Test&Measurement

YOKOGAWA

Getting Started with Electrical Power Measurements

Energy efficiency directives from bodies like International Electro technical Commission (IEC), European commission, California Energy Commission (CEC) and others govern standards across various classes of electrical, electronic and mechatronic equipment.

This infographic provides a snapshot guide for making reliable power measurements across your product development lifecycle with particular emphasis on the high accuracy needs of compliance testing.

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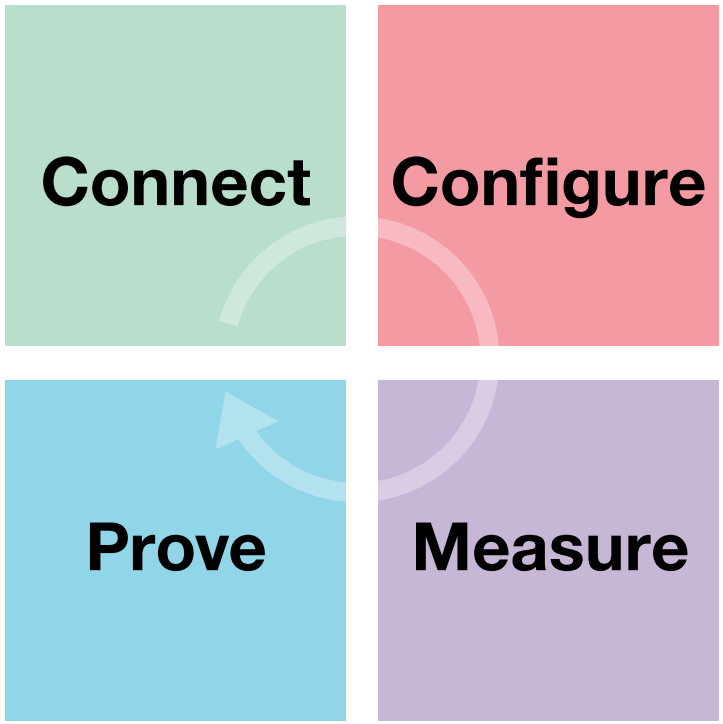
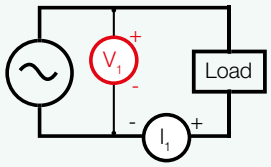

Connect
Configure
Prove
Measure

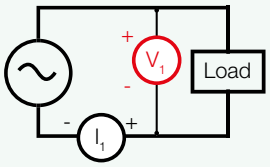
1. Connect your application

The wiring requirements of your application will dictate the number of channels needed from your power measurement instrument.
Choose the wiring configuration and connect the device under test to the voltage and current inputs of the instrument accordingly.

