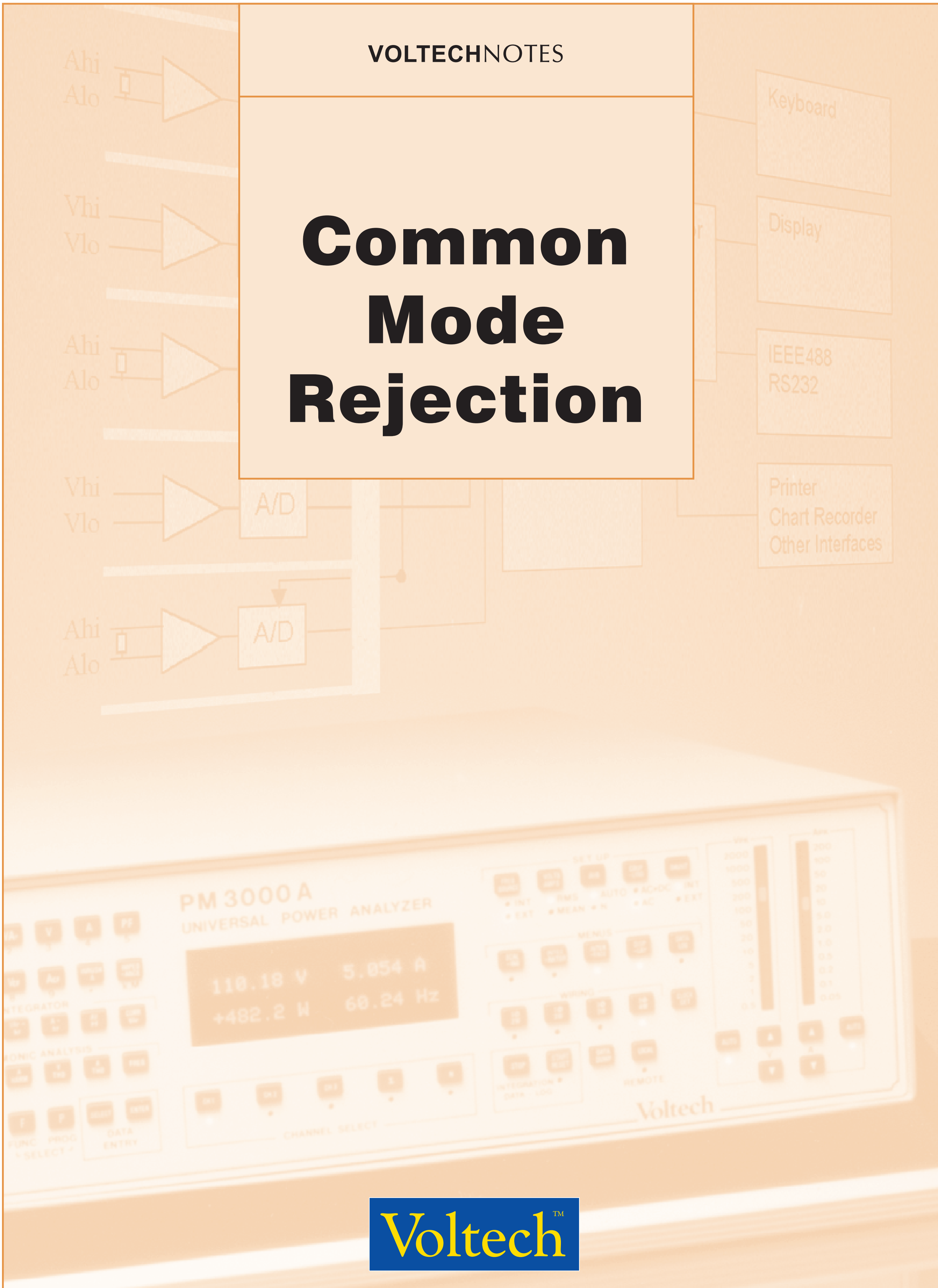
VOLTECHNOTES

Common Mode Rejection



Voltech™

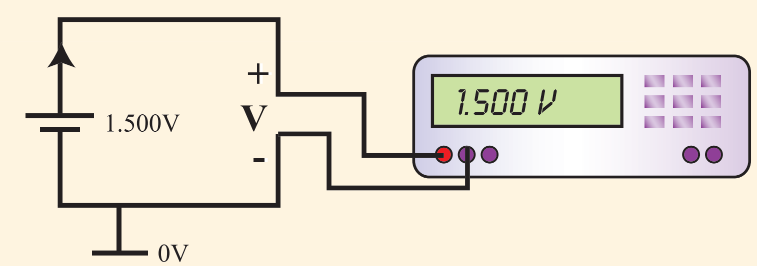
VPN 104-108/2

Common Mode Rejection

What is a common mode signal?

