Powertek

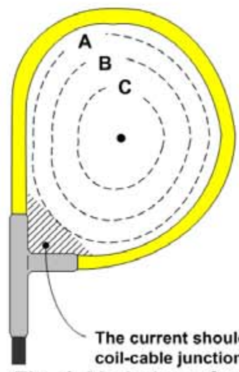
CALIBRATION OF CWT PROBES

These instructions are solely for checking the calibration of a CWT probe. They are not suitable for adjusting the CWT sensitivity. If the probe is outside calibration it must be returned to Powertek for adjustment.

Introduction

The sensitivity (mV/A) of a CWT probe can vary with the following parameters:

- The **position** of the measured current within the Rogowski coil loop. The variation is specified as typically ±1% for standard coils and ±2% for mini and ultra mini coils provided that the measured current and any external currents are not adjacent to the junction between the coil and the connecting cable. Fig. 1 shows the allowable position of current within the loop.



POSITIONAL ACCURACY OF A STANDARD ROGOWKSI COIL - % error with a point source of current

Type	A	B	C
Miniature Coil	±3%	±1%	±0.5%
Standard Coil	±2%	±1%	±0.5%

Fig. 1 Variation of sensitivity (mV/A) with position

- The **frequency** of the measured current. The sensitivity at lower frequencies can be slightly different to that at higher frequencies as shown by trace (a) of Fig. 2 since CWT probes utilise two integrators [1]. The difference should not be greater than ±1%. Trace (b) shows the ideal variation.

  f_L and f_H are the 3dB low frequency and high frequency bandwidths. Values are given on the CWT specification sheet.

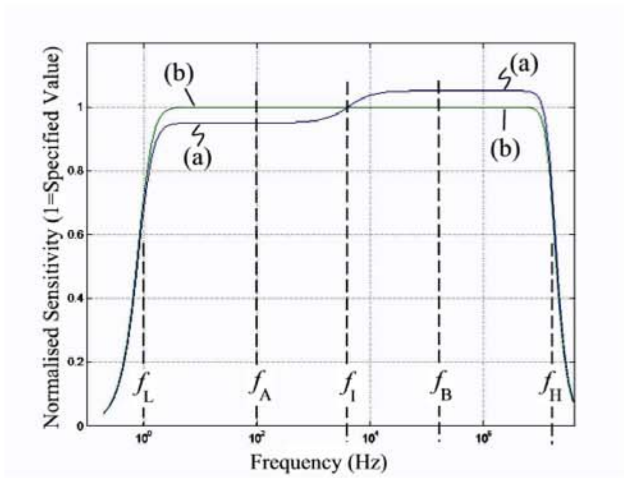


Fig. 2 Variation of sensitivity (mV/A) with frequency

- The **magnitude** of the measured current. Since the CWT probes are very linear [3] it is not necessary to check the sensitivity at different values of current at a particular frequency. However it is recommended that the current should not be less than 5% of its rated value to avoid inaccuracy due to noise.

- The **ambient temperature** around the coil and the integrator. Temperature coefficients are given in [3].

The main objective of calibration is to measure the CWT sensitivity at a particular frequency (the calibration frequency) at typical ambient temperature and to check that it lies within the specified tolerance of its nominal value (e.g. 1mV/A ±2%).

As a secondary objective the procedure may be repeated at one or more different frequencies to check the sensitivity over the specified operating range of frequencies. Alternatively and preferably this may be checked using a repetitive current pulse.

Values of current, frequency and pulse duration for the tests undertaken by Powertek for each type of CWT are given in Table 1. It is not necessary that exactly the same values are used although they should comply with the various rules given below. The test current may be in a single conductor or in several turns of a test coil - in the latter case the current measured by the CWT is the coil current multiplied by the number of turns.

Main Calibration – Checking Sensitivity (mV/A)

Powertek issues a calibration certificate for this test.