Single Phase Wiring

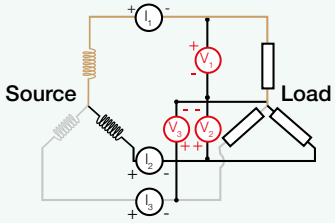


For low current loads

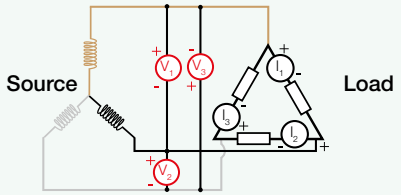


For lower voltages

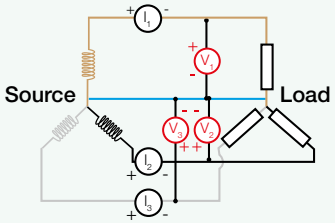
Three Phase Wiring



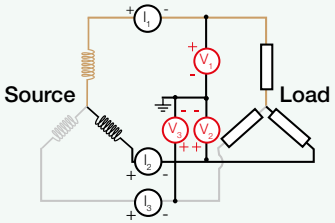
Star load



Delta load



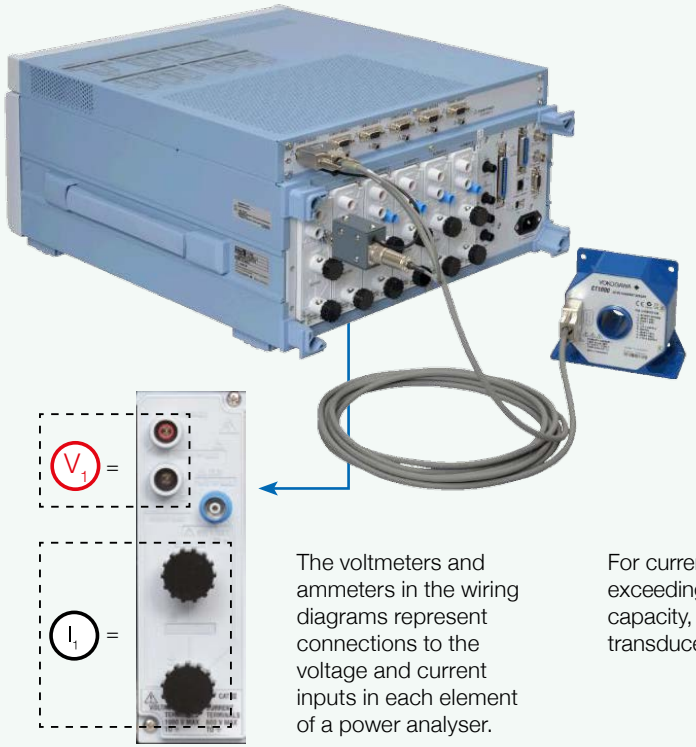
Ideal 4 wire connection for star load



Virtual Star Point when internal load connections are inaccesible

* Total power of a 3 phase circuit can also be measured using two power input elements (2 Wattmeter method).

Connecting to a power measurement instrument*



The voltmeters and ammeters in the wiring diagrams represent connections to the voltage and current inputs in each element of a power analyser.

For currents or voltages exceeding direct input capacity, external sensors or transducers can be used.

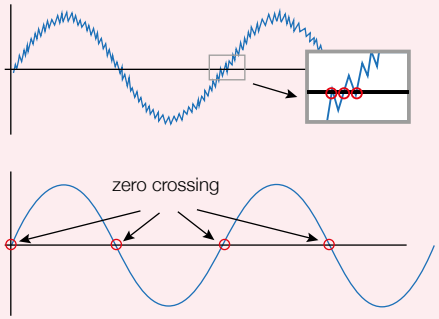
* Oscilloscope, Power Analyser or power scope - Scan the QR code to learn about which instrument to use when.

2. Configure your instrument

Your instrument will now display readings and compute poly-phase power and efficiency based on your chosen wiring.
This section describes some of the most common settings you can configure in order to acquire the best results.

Tweak the measurement period

Your instrument synchronises all measurements to the fundamental frequency of one of the input signals. Use the least distorted input signal (voltage or current) as the synchronisation source. The cleaner the signal, the better the instrument detects zero crossings to determine correct measurement periods.



A frequency filter can remove noise from the chosen synchronisation signal for cleaner period detection

Select the measurement range

To ensure the best accuracy, pick the voltage and current ranges closest to the RMS value of the signal being measured or use auto-ranging function.

*Apply a Line filter if you need to remove unnecessary noise/high frequency components.

* Some measurement instruments offer measurement of electromechanical parameters such as torque, mechanical power, synchronous speed, slip, electrical angle, motor efficiency and total system efficiency from the analogue or pulse inputs of rotation and torque sensors.

Set the data update rate

The data update rate needs to be longer than 1 period of the measurement signal. Longer update rates help average out noise while shorter update rates are useful to detect / analyse inconsistencies. For fluctuating frequencies, the update rate may be set to change automatically based on changing input frequencies.
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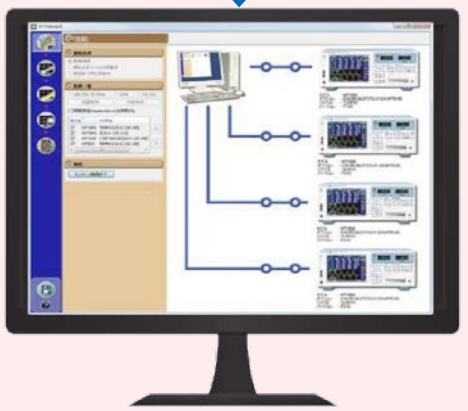
Connected to PC via Ethernet /USB GPIB / Modbus/ Webserver/TCP