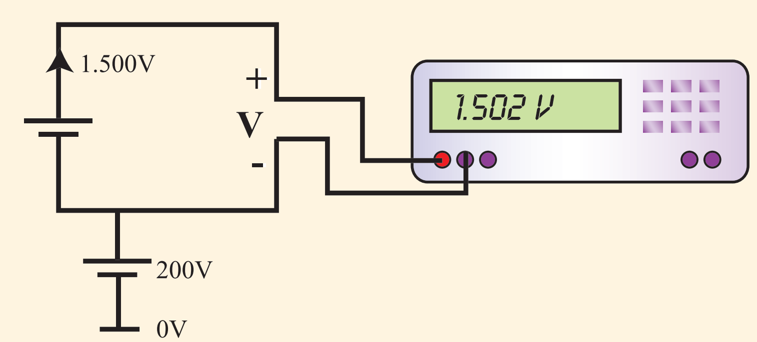
A common mode signal is one that is present on more than one connection. Imagine a bench voltmeter measuring the voltage produced by a battery: The voltmeter correctly reads the 'differential' or 'normal' mode voltage of 1.500V.

Normal measurement



Now another voltage source is connected between 0V and the battery. This voltage is common to both terminals of the DVM and should have no effect on the reading, as the differential voltage between the terminals is still 1.500V.

Measurement with a common voltage



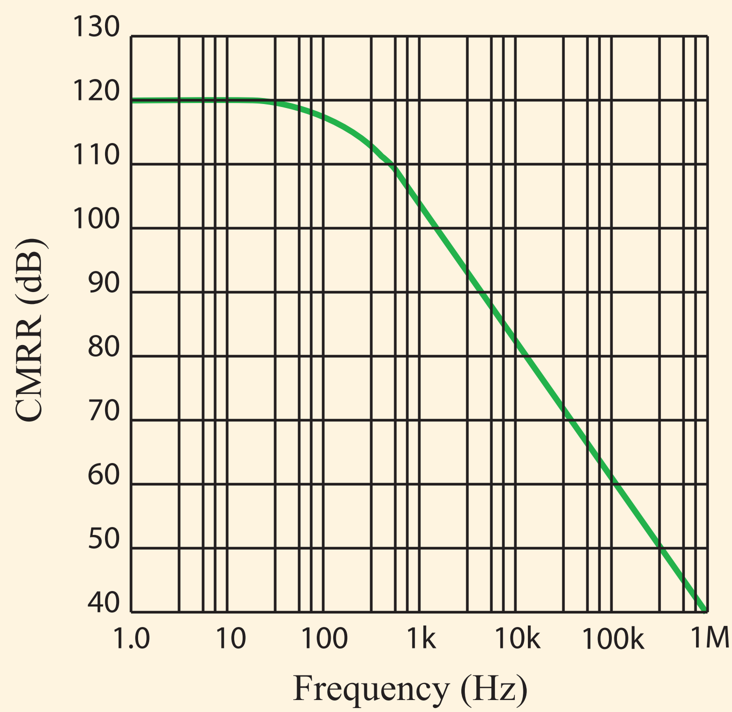
The differential voltage at the terminals of the meter is still 1.500V, but the meter now reads 1.502V. This is an error of 2mV, introduced by the common mode signal of 200V. The common mode error of 2mV is often expressed as a rejection ratio: 200/0.002 = 100000:1 and then (because the ratio is usually very large) in decibels: 20 $\log_{10}$ (200/0.002) = 100dB.

What causes common mode error?

Common mode error is part of the fundamental specification of the differential amplifiers used in instrumentation. Further common mode error may be caused by the proximity and orientation of measuring circuits to ground and to one another. The effect can be minimized by using high-quality instrumentation operational amplifiers and by careful design and shielding of the circuits inside the instrument.

