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APPLICATION NOTE 43

Traceable CT adjustment by PPA Scale Correlation

Introduction

When using external sensors to measure current levels that are above the direct current rating of a measurement instrument, it becomes difficult to quantify the total system accuracy because this is the sum of two separate error components with uncertainty that is sometimes unknown.

N4L offer a leading solution to this problem by providing end-to-end ‘system calibration’ of high current measurement systems comprising PPA power analyzers together with LEM current transducers. This involves an ISO17025 calibration system that supplies a traceable current up to 500A and adjusts the PPA scaling to achieve a defined total system accuracy.

System calibration is offered on a wide range of LEM fixed core CT’s and N4L precision shunts. However, we do not offer system calibration for clamp-on current sensor designs including Rogowski Coils.

This document explains how optimum system accuracy can be achieved with clamp-on sensing devices at the point of use, by using sensors with proven linearity and achieving traceable accuracy by correlation with an ISO17025 certified PPA series Precision Power Analyzer.

Why does laboratory calibration of clamp-on current sensors often become meaningless?

The simple answer is positional error. To some extent, all non-contact current sensors will exhibit positional error and it is this error component that encourages most precision power measurement products to utilise resistive current sensing techniques where possible.

The positional error of LEM CT designs used by N4L is a low proportion of total accuracy and therefore system calibration is a useful and meaningful process.

However, the positional error associated with most clamp-on CT designs may be a large portion of total error and therefore a system calibration becomes less reliable, because the conductor position at the point of use is unlikely to the be the same as the conductor position during calibration.

This problem can be more pronounced than many users realise, for example, even high specification Rogowski designs can typically exhibit a positional error component of ± 1%. It is an unavoidable fact that the convenience offered by clamp on sensors brings with it a sacrifice in precision compared to fixed core solutions.

Measurement correlation - A practical and effective solution for clamp-on current sensor calibration

Users of N4L measurement products will be familiar with our commitment to good metrology practice and this includes our recommendation for customers to optimise a measurement at the point of use, when this will result in a superior outcome.

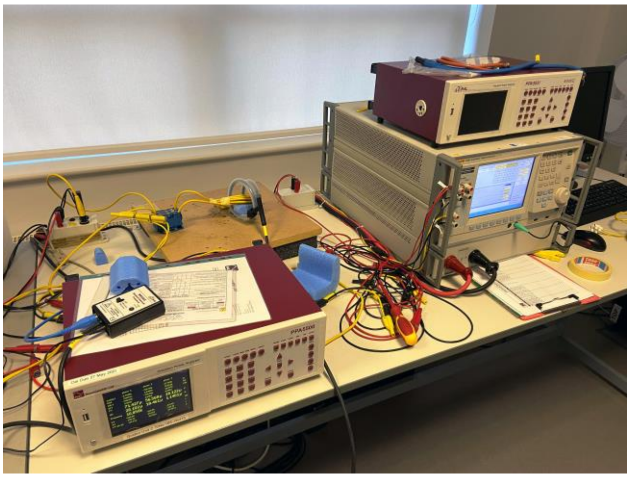
Precision metrology depends on repeatability and traceability.

Repeatability:	This is achieved calibrating a sensor when the conductor is in the position that will be used in operation.
Traceability:	This is provided by the ISO17025 accredited calibration reference of a PPA series direct measurement channel.

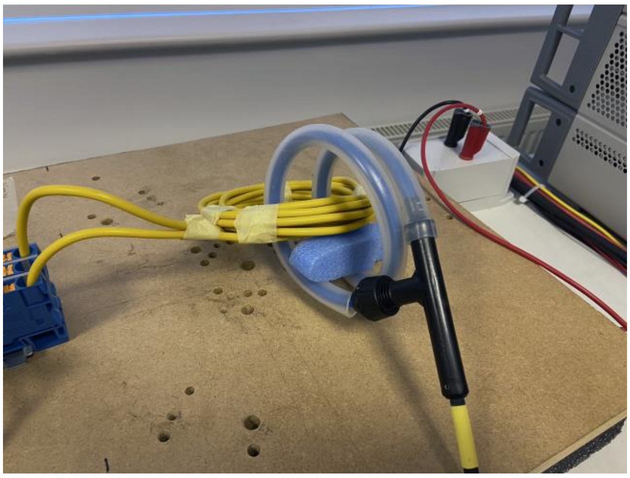
The principle of measurement correlation embraces the two elements of **Repeatability**, by applying calibration when the CT is in the same position that it will be used in practice and **Traceability**, by setting the scaling factor of a channel to which the CT is connected, at the same time that direct (and traceable) measurements are being made. Also, since the optimum scaling of a high current sensor by correlation will usually be established at a level that is low in the current sensor range, it is necessary to confirm the sensor linearity down to this level.

