Making a choice amongst such a wide variety of products can be challenging, particularly when these instruments often range from a few thousand euros in price to tens of thousands. Making educated decisions and adopting a long term measurement strategy is key to realizing the ROI of such an outlay. Some of the common questions that come up when selecting a measurement instrument are listed below.

What do I need to measure?

- AC and DC electrical parameters only or other physical phenomena?
- What is the level of the voltage and current?
- At what frequency range/bandwidth do measurements need to be made?
- What Wiring will be used? Single phase, three phase or combination
- What is the shape of the signal, Sinusoidal? PWM? Complex waveforms?
- Is the power repetitive? Stable? Intermittent? Continuous or fluctuating?
- Are cycle by cycle or sub cycle power transients required to be measured?
- How distorted are the waveforms? Are the signals noisy?
- What is the power factor?

What accuracy will I need?

- What needs to be shown to customers?
- What industry/quality standards need to be adhered to?

- Crest factor considerations and effect on overall measurement accuracy
- Common mode considerations and CMRR
- Is traceability necessary?

Can I trust my measurements?
- Is the measuring instrument stable? Will it provide repeatable measurements?
- How can I have confidence in the specified accuracy?
- Is there one instrument that will satisfy all my measurement needs?
- What about cost effectiveness?

The answers to most of these depend on your industry, application and the development stage you are in. We will discuss this in the next section before navigating the selection criteria.

What factors should influence my choice?

Industry and application

Some of the key measurement considerations that depend on your industry or application are:
- the parameters to be measured
- the operating frequencies they need to be measured at
- the level of accuracy required.

You may also need to compare readings across multiple inputs, compute efficiency, measure power consumption at startup, operation and standby modes, or assess the effects of high frequency harmonics. Thus industry and application can influence your choice of measurement instrument

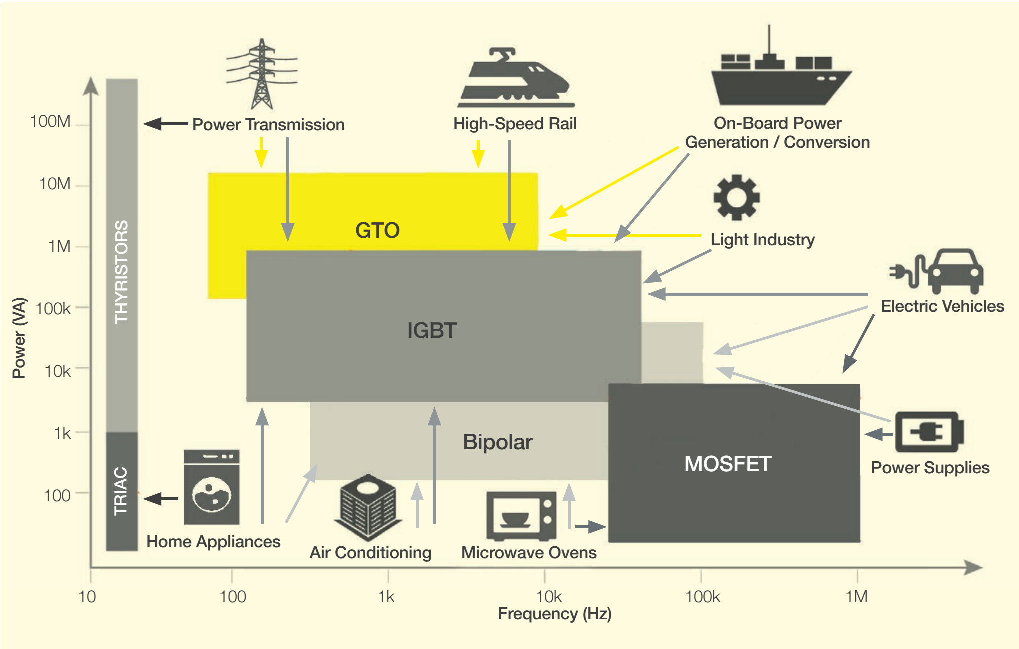
Common power measurement applications

Here are a few examples of different power measurement applications.