In the previous example, DC voltages are used to illustrate the principles but, in general, the common mode error is greater with AC voltages and is invariably much worse at higher frequencies.

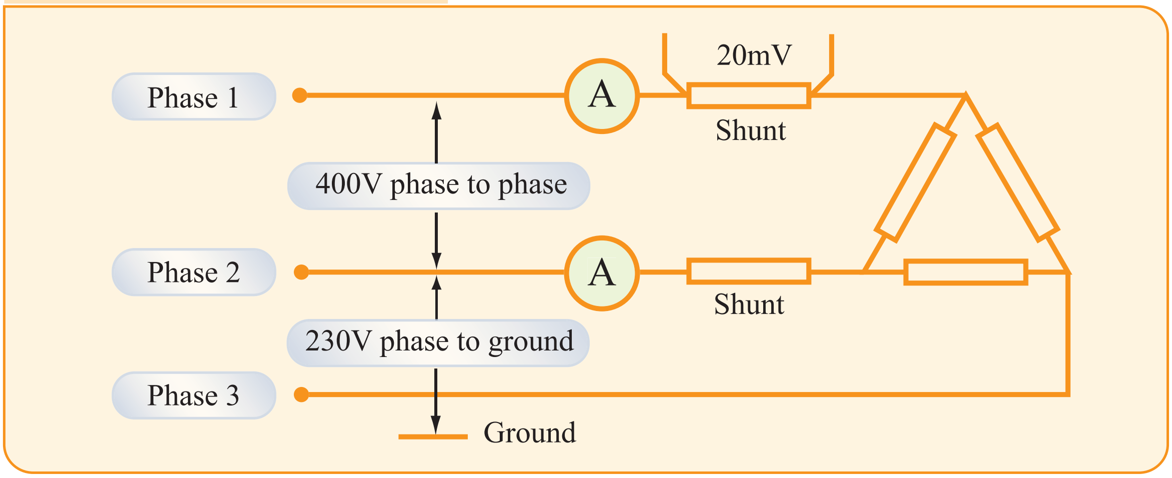
Typical common mode rejection



Why is common mode rejection important?

It can be seen from the DVM example given earlier that a common mode voltage will result in a differential voltage reading error. With power measurements, however, the problem is even greater, as a power meter must measure both voltage and current signals. This is of particular significance, since the problem of common mode signals on the current channel is usually greater than that of the voltage channel. This is illustrated on the diagram below using a three-phase delta-connected circuit.

Taking account of 3-phase CMRR



The current shunt in a power analyzer has a low resistance, producing a small voltage, from which the current value is calculated. In this example, the current shunt generates a 20mV differential voltage, yet it can be seen that the phase-to-ground common mode voltage is 230V. This high ratio of common mode to differential mode voltage increases the differential voltage error in the current measuring circuit, which will result in an increased current reading error.

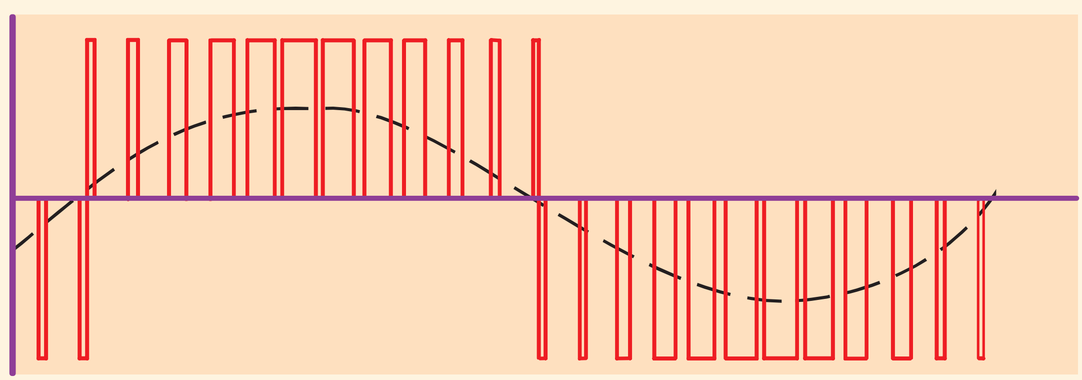
Since power measurement is a function of voltage multiplied by current, it is essential for good-quality power analyzers to exhibit high common mode rejection on both voltage and current channels.