Proof of linearity on a WR5000 Rogowski current transducer

In this WR5000 type test, we apply a known current that we can measure traceably with the direct input of a PPA5530 measurement channel (PH1) and then a second measurement channel (PH2) is connected to the output of the CT. The CT is set up with a defined number of turns to achieve a CT current from 80% down to 0.2% of the CT range and the physical position of the turns will not be changed during the test.



PPA5530 + WR5000 + Fluke 6105A Watts Standard



WR5000 with 500A (2 turns) range and 10 primary turns gives a total x 20 ratio.

A 20:1 scaling factor is applied to PH1 direct current input of the PPA5530 and PH2 is configured with the default equivalent shunt value for the WR5000 500A range which is 2m Ohm and the default scale factor of 1:1. With this default 'non-adjusted' measurement, the optimum scale factor can be derived from the ratio of PH1/PH2 measured current. This 'corrected' scale factor can now be entered into the PH2 scale factor.

PHASE 2 RANGING

voltage input	internal
autoranging	full autorange
minimum range	300mV
scale factor	+1.0000
current input	external shunt
autoranging	full autorange
minimum range	[illegible]
scale factor	+1.0013
shunt	2.0000mΩ
dc offset	+0.0000A

< phase 1 ranging   phase 3 ranging >

Correction scale factor (1.0013) derived from the measured PH1/PH2 current when using a default 1:1 factor

POWER ANALYZER 14:21:37

	phase 1	phase 2	phase 3	
watts.f	91.983k	-91.990k	-3.4105m	W
VA.f	91.983k	91.990k	5.2299m	VA
VAr.f	-12.590	-77.467	-3.9649m	VAr
pf.f	1.0000	1.0000	0.6521	
V.f	230.00	229.99	229.98	V
A.f	399.93	399.98	22.741µ	A
frequency	135.00			Hz
V.f	+000.00	-000.00	-000.00	°
A.f	-000.01	-179.96	-130.71	°
V.f ph-ph	18.268m	8.6694m	25.778m	V

When the corrected scale factor is entered, the WR5000 current measurement correlates with the PPA direct input

Having established and entered the corrected WR5000 scale factor, measurements were made from 400Arms down to 1Arms and compared with direct reference measurements made on PH1 from 20Arms to 50mArms with 20:1 scaling to account for the CT ratio.

POWER ANALYZER 14:21:37

	phase 1	phase 2	phase 3	
watts.f	91.983k	-91.990k	-3.4105m	W
VA.f	91.983k	91.990k	5.2299m	VA
VAr.f	-12.590	-77.467	-3.9649m	VAr
pf.f	1.0000	1.0000	0.6521	
V.f	230.00	229.99	229.98	V
A.f	399.93	399.98	22.741µ	A
frequency	135.00			Hz
V.f	+000.00	-000.00	-000.00	°
A.f	-000.01	-179.96	-130.71	°
V.f ph-ph	18.268m	8.6694m	25.778m	V

POWER ANALYZER 14:21:47

	phase 1	phase 2	phase 3	
watts.f	45.984k	-45.995k	-1.5573m	W
VA.f	45.984k	45.995k	4.0231m	VA
VAr.f	-4.3602	-38.154	-3.7094m	VAr
pf.f	1.0000	1.0000	0.3871	
V.f	229.99	229.99	229.98	V
A.f	199.94	199.99	17.493µ	A
frequency	135.00			Hz
V.f	+000.00	-000.00	-000.00	°
A.f	-000.01	-179.95	-112.78	°
V.f ph-ph	10.307m	8.2903m	18.040m	V

POWER ANALYZER 14:21:57

	phase 1	phase 2	phase 3	
watts.f	22.989k	-22.998k	-947.27µ	W
VA.f	22.989k	22.998k	1.5220m	VA
VAr.f	-1.7917	-18.873	-1.1913m	VAr
pf.f	1.0000	1.0000	0.6224	
V.f	229.99	229.99	229.98	V
A.f	99.954	99.996	6.6180µ	A
frequency	135.00			Hz
V.f	+000.00	-000.00	-000.00	°
A.f	-000.00	-179.95	-128.49	°
V.f ph-ph	7.0910m	7.9476m	14.928m	V

POWER ANALYZER 14:22:10

	phase 1	phase 2	phase 3	
watts.f	4.5987k	-4.5991k	386.73µ	W
VA.f	4.5987k	4.5991k	387.21µ	VA
VAr.f	-311.96m	-3.6689	-19.198µ	VAr
pf.f	1.0000	1.0000	0.9988	
V.f	229.99	229.99	229.98	V
A.f	19.995	19.997	1.6837µ	A
frequency	135.00			Hz
V.f	+000.00	-000.00	-000.00	°
A.f	-000.00	-179.95	-002.84	°
V.f ph-ph	5.4916m	7.0807m	12.542m	V

