DC*flex* Technical Notes

All measuring instruments are subject to limitations. The purpose of these technical notes is to explain some of those limitations and to help the engineer maximise the many advantages of PEM's Rogowski current transducers.

These technical notes should be read in conjunction with the DC*flex*short-form datasheets.

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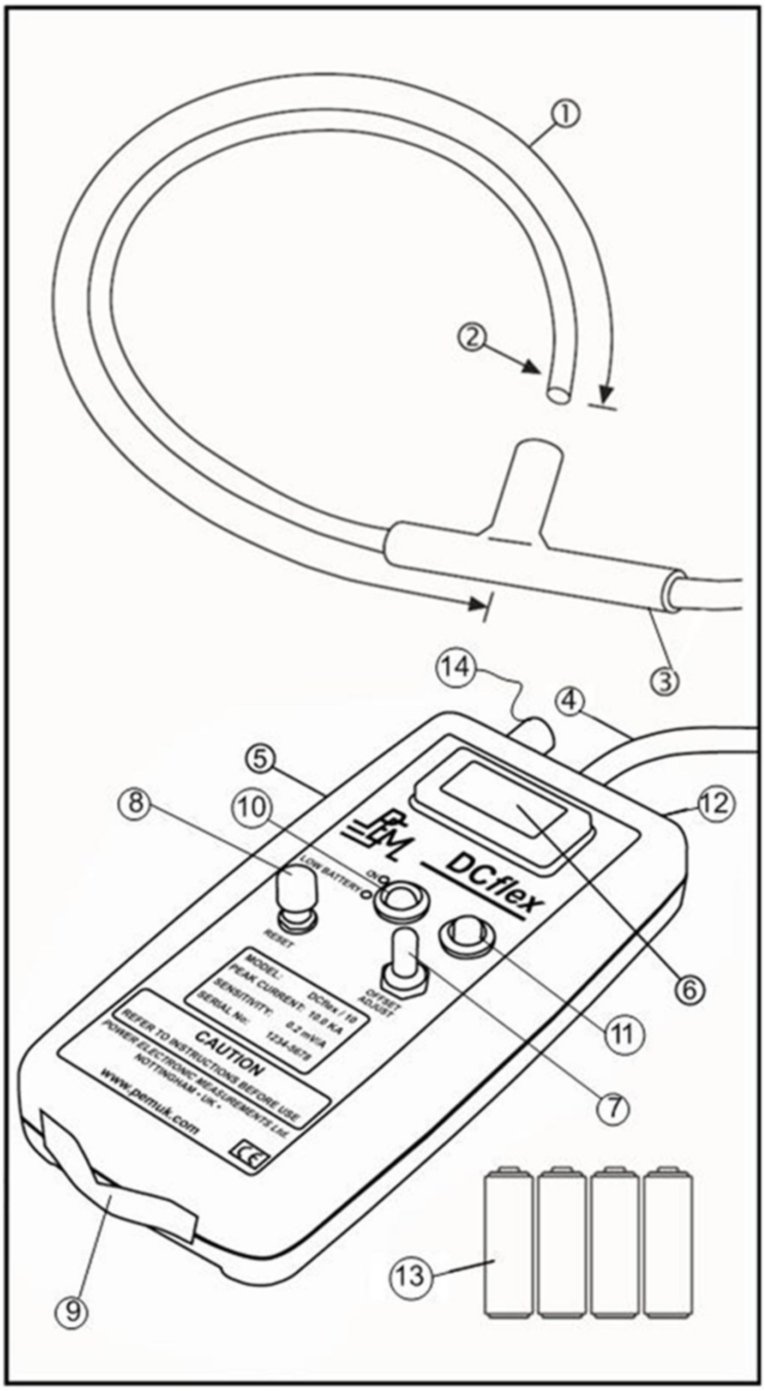
1. Introduction

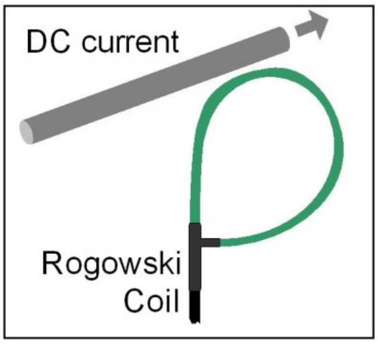
The DC*flex*



1. Rogowski coil (loop)
2. ‘Free end’ of the Rogowski coil
3. Ferrule (the connecting mechanism for closing the Rogowski coil).
4. Cable connecting the Rogowski coil to the integrator electronics
5. Enclosure for the integrator electronics
6. 3½ digit LCD display.
7. OFFSET ADJUST trimmer.
8. RESET push button
9. Clip for attaching lanyard.
10. LED indicator
    - GREEN - CWT is ON
    - RED – low battery
11. Push button ON / OFF switch
12. Socket for connecting external DC supply
13. 4 x AA batteries
14. BNC output

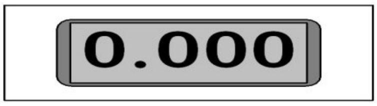
2. Basic Operation

Switch the DCflex on by pressing the grey push button. The green LED will light to show the unit is operational. Allow the DCflex 2 minutes to settle before proceeding. If the LED is RED then the batteries need replacing.