Common mode rejection in real-world applications

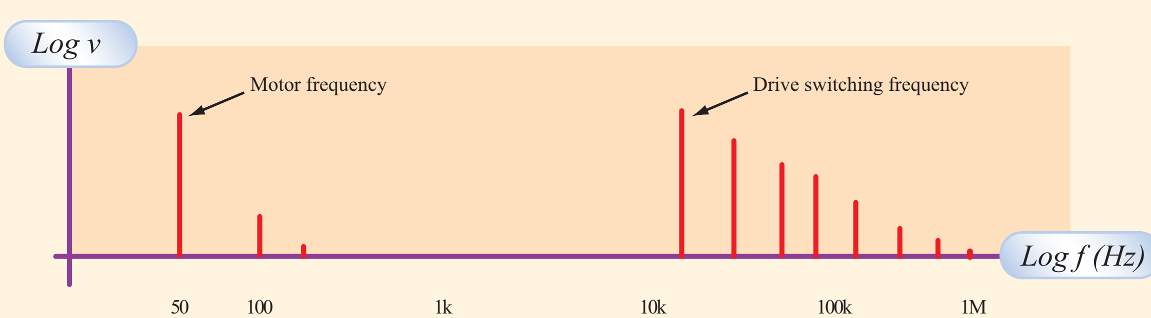
In power electronics applications, such as motor drives and electronic ballasts, the effect of common mode voltages at high frequencies can be severe. So far, we have considered the effect of common mode signals in a DC example and a simple three-phase circuit. In both of these cases, the common mode rejection ratio can easily be established since the equation shown on page 2 may be applied using the DC voltage or the rms AC voltage at specified frequency. An increasing proportion of modern electronics applications, however, are much more complex because the voltage and current signals being measured include many frequency components.

This is illustrated below with the voltage waveform and harmonic spectrum of a pulse with modulated motor drive.

Motor drive output waveform



Harmonic spectrum of motor drive output voltage



These devices operate by modulating a high-frequency carrier and, especially in motor drives, the carrier may be rectangular in shape, containing significant harmonic amplitudes well above the switching frequency.

A power analyzer must be designed to minimize the effect of common mode of such a high frequency and complex waveform on its current measurements.

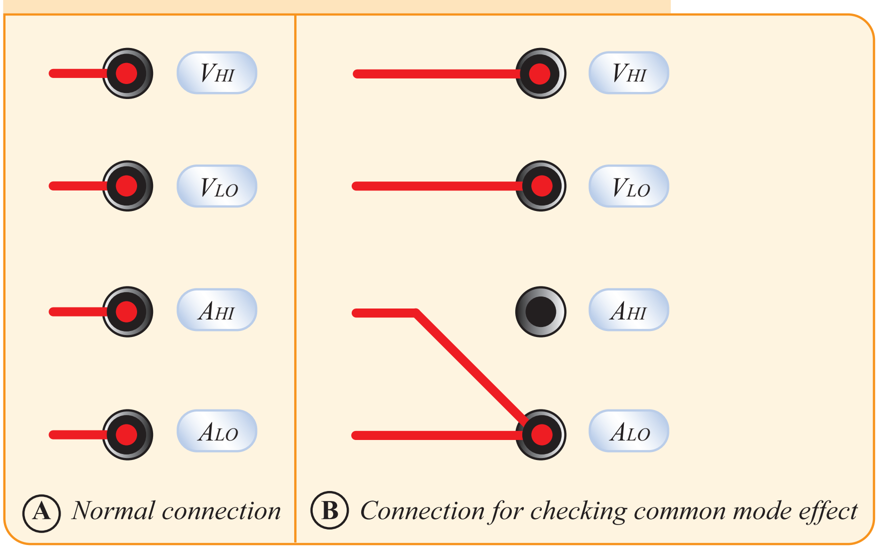
How do you account for the effect of common mode signals in the final measurement?