POWER ANALYZER 14:22:47

	phase 1	phase 2	phase 3	
watts.f	2.2992k	-2.2996k	-108.35µ	W
VA.f	2.2992k	2.2996k	252.39µ	VA
VAr.f	28.066m	-1.9605	227.95µ	VAr
pf.f	-1.0000	1.0000	-0.4293	
V.f	229.99	229.99	229.98	V
A.f	9.9970	9.9989	1.0975µ	A
frequency	135.00			Hz
V.f	+000.00	-360.00	-000.00	°
A.f	-360.00	-179.95	-244.58	°
V.f ph-ph	5.9663m	6.8778m	12.838m	V

POWER ANALYZER 14:23:07

	phase 1	phase 2	phase 3	
watts.f	1.1497k	-1.1495k	2.3451m	W
VA.f	1.1497k	1.1495k	2.3585m	VA
VAr.f	16.537m	-939.61m	251.16µ	VAr
pf.f	-1.0000	1.0000	-0.9943	
V.f	229.99	229.99	229.98	V
A.f	4.9989	4.9983	10.255µ	A
frequency	135.00			Hz
V.f	+000.00	-000.00	-360.00	°
A.f	-360.00	-179.95	-353.89	°
V.f ph-ph	6.2957m	7.4482m	13.719m	V

POWER ANALYZER 14:23:23

	phase 1	phase 2	phase 3	
watts.f	229.91	-229.51	1.8537m	W
VA.f	229.91	229.51	1.8573m	VA
VAr.f	-9.9837m	-215.79m	115.99µ	VAr
pf.f	1.0000	1.0000	-0.9981	
V.f	229.99	229.98	229.98	V
A.f	999.65m	997.91m	8.0761µ	A
frequency	135.00			Hz
V.f	+000.00	-000.00	-000.00	°
A.f	-000.00	-179.95	-356.42	°
V.f ph-ph	6.9733m	7.3723m	14.288m	V

Referencing measurements to the ISO17025 accredited Fluke 6105A, we can produce an accuracy / linearity table.

ISO17025 accredited 6105A Source - Arms	PH1 direct (scaled x20)	PPA Deviation relative to 6105A - %	PH2 WR5000 Ext with PPA derived scaling	WR5000 Deviation relative to 6105A - %
20	399.93	0.017	399.98	0.005
10	199.94	0.030	199.99	0.005
5	99.954	0.046	99.996	0.004
1	19.995	0.025	19.997	0.015
0.5	9.997	0.030	9.9989	0.011
0.25	4.9989	0.022	4.9983	0.034
0.05	0.99965	0.035	0.99791	0.209

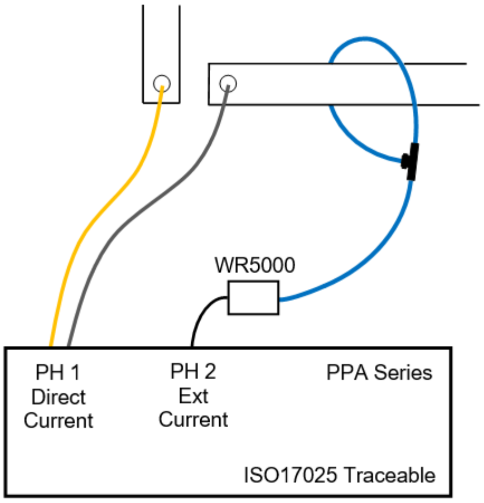
The PPA’s accuracy / linearity remains better than 0.05% over the complete measurement range and the WR5000 also remains better than 0.05% down to 1% if range, dropping to 0.2% error at 0.2% of range.

User process for scale correlation

Given a magnitude error that is typically 10 times less than positional error, it is clear an optimum scale factor for the WR5000 can be achieved by correlation with direct measurements on a traceable power analyzer.

Superior results are obtained with less uncertainty than is inherent with an external laboratory, because the laboratory will not reproduce the same geometry between the CT and conductor being measured that will apply at the point of use.

This remains true even when low in the range of a WR5000.



Conclusions

1. With a fixed conductor position, the WR5000 linearity is 0.05% down to 1% of measurement range and typically 0.2% down to 0.2% of range.
2. This linearity allows scaling by correlation at the point of use, therefore minimising positional error.
3. The optimum ‘corrected scale factor’ for a WR5000 is derived from simultaneous PPA measurement on a reference direct input phase within its measurement range and ≥1% of the WR5000 range.
4. When the correct scale factor is derived from a PPA series power analyzer with ISO17025 accredited certification, the WR5000 measurements are traceable.
5. This method of measurement optimisation will result in superior measurement accuracy at the point of use than is possible with external certification, where positional error introduces significant uncertainty that is not included in a laboratory certificate.