- Electrical and mechanical efficiency of inverters and, motors, in automotive and for, renewable energy
- Power consumption of home and office equipment in standby and operation modes
- Power distribution – load switching and short circuit, no load losses in transformers
- Inrush current of Lighting ballasts and harmonic analyses of LED switching circuits
- Compliance to harmonics and flicker standards for different equipment classes
- Transient responses of industrial robots
- Transient power measurement of multi-function machines
- Inverter driven cooking plates/microwaves
- Inverter boost circuits – reactor loss measurements
- Wireless charger efficiency measurements
- Evaluation of inverter controlled elevators
- Evaluation of magnetic components

Varying requirements

Applications like automotive power trains, inverter motor drives and wind energy need both DC and AC signal analysis along with a combination of electrical and physical phenomena. Several industries now adhere to standards for power consumption in startup, standby and operation modes. Modern electronic circuits in lighting, home appliances and office equipment often feature high speed switching techniques for reducing power consumption and bringing opportunities for component miniaturization. But this also introduces opportunities for harmonic and interharmonic interferences at higher frequencies which when poorly measured can lead to poor performance. In applications such as no load testing for transformers, high accuracies are expected at power factors as low as 0.002. Depending on the needs of your application you may need anywhere from 1 to 8 channels of inputs of voltage and current. You may also need to measure non electrical signals which is where data acquisition comes into play.



(Source: modified from the figure 1 http://www.appliedmaterials.com/ja/nanochip/nanochip-fab-solutions/december-2013/power-struggle)

Thus, depending on the electromechanical phenomena to be measured and your need for multichannel readings, waveform and harmonic analyses and time based/transient behaviour analysis, you may need to use one or more types of power measurement technology.

Development stages

Besides the requirements imposed by the application, different stages of product development demand different capabilities and levels of accuracy. For example isolated tests of individual components in early development stages may only need waveform analysis at limited accuracy but when a multi-component system needs to be tested, the objective is to optimize the system rather than a single component. This calls for sophisticated multichannel, multi parameter measurements, and the closer you get to production testing the stricter the requirements for compliance and adherence to standards. Given the diverse operating conditions and objectives of different development phases one needs to be mindful that measurement needs can vary or evolve across the development cycle.

Architecture and design

During this stage, individual components may need to be measured and engineers have to deal with fast switching speeds (in inverters, power supplies, and electronic circuitry), dynamic behaviours at high frequencies and frequent overshoots on pulses. High sampling rates are therefore needed to capture waveforms faithfully, making the oscilloscope the go-to instrument for such scenarios. Oscilloscopes offer automated measurement of voltage and current waveforms providing peak, average and root mean square values along with power factor and q factor. Although they are also equipped to compute power, oscilloscopes are not ideal for high accuracy measurements.

Development and system testing / Verification and prototyping

As control systems get more sophisticated, measurements are no longer about optimizing individual components. More I/O signals are needed and consequently faster sampling and higher bandwidth to circumvent noise from inverters or power supplies. More channels are needed to capture the dynamic behaviors of each component as part of an overall system.
In an automotive powertrain for example, together with the electrical parameters physical parameters such as rotational speed, fuel injector pulse times and crank angles are measured from sensor signals, rotary encoders etc. For such multi-channel measurements of dynamic system-behavior, the combined features of an oscilloscope and a data-acquisition recorder are needed. The ScopeCorder for example offers a holistic system analysis for powertrain development by combining electromechanical and CAN / LIN bus measurements in a single overview along with waveform and trend calculations for real time analyses of component relationships. This can significantly speed up development & fault finding.

Compliance testing, certification & validation

Industries today have to meet a number of governmental and regulatory standards to ensure product efficiency, safety, comfort and productivity for homes and businesses. Compliance to standards for standby power consumption (EN 50564 and IEC 62301) or Harmonics and Flicker (IEC/EN 61000-3-2 and IEC 61000-4-7) for different classes of electrical and electronic equipment affect both market validation (fit for use) and product differentiation for competitive advantage.
A power analyzer that can guarantee its accuracy over specified operating conditions is the ideal solution for this stage. Power measurements in this stage should not only be guaranteed for accuracy, but also be repeatable and stable over time for the specified ranges. One can gain quantifiable confidence in a measurement system through regular accredited calibration of an instrument's performance against a standard of known accuracy.