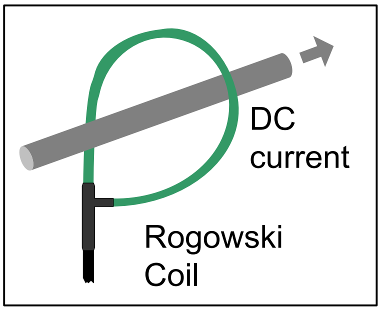


Make sure the Rogowski coil is clipped together but NOT around the conductor under test.

Press the red RESET button and **<u>keep it pressed</u>** whilst trimming the OFFSET ADJUST to give a zero reading on the LCD display.

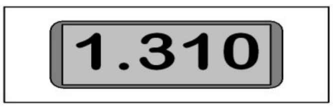


When the LCD display is zero release the RESET BUTTON.



Unclip the Rogowski coil and clip it around the conductor under test as quickly as practicable. The output from the LCD display should be ignored during this process.

Once the **Rogowski coil free end is fully clipped into its socket** take a reading from the LCD display or from the oscilloscope or other recording device into which the BNC output is connected.



Converting this voltage using the 'Sensitivity mV/A' clearly labelled on the front of the DCflex gives the value of your DC current.

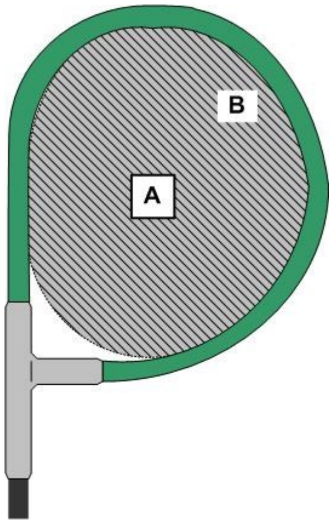
3. Obtaining the best measurement

3.1 Accuracy

The accuracy of the DCflex is dependent on the following:

The position and size of the conductor relative to the coil circumference

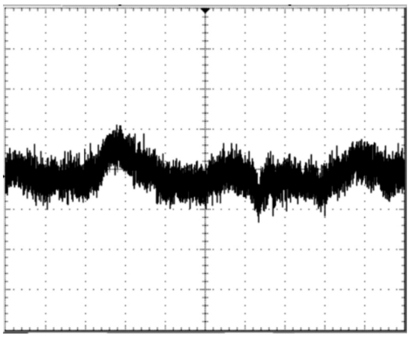
The DCflex is calibrated using a highly stable current source. The conductor is kept central in the Rogowski coil (position **A** on the diagram shown right). The DCflex is calibrated to an accuracy of ±0.4% of reading. The DCflex is supplied with a calibration certificate detailing the procedure and those comparative measurement devices with traceable certification to UKAS.



As an example of how the output can vary with conductor position a 20cm^2 conductor is moved around the Rogowski coil (shaded area **B** on the diagram right). The output does not vary from the calibrated value by more than ±0.5% of reading. As the conductor gets larger this error will reduce.

Uncertainty due to low frequency noise

The integrator op-amp generates a random low frequency noise. An example of the noise produced by the DCflex is shown in the oscilloscope trace right. This noise adds 'uncertainty' to the DCflex measurement.



5A/div, Timebase 20sec/div

The noise is 10A p-p max.. Its effect reduces with increased current magnitude e.g. for the 10kA version a noise of 10Ap-p represents 0.1% of FS and for the 40kA version only 0.025% of FS.

Display error

0.1% of FS (due to offset and non-linearity errors in the LCD display).

Temperature coefficient

-0.016 %/°C Clip-around Rogowski coil
±0.017 %/°C Electronics

4. Measurement Drift

SET-UP DRIFT	0.025% per sec (of reading) From reset to clipping the coil into its socket around the bus bar.
OUTPUT DRIFT	< 5.0A per sec From clipping the coil into its socket to taking a reading

The DCflex is a single shot measurement. The integrator offset needs to be nulled to zero before taking a reading. Once nulled the integrator will begin to drift – this is termed 'Set-Up Drift'.

Once the Rogowski coil has been clipped around the conductor the reading displayed on the LCD meter will begin to drift – this is termed 'Output Drift'.

