News from VSL (2013 – 2014)

Euramet Electricity Contact Persons meeting
16 – 17 October, Ljubljana, Slovenia

New SI

As part of the task of the CCEM task group on the new SI, a paper has been written on the envisaged consequences of the new SI on electrical metrology. The paper has been presented at the NCSLI and CPEM 2014 conferences. It is published in the September issue of the NCSLI magazine "Measure". (available via http://www.vsl.nl/sites/default/files/rtf/ncsli-measure-2014-september-milton.pdf)

Contact: Gert Rietveld (GRietveld@vsl.nl)

Subfield DC

DC voltage and Josephson

Within the JRP "Q-wave" VSL is working on the practical and theoretical aspects of quantum waveform metrology, including generation of arbitrary Josephson signals, the MHz-resonance problem of voltage leads, a Josephson delta-sigma converter, asynchronous sampling techniques and uncertainty calculations. Various shielding and guarding topologies are under investigation.

Contact: Helko van den Brom (HvdBrom@vsl.nl) and Ernest Houtzager (Ehoutzager@vsl.nl)

Resistance

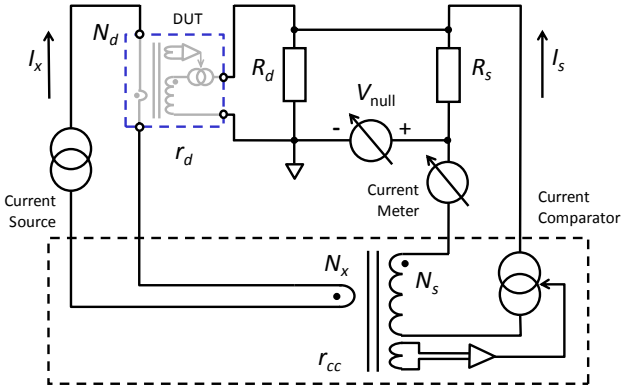
A joint VSL-METAS-NIST paper has been presented on CPEM2014 on high-precision resistance measurement methods for resistances of 10 MΩ and higher. Discussions with several NMIs worldwide entering this area have been held on details of the VSL measurement setup. One of the unique properties of the VSL system is that both current and voltage null-detection can be used, which allows for verification of some systematic effects.
Presently, a review paper is in preparation, together with NIST and METAS, summarising the experiences of the past decade(s) in accurate high-ohmic measurements.

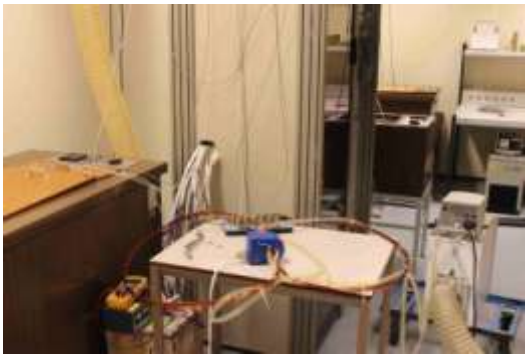
In summer 2014, VSL has performed the measurements of the CCEM.K2-2012 comparison of 10 MΩ and 1 GΩ resistance. Very good results with low uncertainties were achieved, better than 1 ppm and 3 ppm at 10 MΩ and 1 GΩ respectively.

Contact: Gert Rietveld (GRietveld@vsl.nl)

DC current

A setup has been developed for the accurate measurement of DC current ratios up to 600 A based on a DC current comparator bridge (see the schematic of the setup below). With this setup, VSL has participated in the Euramet.EM-S35 comparison on DC current ratio. The travelling standard in this comparison is a zero-flux based DC current transformer. The picture shows the setup in the VSL laboratory during the comparison measurements.





A description of the new setup and of the results achieved with it has been presented at the CPEM2014 conference and a full paper is submitted for publication in IEEE I&M. The uncertainty that can be achieved with the VSL DC current ratio system is around 0.5 ppm. In the case of the Euramet.EM-S35 comparison, the final uncertainty was 1 ppm, due to limitations in the behaviour of the travelling standard (stability, current conductor position sensitivity).

Contact: Gert Rietveld (GRietveld@vsl.nl)

Subfield LF

Impedance

Developments on our sampling bridge for impedance ratio measurements have been continued to integrate both low-ohmic and high-ohmic impedances into a single bridge.