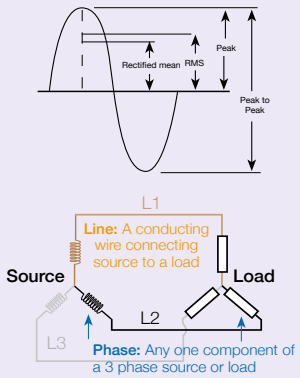


Use measurement software to control, monitor, collect, analyse and save measurements remotely.

Customise your display to analyse multiple input signals in numeric, waveform, trend, vector or harmonic bar displays.

3. Take the measurements

A number of electrical parameters need to be measured across development, production monitoring and compliance testing. Given below are some of the common phenomena being measured.



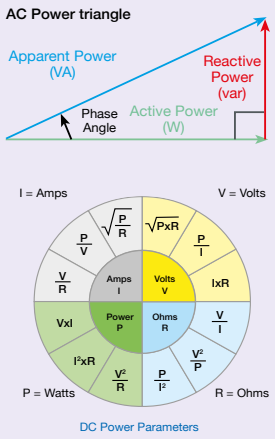
Voltage and Current

- **RMS (Root mean square) values** of voltage (Vrms) and current (Irms) are the amount of AC voltage and current that does the same work as DC voltage and current
- **Peak value** of Voltage (Vpk) or current (Ipk) is the highest absolute value of the input signal
- **Rectified mean value** of voltage (Vrmn) or current (Irmsn) is the average of all rectified instantaneous values over a whole number of periods.
- **Line current:** Current through any one line between a three-phase source and load.
- **Line voltage:** Voltage between any two lines
- **Phase current:** Current through any one component in a three-phase source or load.
- **Phase voltage:** Voltage across a load in a particular phase

Impedance

Load type	Circuit	Voltage / Current waveform	Vector diagram
Resistance		Voltage (u) Current (i)	Voltage (u) Current (i)
Coil (inductor)		Lags by 90°	
Capacitor		Leads by 90°	

In addition to resistance, AC circuits may have inductive and capacitive loads that add reactance to the total circuit impedance and cause voltage and current to be out of phase by an angle Φ



Power and Energy

- **(Active) Power (P)** is the rate at which energy is generated or dissipated, measured in Watts. It is the average value over time of the instantaneous power of alternating current. It depends on voltage (V), current (I) and cos Φ, 'Φ' being the angle of the phase difference between V and I.
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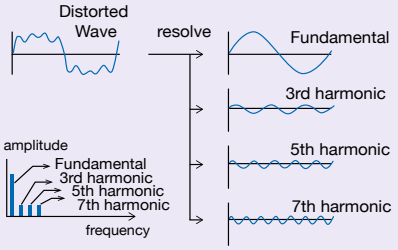
- **Apparent Power (S)** - Total power in an AC circuit, both dissipated and absorbed/returned measured in Volt-Amps (VA).
- **Power Factor (λ)** - Ratio of active power to apparent power. Used instead of cosΦ for distorted waveforms.
- **Energy** - The total energy consumed or generated over a defined period. (Watthours) Computed as power integrated over specified time period
- **Efficiency** - Ratio of output power to input power

Harmonics & Distortions



Total Harmonic Distortion THD *

$$\frac{\text{Root of sum of squares of all harmonics except fundamental}}{\text{RMS value of fundamental wave}}$$

Harmonic Distortion Factor *

$$\frac{\text{RMS value of nth harmonic}}{\text{RMS value of fundamental wave}}$$

- Any complex waveform can be split into its constituent fundamental wave and higher order harmonics.
- While useful in applications such as VFDs (Variable frequency drive), harmonics can cause noise, heating and unwanted vibrations when left unchecked and can pollute the electricity grid.
- Standards like IEC61000-3-2 place restrictions on harmonics across various classes of products in order to ensure reliable electrical systems.

