Making electrical measurements on your phone

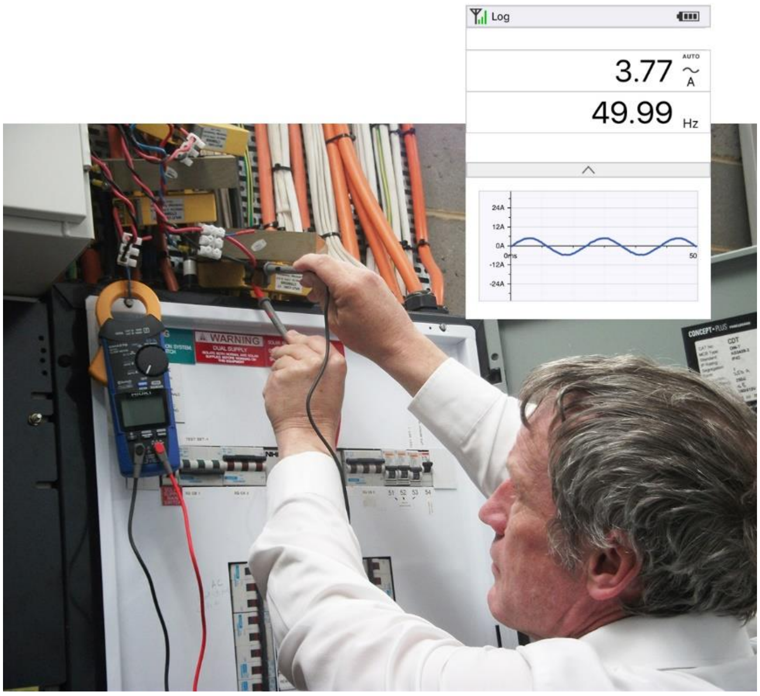
The Hioki CM4372 600 amp and CM4374 2000 amp

Bluetooth compatible AC, DC and AC+DC clamp testers

The fulfilment of a bucket list for clamp-on testers now provides trms measurements for highly distorted waveforms with crest factors as high as 7.5, inrush current peaks and rms values for motors, etc., simultaneous DC voltage and current measurement—all this Bluetooth compatible with smart phone readout.

Making accurate measurements of voltage, current, etc. is important and often challenging in harmonic-intense supply systems. When you add another dimension: hard to reach locations—then it's time for being able to concentrate on the job of attaching the measuring instrument safely and not having to worry about reading the display.

In the case of the Hioki CM4372/4 clamp-on testers, the Bluetooth-compatible readout provides the measured parameters on one's smart phone.



Making a measurement in an awkward location—the inset shows a the smart phone display

True RMS measurements

True rms measurements are essential—that is more or less a given. However, how true is a true rms measurement? The CM4372/4 clamp-on testers break new ground in this area. And it is an area where differences in performance of instruments can stand out starkly.

The higher the incidence of high frequency harmonics, the more challenging the task becomes. Sampling frequency is critically important. For the theoretically inclined, the rms value of a harmonic rich current (or voltage) is given by:

$$\boldsymbol{I_{rms}}^{2} = \frac{\boldsymbol{I_m^2}}{\boldsymbol{2\pi}}\int_{0}^{2\pi} \boldsymbol{sin^2\,\theta d\theta} + (\boldsymbol{sin^2}(\boldsymbol{2\theta} - \boldsymbol{\varphi_{2\theta}}) + \cdots)\boldsymbol{d\theta}$$

All this integral calculus is of no use to us practical engineering types. In the case of the Hioki instruments, a specially designed ASIC takes care of the numerical integration, using as a template the acquisition of small time slices equivalent to ***2πfΔt***, or ***Δθ.*** The relationship is shown below:

$$I_{rms}^2 = \frac{\sum_{1}^{N\Delta\theta=(2\pi)} i_\theta^2 \Delta\theta}{N\Delta\theta}$$

OK, we have done with the theory but there are some very important practical things that come to the attention. In order to cater for high order harmonics, the higher the sampling frequency the better.

In the case of the Hioki CM4372/4 clamp testers, the sampling frequency of 10 kHz provides a Nyquist limit of 5 kHz (catering for harmonics to the 50th and beyond). In other words, high frequency inter-harmonics contribute to the overall accuracy of rms current and voltage.

Equally important is the dynamic range of the sample and hold circuitry, and it shows up in a practical way through the specification of crest factor (peak to rms ratio). For example, on the 20 amp range, crest factor is 7.5, a truly impressive figure, and even on the 600 amp range, it is a factor of 3, demonstrating outstanding linearity.

Inrush current--Motors

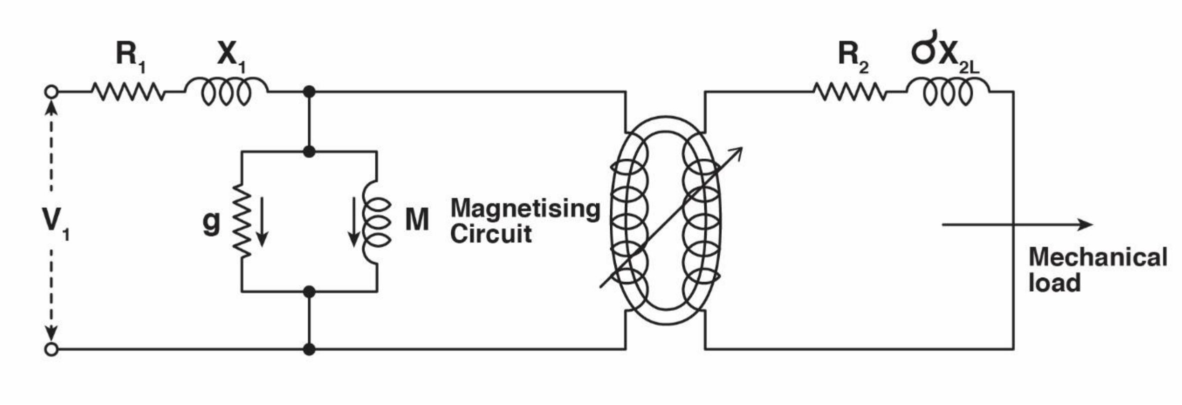
Here again the CM4372/4 series are very well equipped to make accurate measurements, where again sampling frequency is all important.