Contact: Erik Dierikx (EDierikx@vsl.nl), Ernest Houtzager (Ehoutzager@vsl.nl)

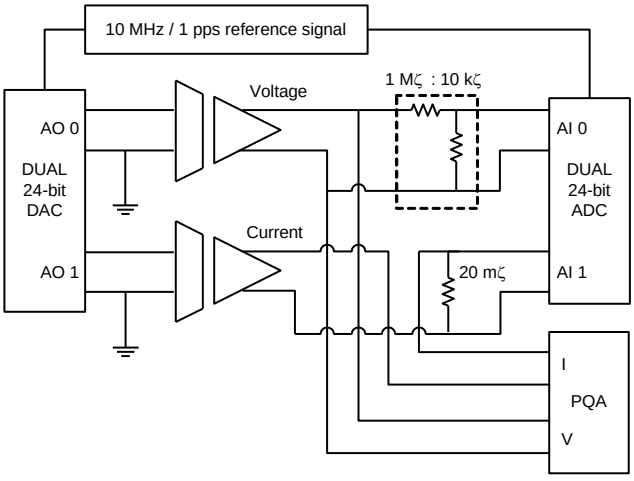
AC/DC Transfer

In March 2014, measurements have been performed for the VSL participation in the Euramet AC/DC current comparison.

Contact: Erik Dierikx (EDierikx@vsl.nl) and Joop Dessens (JDessens@vsl.nl)

Power Quality

The recently developed PQ calibration setup has been upgraded to a 3-phase system. It is suitable for calibration of PQ analyzers as well as calibrators for a variety of parameters. In collaboration with NMi Certin, a sister organization of VSL and notified body in the Netherlands, we can now also perform compliance tests with respect to the IEC 61000-4-30.



Contact: Helko van den Brom (HvdBrom@vsl.nl)

Wideband Power

The JRP "ENG62 MESaIL Metrology for Efficient and Safe Innovative Lighting" started July 2014, as a successor of "ENG05 LIGHTING Metrology for Solid State Lighting". In this project, there are two tasks relevant to electrical measurement.

In JRP ENG05, it was established that the source impedance and the presence of harmonics in the AC power supply prevented repeatable measurements of the RMS current, power factor and electrical power consumed by SSL devices at different laboratories. To circumvent this problem, a source impedance stabilisation network needs to be placed between the AC power supply and the SSL so that the device under test sees always the same source impedance. In the first task, the analysis, design and realisation of such a network will be undertaken.

The aim of the second task is, to develop an electronic load with similar electrical behaviour as SSL devices in this project. Key features of the electronic load are rapid stabilization and switchable impedance to simulate typical SSL topologies. This electrical test standard is used to check the reliability of the electrical measurement setup in testing laboratories.

Contact: Dongsheng Zhao (dzhao@vsl.nl)

HV revenue metering

As part of the EMRP JRP on "Metrology for Smart Electrical Grids", VSL developed a reference set-up for on-site calibration of revenue metering installations in three phase high voltage electricity grids (up to 150 kV and 5 kA). The basis of the VSL reference set-up is composed of three current transformers, three voltage transformers, and a reference power / energy meter. The interconnections between the transformers and the power / energy meter are made with double shielded twisted pair cables to ensure signal integrity. The complete set-up was validated at the Canadian metrology institute, NRC, and was verified to have an uncertainty of less than 0.005 % (50 ppm), k=2, under laboratory conditions. The VSL reference set-up is completed with peripheral components to enable remote read-out and control. After more extensive tests and characterization at VSL it was verified that the set-up has an uncertainty of less than 0.03 % (300 ppm), k=2, for on-site measurements.

The setup has been presented at the CPEM 2014 conference, and a full peer reviewed paper describing the setup presently is in preparation.

Contact: Gert Rietveld (GRietveld@vsl.nl)

Phasor measurement units (PMUs)

In the new EMRP JRP "Smart Grid II" project, VSL is actively involved in research on PMUs. First of all, the VSL system for testing PMUs will be further developed, among others with the aim to include facilities for dynamic testing of PMUs. Subsequently, this facility will be expanded to allow for calibration of commercial PMU calibrator systems.
A second major line of research concerns applications of PMUs in on-site measurements in electricity grids, for example with the aim to accurately determine line impedances.

A joint project is started with DELTA, one of the Dutch distribution system operators, on the application of PMUs in distribution grids. In autumn 2014, PMUs will be installed in a 50 kV

ring that is heavily loaded by renewable energy sources (wind, CHP). Once installed, the PMU data originating from this grid will be analysed within the EMRP "Smart Grid II" and "GridSens" projects.

Contact: Gert Rietveld (GRietveld@vsl.nl) and Helko van den Brom (HvdBrom@vsl.nl)

Non-conventional Transducers and Instrument Transformers

The EMRP JRP on "Future grids" started in May 2014.
Part of the project aims at adjusting the current measurements setups to accept signals from non conventional transformers having non conventional voltage/currents/digital outputs. A second part of the VSL involvement in this project is the calibration of commercial transformer test sets suitable for testing non-conventional transformers.