For example if the user is measuring a 10kA dc current and it takes 10 seconds from nulling the integrator to clipping it in place around the conductor, then a further 5 seconds before looking at the display, the drift error will be;

Set –up drift = 0.025% of 10kA /s * 10 seconds = 25A
Output drift = 5A/s * 5 seconds = 25A

Then,

Drift error = $\frac{\text{(output drift + set-up drift)} * 100}{\text{10kA}}$ = 0.5% of reading

The drift error can be significantly reduced by taking two measurements in relatively quick succession and then averaging the result i.e.

Measurement 1. – As per 'Basic Operation'

- The Rogowski coil should be clipped together NOT encircling the conductor
- Reset
- Trim the offset adjust to give zero reading
- Un-clip coil and clip-around conductor
- Take first reading (+ve output voltage), (Reading 1.)

Measurement 2.

- The Rogowski coil should remain clipped around the conductor under test.
- Reset – but do not trim the offset adjust
- Un-clip the coil and clip together again away from the conductor
- Take second reading (-ve output voltage), (Reading 2.)

Average reading =

$$\frac{\text{(Reading 1. – Reading 2. (remembering the second reading will be the opposite polarity to the first))}}{2}$$

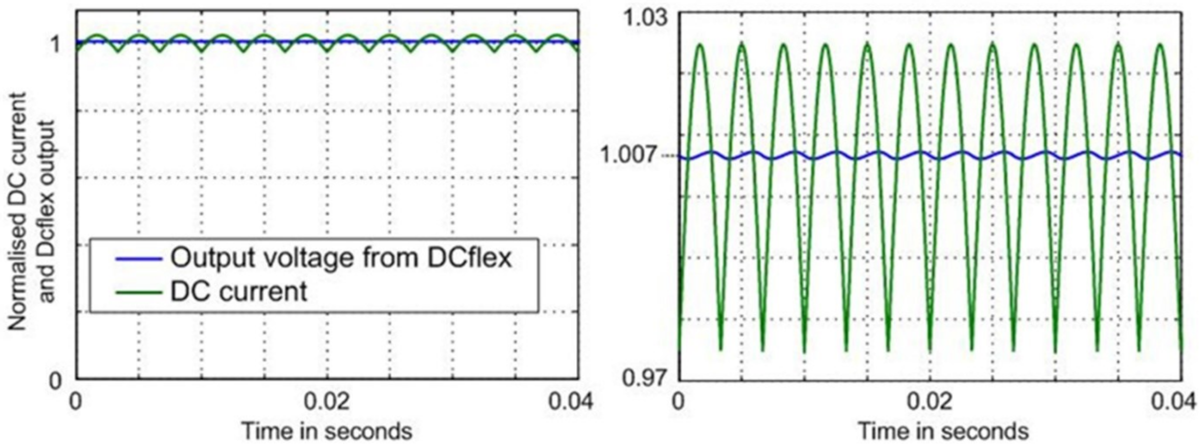
By not nulling the output to zero in between readings the user guarantees that the drift is in the same direction for both readings, assuming that it takes roughly the same amount of time to do the procedure in both directions the effect of the drift is significantly reduced.

5. Measuring a DC current with an AC Ripple Component

Large DC currents are often created by a power electronic converter whose switching operation adds an ac ripple component to the dc current.

OUTPUT FROM THE 3½ DIGIT LCD DISPLAY

The LCD display has a low pass filter on the output which sets the high frequency -3dB cut-off to 8Hz. This attenuates the effect of any ripple component.