Equipment required

(a) A high stability sinusoidal or approximately sinusoidal (i.e. with relatively low harmonic content) continuous current source of appropriate magnitude and frequency (for values used by PEM see Table 1).

(b) A reference current transducer with traceable calibration to provide an independent current measurement for comparison. For accurate comparison it is best to arrange that the sensitivity is equivalent to the CWT under test.

(c) A digital voltmeter to measure and compare the output voltages from the CWT and the reference transducer.

Choice of frequency and current magnitude

The value of the test frequency f_A is not critical provided it is sufficiently higher than the low frequency 3dB bandwidth f_L (or sufficiently lower than the high frequency 3dB bandwidth f_H) otherwise the sensitivity will not correspond to its nominal value. The following rule gives sufficient accuracy:

$$30f_L < f_A < f_H / 30 \quad (1)$$

Lower frequency currents are easier to generate and are generally used – see Table 1.

The current magnitude needs to be sufficiently large in relation to the current rating of the CWT. PEM either uses 4000Arms (CWT150 and greater) or uses currents which give a 1.000Vrms measurement (23.6% of full scale – CWT60 and below.

For the CWT15 and greater (current ratings ≥ 3000A pk) Powertek uses a specially designed highly stable 50Hz current source in a single conductor with currents up to 5000Arms [2]. The reference transducer is a 4000:1 CT with various burden resistors such that the CWT and reference CT sensitivities (mV/A) are equivalent. The CT and burden resistors are calibrated at the UK's National Measurement Laboratory.

For the CWT6 and lower (current ratings ≤ 1200A pk), frequencies in the range 250Hz to 10kHz and currents in the range of 5 to 200Arms are appropriate – see Table 1 for details of recommended values. Powertek uses a 400W "Phonic" audio amplifier giving 5Arms in coils of various numbers of turns ranging from 1 to 40. The reference transducer is a 100mV/A Pearson 411 CT with a traceable NAMAS certificate.

Procedure

1. Link the CWT Rogowski coil with the appropriate test current source so that the test current is situated as close as possible to the centre of the Rogowski coil loop. Situate the Rogowski coil such that the ferrule (where the coil is attached to the cable) is as distant from any external currents as possible.

2. Switch on the CWT and the test current source and adjust the current to the appropriate magnitude at frequency f_A (see Table 1) using the reference current transducer and digital voltmeter to measure the current. Allow at least 1 min to stabilise.

3. Measure the CWT output voltage using the digital voltmeter and compare this with the predicted voltage. The predicted voltage is the measured current from 2 multiplied by the specified sensitivity for the CWT.

Secondary Calibration – checking the variation with frequency

Equipment required

(a) A high stability repetitive current pulse source of appropriate frequency, duration and magnitude (for values see Table 1).

(b) A reference current transducer with a high bandwidth (>20 MHz) and with traceable calibration to provide an independent current measurement for comparison.

(c) A 200 MHz digital storage oscilloscope to monitor and compare the pulse waveform measurements (output voltages) from the CWT and the reference transducer.

Method

This method utilises repetitive pulses of current which are measured both by the CWT and the reference current transducer.

The pulses are preferably unidirectional. Powertek uses exponentially decaying pulses ($i = I_{pk}.\exp(-t / T_P)$) since these are relatively easy to generate, but the shape is not critical – rectangular, triangular, etc would also suffice. However three criteria are necessary:

1. The pulse duration must be > T_I, preferably >> T_I. For exponential decay pulses, the duration is taken to be T_P.
2. The pulse duration (μs) should be < $300/f_L$(Hz) to avoid droop.
3. The rising edge time T_R must be < 0.2 T_I, preferably << T_I.

where T_I is the integrator time constant. Values for T_I are given in Table 1.