The general expression for the current after connection of voltage to an inductive circuit, is of the form:

$$e = ri + L\frac{di}{dt}$$

Now that's all well and good but doesn't help when you are checking out why a moulded case breaker is popping on start-up of a motor.

The start-up current is highly asymmetrical, and particularly for high efficiency motors, far surpasses the locked rotor current. The latter might typically be of the order of 6 times full load current, whereas the start-up current might easily be 14 times full load, lasting perhaps a cycle and a half. The equivalent circuit below is typical of an induction motor.



i

The effective motor impedance at the start, Z_M, equal to $r + jx$ should be considered as the per phase value. Unsurprisingly the inrush current depends on the phase angle of the supply voltage when connection is being made—and there are three phases. To keep things mathematically consistent, e_1 is given by:

$e_1 = V_{1\text{-peak}} \cos(\Theta - \delta)$,

where e_1 is the instantaneous voltage, at Θ

δ is the phase angle of the voltage when connected

Θ is $2\pi ft$, (in expressions below, $2\pi f$ is replaced with the symbol ω, the angular frequency.

Where: e_1 is instantaneous voltage, r is lumped resistance and L, lumped inductance. The inrush current, I is described by the equation below.

$$i = \frac{V_{1-p}}{Z_m}\cos(\Theta - \delta - \theta_1) - \frac{V_{1-p}}{Z_m}e^{-\frac{r\Theta}{x}}\cos(\delta + \theta_1)$$

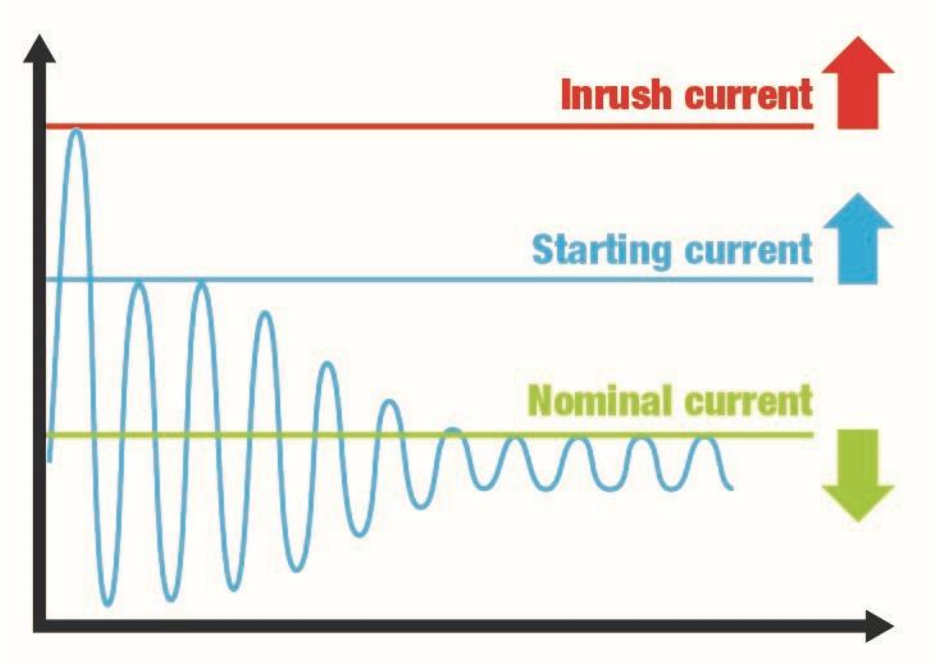
Where $V_{1\text{-}p}$ ($V_{1\text{—}peak}$) is as before, the peak voltage

Z_m is the motor impedance under locked rotor conditions (i.e. at the moment of connection).

Θ is ωt

δ is the phase lag of the voltage at the moment of connection

θ_1 is the arctangent of r/x these being the resistive and reactive components respectively of Z_m



The second term in equation is an exponentially decaying baseline on which the oscillating (at power frequency) current rests. The bigger in value *r* is, and the smaller in value *x* is, the sooner the decay takes place. This is shown graphically in in the above figure.

The smart phone display will show both the initial rms values as well as peak current and obviously this is invaluable in working out protection grading on motor control gear.

DC measurements

DC link measurements in solar inverters are essential when a fault finding procedure is required. Because there is an AC component present, accurate measurement of average power is important. The CM4372/4 are able to measure average values for current (and voltage) correctly. In other words, according to the formula as shown below:

$$I_{eff} = \sqrt{I_{DC}^2 + \frac{I_{AC}^2}{2}}$$

The CM4372/4 are able to simultaneously display DC current and voltage, making the clamp-on testers very useful in DC traction and electric vehicle testing.

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