Production and field testing

Measurements in production line testing and field tests have a different set of requirements. It may be necessary to measure energy generated, converted or consumed along with the effects of harmonics. It may also be required to analyze power consumption in startup, standby or operation modes, or use high crest factors at every measurement range for capturing inrush currents. This would be best served by power analyzers calibrated to minimize uncertainty within the specified operating ranges. ScopeCorder and data loggers may be useful in this stage if there is a need for collecting data over extended and unattended periods.

Choosing the right instrument

Once you know what needs to be measured at what accuracy for which development stage, you will be in a better position to make an educated choice of measurement technology. The measurement instrument needs to match your application's needs of operating bandwidth, voltage, current, accuracy and number of inputs. In addition, depending on waveform complexity, types of computations, and electromechanical measurements needed, one or more of the requirements below may also need to be satisfied:

- Fast and automatic updates of measurement range or update rate to measure input signals fluctuating in amplitude or frequency
- Specifications not only at power factor = 1 but also at power factors applicable to the needs of the application and accounting for uncertainty contributions from internal phase shifts
- Harmonic and flicker analysis capabilities based on IEC standards
- Measurement ranges with high crest factors to capture distorted signals or large, unexpected peaks
- Compute electrical parameters in star, delta and other wiring configurations
- Functionality and sampling rates for analyzing PWM and other complex waveforms
- Measurement of physical parameters such as torque, mechanical power, slip, rotation speed, temperature, pressure, strain etc.
- Time domain measurements for analyzing cycle by cycle or sub cycle power transients

Is there one instrument that will satisfy all my measurement needs?
This depends entirely upon your application's needs across its development stages. But with oscilloscopes focusing on waveform analysis, power analyzers on accuracy and hybrids extending this to time domain measurements or flexible data acquisition, adopting a single instrument may call for a compromise on capabilities and this may be easier with some industries or applications than others.

Today most development and test benches feature an oscilloscope as a general purpose measurement instrument. Waveform analysis aside, it can double as an intuitive low cost solution for power measurement. But with AC accuracy specified at best in ENOBs (effective number of bits), oscilloscopes cannot offer the traceable accuracies needed for confidence in compliance testing. Neither do they offer the versatility and flexible data acquisition capabilities needed for system testing.

The high accuracy needs of compliance and efficiency testing are instead better served by power analyzers that specify their uncertainties across different operating conditions. Unlike oscilloscopes, they feature direct inputs for current and isolated voltages thus eliminating errors from probes, transducers and internal phase which can add considerably to the total measurement uncertainty. Moreover unlike oscilloscopes, errors due to common mode are actually specified, not just stated as a CMRR. If on the other hand, the measurement focus is on interrelationships between components to assess system behaviour, the flexible data acquisition capabilities of a ScopeCorder are far more suitable.

What accuracy will I need?
Your need for accuracy will depend on quality commitments to customers or industry standards. The greater this is the more particular and forthcoming you would need to be in your use of measurement instrument, external sensors and probes. It is in compliance testing that the accuracy of your measurement instrument becomes the most important. The effects of harmonics, noise and distortion can also influence instrument selection with higher end power analyzers enabling precision analysis of harmonics up to the 500th order of a 50Hz fundamental.

How can I trust my measurements?
With instruments belonging to different accuracy classes and different manufacturers specifying accuracy differently, it is important to understand the sources of measurement inaccuracies such as reading and range errors, phase error and power factor, crest factor, harmonics, zero crossing detection, temperature, probes, external sensors etc..