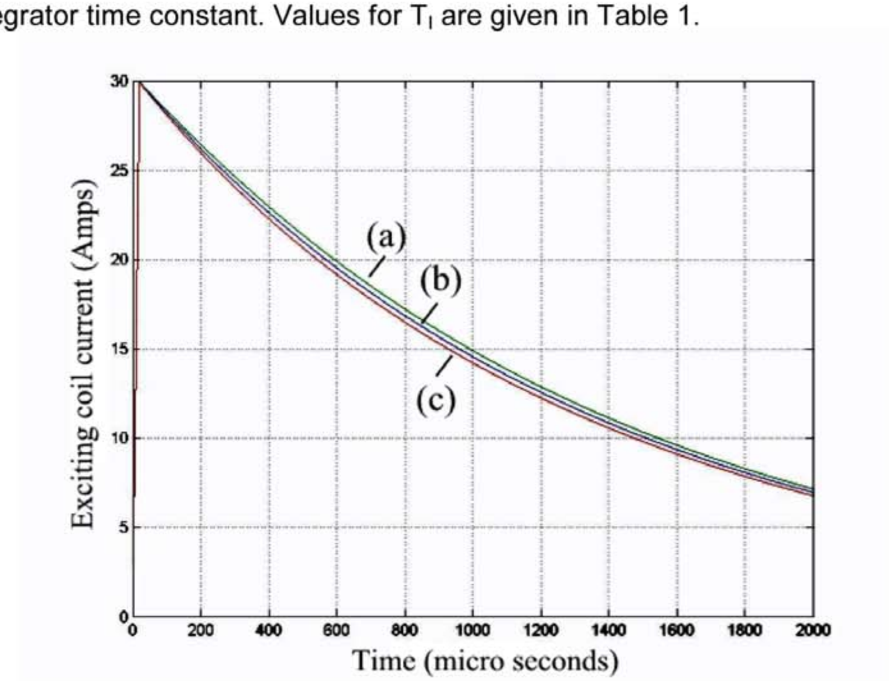


Figure 3 - Current Pulse for Setting-Up Stage 2.

Fig. 3 shows the pulse used by Powertek for testing a CWT600 with an integrator time constant T_I = 360 μs. The exciting coil has 200 turns and the peak current seen by the CWT is 6000A. The pulse has an exponential decay constant T_P = 1360 μs and a rise time of 20 μs. The pulse repetition frequency is 12.5 Hz.

Trace (b) shows the true current pulse as measured by the reference transducer and the CWT when the low frequency and high frequency sensitivities are matched.

Trace (a) shows the CWT measurement if the sensitivity at high frequencies is 2% lower than the sensitivity at low frequencies.

Trace (c) shows the CWT measurement if the sensitivity at high frequencies is 2% higher than the sensitivity at low frequencies.

In each case the oscilloscope sensitivity for the CWT channel is adjusted so that the rising edge coincides with the reference current transducer measurement as shown in Figure 2.

The current pulse shown in Figure 3 is only suitable for higher current units in the CWT range. Table 1 shows the values of rise time T_R and pulse duration T_P used by PEM for each unit.

Figure 4 shows the pulse shape used for CWT3 to CWT 30 – T_P can be varied from 16 μs to 44 μs.

Figure 5 shows the pulse shape used for CWT015 to CWT1 - T_P can be varied from 1.2 μs to 13 μs