* IEC method

4. Prove the accuracy

Manufacturers today have to meet a number of governmental and regulatory standards to ensure product efficiency, safety, comfort and productivity for consumers and businesses. Adherence to such standards often requires uncertainty specifications that are traceable to national and international calibration references. This section lists some of the factors influencing measurement uncertainty and how to achieve accurate measurements today and over the long term.

Measurement and uncertainty

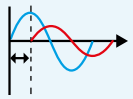
No measurement is complete unless its uncertainty is specified

	Magnitude of measurement	±	Uncertainty of measurement	Units
e.g.	50	±	0.005	Watts

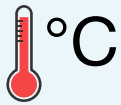
At power factor 1, Total Measurement Uncertainty is expressed as
Uncertainty of Reading + Uncertainty of Range.
In reality, there are more factors affecting total uncertainty which can be accounted for using the measurement instrument's specification sheet

Factors affecting measurement uncertainty

Selected voltage / current range

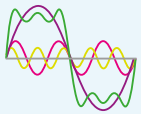

Internal phase shift

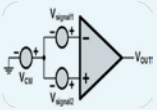
Frequency



Temperature


Instrument crest factor


Wave shape



Common mode rejection ratio


Sensor uncertainties

Reliability of your measurement

How accurate is it today?

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Note: Some instruments are specified based on RMS range reference while others are specified using Peak reference.

To ensure compliance with stringent and evolving international standards, measurements not only have to be accurate today but also offer repeatable results from day to day and over the long term.

EUROPEAN STANDARDS

How reliable is it 5, 10, n years from now?

Regardless of the stability of an instrument, its specifications are valid for up to a year. The only way to ascertain its stability and therefore reliability is to have a competent (ISO17025 accredited) laboratory calibrate it for your specific measurement conditions including the higher frequencies. An unstable instrument is likely to require adjustment to ensure that it remains within its accuracy specifications.

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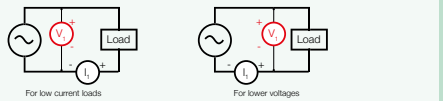
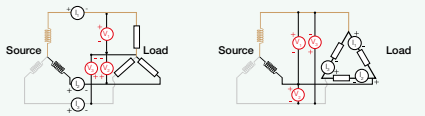


For low current loads | For lower voltages

Three Phase Wiring



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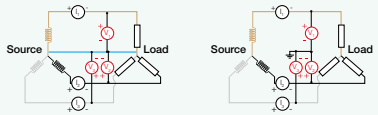

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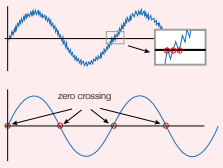

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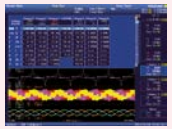

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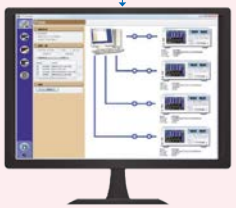

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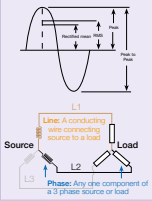

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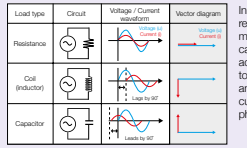

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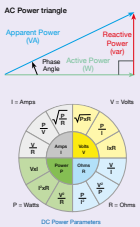

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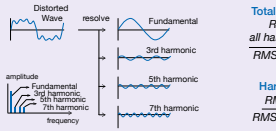

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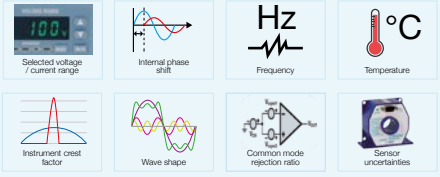

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ISO 9001 | IEC | EN EUROPEAN STANDARDS | CE

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ISO 17025 ACCREDITED LABORATORY

Precision Making

For more information: tmi.yokogawa.com