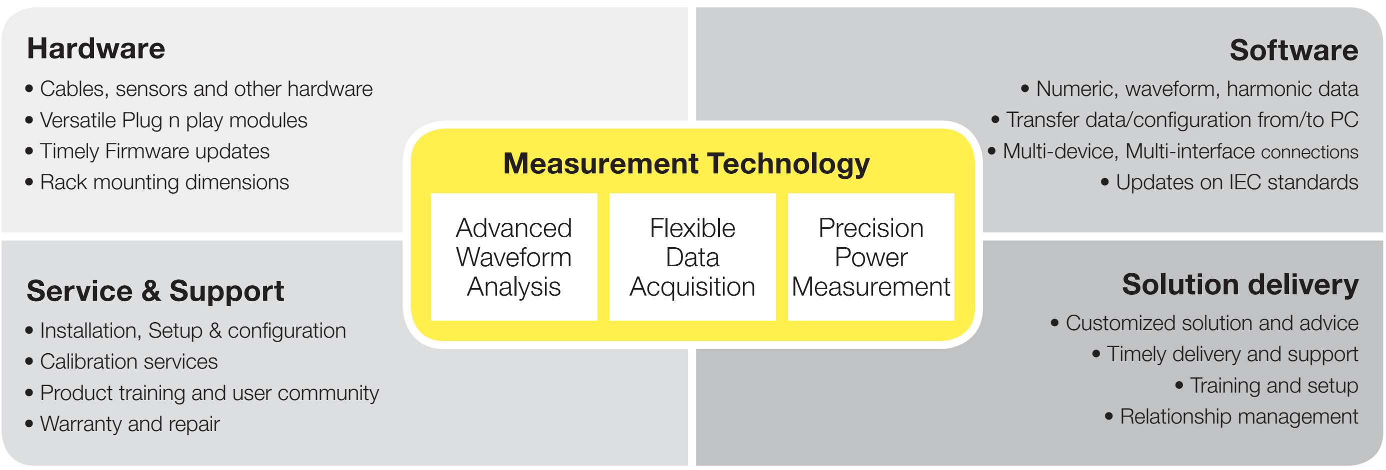
An ISO 17025 accredited calibration that proves the accuracy specifications of an instrument under different operating conditions can go a long way in instilling this confidence. If it is discovered during a calibration that an instrument needs to be adjusted or that the specifications imply that this is a normal requirement, then the product is not stable and will not be delivering long term stability and repeatable measurements.

Making a choice
Thus once you know what your application's measurement needs are you can home in on the right combination of accuracy class, number of channels, voltage and current ranges, electromechanical and computational capabilities, data update rates, A/D resolution, harmonic analysis communication interfaces and other necessary criteria to choose your instrument.

Measurement as a strategy

We have seen that measurement needs can vary or evolve depending on your application and stage of the development cycle. It is therefore important to assess your existing measurement technology against these stage based needs before investing in technologies to achieve long term improvements in manufacturing productivity, time to market and product quality. It is therefore key to adopt a measurement strategy that takes steps to:

- Understand the measurement objectives across each stage of the development cycle
- Assess the technology existing on test benches and identify gaps in capabilities
- Empower development and testing teams with the technologies that address these gaps in insights, functionality and accuracy to ensure data driven manufacturing decisions.



In order to empower development teams to fulfill the objectives across the development cycle, it is also important to consider a whole solution approach towards instrument selection. Aside from satisfying your unique needs for power accuracy, waveform, analysis, data acquisition etc., your technology needs to be supported with the appropriate training, additional hardware and software to get the most out of your investment.

Thus, regardless of the electromechanical phenomena to be measured, the computation capabilities and the level of accuracy, measurement technologies need to be reliable over the long term and offer healthy support in hardware, software and services in order to help manufacturers take their products from concept through production with greater quality in shorter time frames.

About Yokogawa Test & Measurement

Yokogawa has been developing measurement solutions for 100 years, consistently finding new ways to give R&D teams the tools they need to gain the best insights from their measurement strategies. The company has pioneered accurate power measurement throughout its history, and is the market leader in digital power analysers.

Yokogawa instruments are renowned for maintaining high levels of precision and for continuing to deliver value for far longer than the typical shelf-life of such equipment. Yokogawa believes that precise and effective measurement lies at the heart of successful innovation - and has focused its own R&D on providing the tools that researchers and engineers need to address challenges great and small.

Yokogawa takes pride in its reputation for quality, both in the products it delivers - often adding new features in response to specific client requests - and the level of service and advice provided to clients, helping to devise measurement strategies for even the most challenging environments.

The guaranteed accuracy and precision of Yokogawa's instruments results from the fact that Yokogawa has its own European standards laboratory at its European headquarters in The Netherlands. This facility is the only industrial (i.e. non-government or national) organisation in the world to offer accredited power calibration, at frequencies up to 100 kHz. ISO 17025 accreditation demonstrates the international competence of the laboratory.

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