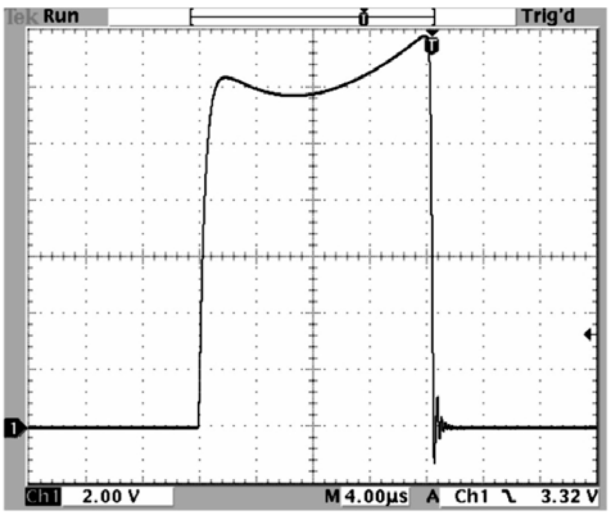


Fig. 4 - 140 A_{pk} 16 μs test pulse for CWT3 to CWT30 units

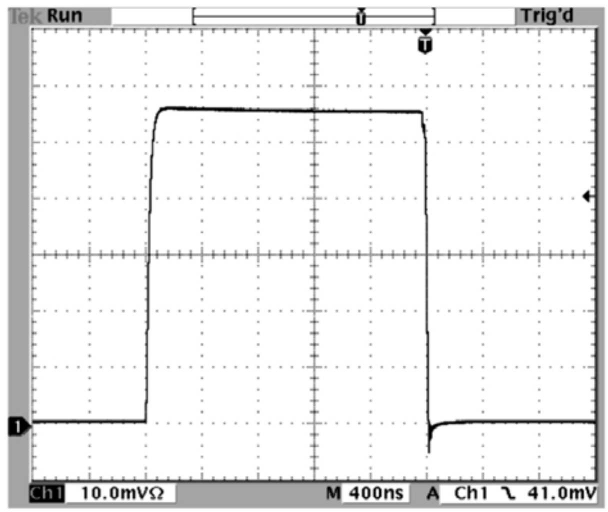


Fig. 5 - 5.6 A_{pk} 2.0 μs test pulse for CWT015 to CWT1 units

Procedure

1. Link the CWT Rogowski coil with the exciting coil carrying the pulsed current.

2. Switch on the CWT and the pulse current source and compare the measured pulses from the CWT and the reference current transducer on a 2 channel oscilloscope.

3. Adjust the sensitivity of the CWT channel so that the rising edge is coincidental for both traces. The remainder of the current pulse should also be identical if the sensitivity is constant over the frequency range.

References

[1] W F Ray and R M Davis. *"High Frequency Improvements in Wide Bandwidth Rogowski Current Transducers"*, 8th European Conference on Power Electronics and Applications (EPE), Lausanne, Sept '99.

[2] W F Ray. "*A 4000Arms Highly Stable Calibration Current Source"*, ibid

[3] PEM Application Notes, Sept 2002.

Table 1.a. - Test Values for CWT and CWT mini Ranges

The values for f_A, I_{CWT}, N_A, N_B, T_R and T_p are those used by Powertek. The rules constraining these values for a given CWT probe are described in the main text.

CWT and CWT mini Ranges

				A – Single Frequency Test Main Calibration				B – Pulse Shape Test Secondary calibration			
CWT	**R_{sh} (mV/A)**	**f_L (Hz)**	**T_I (µs)**	**f_A (Hz)**	**N_A**	**I_{cwt} (A rms)**	**V_{cwt} (mV rms)**	**N_B**	**I_{cwt} (A pk)**	**T_R (µs)**	**T_P (µs)**
015	200	150	0.22*	10k	1	5	1000	1	6	0.05	2
03	100	105	0.26*	10k	2	10	1000	1	6	0.05	2
06	50	80	0.43*	10k	4	20	1000	1	6	0.05	2
1	20	50	0.90	4k	10	50	1000	4	22	0.11	3
1N	20	25	1.80	4k	10	50	1000	4	22	0.11	6
3	10	3.5	1.80	2k	20	100	1000	4	22	0.11	13
3N	10	1.0	3.60	2k	20	100	1000	1	140	0.8	16
6	5	1.0	3.60	1k	40	200	1000	2	280	0.8	16
15	2	0.8	9.0	50	1	500	1000	10	1400	0.8	16
30	1	0.8	18.0	50	1	1000	1000	10	3000	0.8	44
60	0.5	0.4	36.0	50	1	2000	1000	100	2400	4	530
150	0.2	0.2	90	50	1	4000	800	100	2400	4	530
300	0.1	0.1	180	50	1	4000	400	200	6000	20	1360
600	0.05	0.05	360	50	1	4000	200	200	6000	20	1360
1500	0.02	0.03	900	50	1	4000	80	200	6000	20	1360