Since the common mode rejection will be different for each harmonic present in a complex and variable common mode signal, it is very difficult to calculate precisely the effect on the measurement from specifications alone.

The easiest and most reliable way to check the effect of a common mode signal is to measure it, i.e. apply the common signal only, and note the result.

Measuring the effect of common mode on current and power measurement

To measure common mode effect using a power analyzer



1. Connect as normal connection, set up analyzer as required, and make measurements of voltage, current, power, etc. Record results. Turn off supply.

2. Reconnect analyzer as shown in B above and repeat measurements, using exactly the same conditions as before. The analyzer has no normal (differential) current input and would ideally ready zero for current and power—but it will not. This is the effect of common mode signals. Record these results.

3. If the values of current and power in the common mode connection are significant compared with those in the normal measurement, these can be compensated on each channel as follows:

Power compensated for common mode
= Power (normal) - Power (common mode)

Current compensated for common mode
$$= [\text{Current (normal)}^2 - \text{Current (common mode)}^2]^{1/2}$$

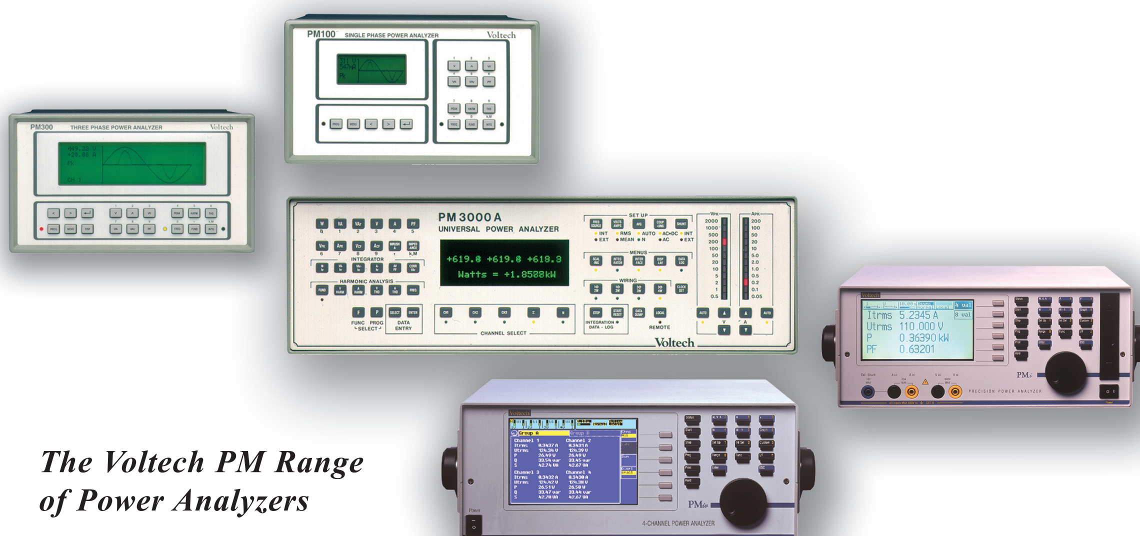
Best results, however, are always obtained by using an analyzer with as high a common mode rejection as possible to high-frequency, complex waveforms, and Voltech analyzers are designed to achieve this. This is illustrated by a comparison of a Voltech PM3000A with another well-known three-phase analyzer in a PWM motor drive situation.

	PM3000A	**Other 3-phase Analyzer**
Power Normal	1074.2W	1058.3W
Power CM	-2.1W	-11.3W
CM Error %	0.2%	1.1%

Note: Many analyzers will not display small measurements—typically below 10% of a given range. This feature may have to be switched off in order to measure the common mode effect. For example, on a Voltech PM3000A this can be done using the key sequence [F], [P], 2, 6 'disable low value blanking'.

Conclusion

- The rejection of common mode signals is an important part of the design of a power analyzer.
- The ability of a power analyzer to reject common mode signals is dependent on the careful physical layout and shielding of the measurement channels as well as the quality of the components used.
- The specification of common mode rejection at 50 or 60Hz only, or even at higher frequencies, is not sufficient to asses the overall performance of a power analyzer in real-world applications.
- The best way to asses the common mode effect is to measure it in the application where the power analyzer is being used.



The Voltech PM Range of Power Analyzers

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