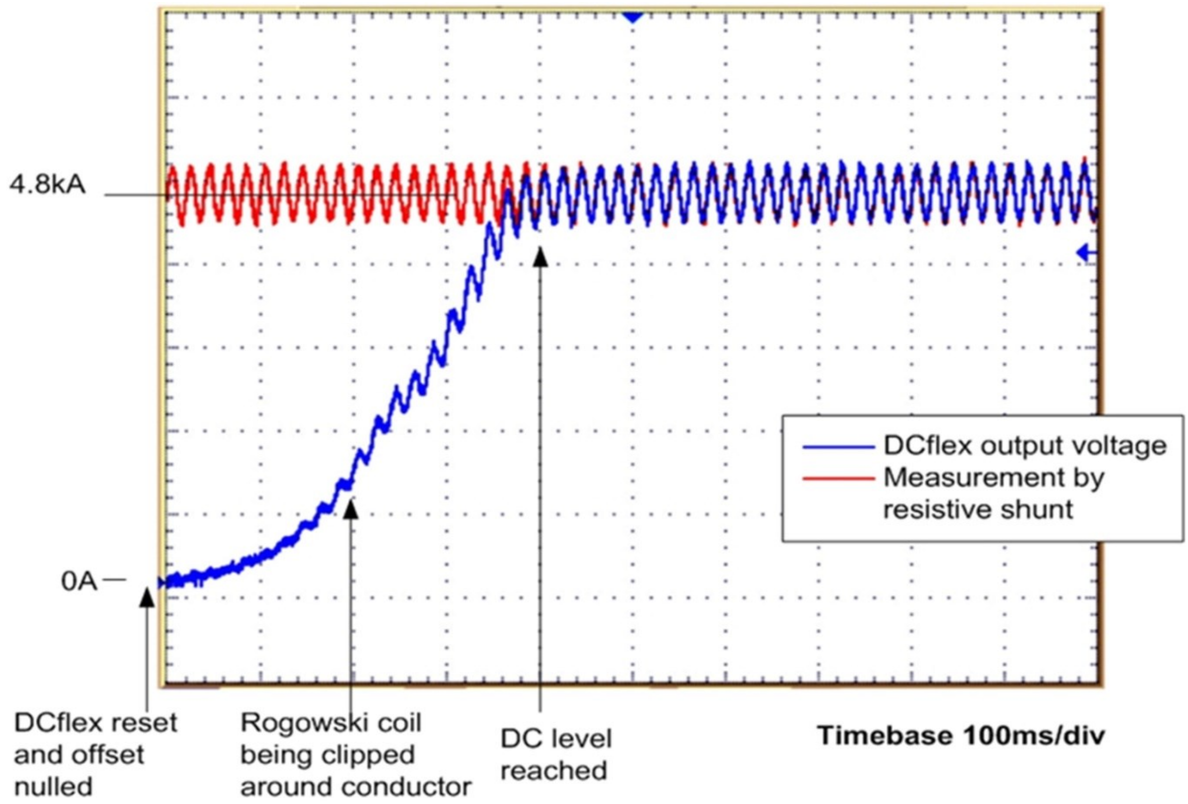
DCflex measurement of a DC current with a 5% rectified sinusoidal ac ripple component at 300Hz

The example above shows a DC current with a 5% rectified sinusoidal ac ripple component at 300Hz such as may be encountered at the output of a three phase rectifier with resistive load.

It is important to note that the resultant measurement is the MEAN COMPONENT of the current and NOT THE RMS. The second waveform is expanded to show the ripple component and the output from the DCflex in greater detail. The output from the DC flex is the mean DC value (=1.007) and not the rms value which would be larger (=1.010). The output has a very small ripple, 0.1% of the output signal. If the DC current was large enough this measurement ripple would just be visible as a flickering of the last digit on the LCD display of between say 1.001 and 1.002.

6. Output from the BNC Socket

The customer may wish to examine both DC and the ripple component. In such cases the user can connect the output BNC socket on the DCflex via a BNC:BNC cable to an oscilloscope. In this way both the DC component and ripple can be displayed. The scope or other recording device must be high impedance, >1MΩ for rated accuracy. The example shows a 4.8kA DC current with a 50Hz ripple superimposed.



The mean output from the DCflex will drift in time at a rate of 5A/s. To take another reading the coil must be un-clipped, or clipped around the conductor once more.

7. Product safety and standards

7.1 How does PEM rate the voltage insulation of itsRogowskicoils?

Every Rogowski coil supplied by PEM is given a peak voltage insulation rating. The rating is derived from the following test:

The coil is exposed to an ***ACtest voltage = (2 x Peak voltage rating (kV)+ 1)/√2 (kVrms)****, for 60 seconds at 50Hz. The DCflex is rated at 2kV peak and will be flash tested at 4kVrms (11kV peak to peak), 50Hz, for 1 minute.*

The user should visually inspect the Rogowski coil and cable for insulation damage each time the transducer is used. Every Rogowski coil has at least two layers of insulation covering the winding. These are always different colours making visual inspection of the integrity of the insulation easier.

As with the majority of plastics, the material used for insulating PEM's Rogowski coils can be damaged by exposure to corona over a reasonably long period of time.However for voltages to ground of less than 2kV peak (i.e. 1.41kVrms for a sinusoidal voltage), corona effects will be negligible, and continuous operation is permitted.

7.2 Maximum Bend Radius

The flexible Rogowski coil consists of a fine wire toroidal winding on a plastic former. Whilst every effort has been made to ensure that the coil is as robust as possible it is possible to damage the Rogowski coil winding by exceeding the bending radius:

The maximum bending radius for the Rogowski coil is 250mm (9.8")
– bending the coil beyond this radius will permanently damage the coil.

7.3 Product safety and EMC compliance

The DC*flex* range of dc current transducers has been designed and assessed to ensure they comply with relevant EU standards and all products carry the CE mark of conformity.

The DC*flex* product complies with:

EMC: IEC 61326-1:2006
Safety: IEC 61010-1:2001; Pollution Degree 2

Refer to the' Instructions for use' document before use.