* Typical value (varies with coil and cable length)

Glossary of terms

R_{sh} CWT sensitivity in mV/A
T_I The integrator time constant
f_L Low frequency -3dB cut-off
f_A The test frequency for the main calibration (single frequency test)
N_A,N_B The number of coil turns of the test conductor linking the Rogowski coil
I_{CWT} The current measured by the Rogowski coil
V_{CWT} The corresponding output voltage from the CWT transducer given R_{sh} and I_{CWT}
T_R Rise time of the test pulse
T_P The duration of the test pulse, (in the case of an expontential decay this is the decay constant)

Table 1.b. - Test Values for CWTLF and CWTLF mini Ranges

CWT LF Range – standard coils

				A – Single Frequency Test Main Calibration				B – Pulse Shape Test Secondary calibration			
CWTLF	R_{sh} (mV/A)	f_L (Hz)	T_I (µs)	f_A (Hz)	N_A	I_{cwt} (A rms)	V_{cwt} (mV rms)	N_B	I_{cwt} (A pk)	T_R (µs)	T_P (µs)
03LF	100	5.1	1.2*	5k	2	10	1000	1	6	0.05	13
06LF	50	2.6	2.9*	2.5k	4	20	1000	1	6	0.05	13
1LF	20	1.0	3.3	1k	10	50	1000	4	22	0.11	13
3LF	10	0.55	6.6	500	20	100	1000	1	140	0.8	16
6LF	5	0.27	13	250	40	200	1000	1	300	0.8	44
15LF	2	0.11	33	50	1	500	1000	2	600	0.8	44
30LF	1	0.055	66	50	1	1000	1000	100	2400	4	530
60LF	0.5	0.022	130	50	1	2000	1000	100	2400	4	530
150LF	0.2	0.011	330	50	1	4000	800	200	6000	20	1360
300LF	0.1	0.008	660	50	1	4000	400	200	6000	20	1360
600LF	0.05	0.008	1300	50	1	4000	200	200	6000	20	1360
1500LF	0.02	0.008	3300	50	1	4000	80	200	6000	20	1360

CWT LF Mini Range – Mini coils

				A – Single Frequency Test Main Calibration				B – Pulse Shape Test Secondary calibration			
CWTLF Mini	R_{sh} (mV/A)	f_L (Hz)	T_I (µs)	f_A (Hz)	N_A	I_{cwt} (A rms)	V_{cwt} (mV rms)	N_B	I_{cwt} (A pk)	T_R (µs)	T_P (µs)
03LF	100	11	0.8*	5k	2	10	1000	1	6	0.05	13
06LF	50	5.6	1.1*	2.5k	4	20	1000	1	6	0.05	13
1LF	20	2.3	1.4	1k	10	50	1000	4	22	0.11	13
3LF	10	1.1	2.8	500	20	100	1000	4	22	0.11	13
6LF	5	0.55	5.7	250	40	200	1000	1	300	0.8	44
15LF	2	0.22	14	50	1	500	1000	2	600	0.8	44
30LF	1	0.11	28	50	1	1000	1000	100	2400	4	530
60LF	0.5	0.055	57	50	1	2000	1000	100	2400	4	530
150LF	0.2	0.022	140	50	1	4000	800	200	6000	20	1360
300LF	0.1	0.011	280	50	1	4000	400	200	6000	20	1360
600LF	0.05	0.008	570	50	1	4000	200	200	6000	20	1360

* Typical value (varies with coil and cable length)

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