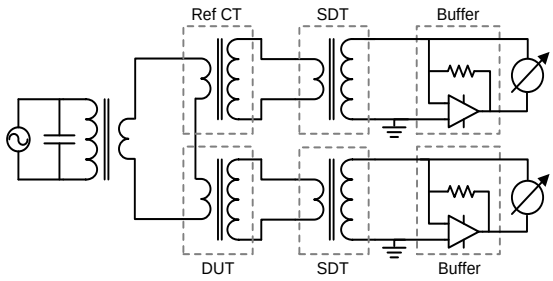
Contact: Ernest Houtzager (Ehoutzager@vsl.nl),

High voltage and high current

The high voltage laboratory has moved to a new laboratory giving more room to work. This laboratory will hold all power related measurement setups.

Work has progressed very well on the upgrade of the VSL AC high voltage measurement facilities. A current-comparator based measurement bridge has been successfully tested and calibrated. This has led to improved CMCs in this area from around 100 ppm down to 20 ppm. The setup has already been successfully used for an on-site calibration at a customer's site.

We also finalized the development of our new sampling measurement setup for the accurate ratio measurement of AC current transformers (CTs) for primary currents up to 5 kA at a frequency of 50 Hz or 60 Hz. The schematic of the bridge is as follows:



At CPEM a presentation was given on the final evaluation of the system, including the results of a comparison with NRC. The results of this comparison confirm the claimed uncertainty for CT calibration of $5 \cdot 10^{-6}$ in magnitude and 5 µrad in phase at 50 Hz or 60 Hz (k=2).

Within the JRP on "HVDC", VSL has finished the work on the non-invasive measurement system for on-site accurate measurement of AC currents. An openable core CT (OCCT) has been made with magnitude error less than 10 µV/V and a phase error of 20 µrad at 2000 ampere. The OCCT has been presented at the CPEM 2014 conference.

A future project will add remote readout and phase measurement capabilities to this CT.

Contact: Gert Rietveld (grietveld@vsl.nl), Ernest Houtzager (Ehoutzager@vsl.nl), and Helko van den Brom (HvdBrom@vsl.nl)

Transformer Load Loss

A calibration of a Power Transformer Load Loss Measurement system has been performed on-site at the customer's location. These measurements involved both CT and VT calibrations at the level of 30 – 80 ppm and 30 – 50 μrad. For this exercise the several setups have been made transportable and rugged.
Present work concentrates on developing a reference setup for complete on-site system validation of transformer loss measurement systems.

Contact: Gert Rietveld (GRietveld@vsl.nl) and Ernest Houtzager (Ehoutzager@vsl.nl)

Subfield RF&MW including EM fields

RF & MW

- **S-Parameter Measurements:**

  Traceability

  S-parameter metrology related research activities concentrated on realization of traceable S-parameter measurements up to 50 GHz. A primary multi-line calibration kit is developed for each supported connector interface.

  Advanced calibration techniques

  Multi-line calibration technique is modified to allow de-embedding of errors propagating from connectors during the measurements. A significant enhancement of measurement uncertainty is achieved.

  Advanced cable flexure characterization techniques

  A new flexible coaxial cable characterization facility is developed to characterize cable flexure effects for S-parameter measurements.

  Measurement & Uncertainty Software

  An advanced S-parameter measurement and uncertainty calculated software is developed.

- **Power measurements:**

  A Fully automated calibration factor measurement facility

  A fully automated power sensor calibration facility is designed. The measurement method is based on the direct-comparison method and cover frequencies from DC to 50 GHz in a single sweep. The Measurement facility is supported by advanced measurement software, capable of calculating the calibration factor and the corresponding uncertainty values.

- **JRP16i-Ultrafast Electronics**

  The project is completed.
  Uncertainty sources in digital signal instruments are investigated. A number of models are proposed for evaluating EVM sensitivity for RF device level impairements. Furthermore, techniques are proposed for validation of digital signal demodulation software.

Finally, a software tool to enable uncertainty propagation between time and frequency domains for large data sets is developed. The program comprises of a multi-language graphical user interface.
For more information, please visit project website: (http://www.ptb.de/emrp/ultrafast-news.html)

- **SIB61-High Frequency Circuits**
  A new joint research project (JRP) has started with focus on development of traceability chain for VNA coaxial measurement up to 110 GHz and in waveguide interface up to 1.1 THz.
  VSL is investigating uncertainty assessment techniques suitable for the uncertainty limits presently realized.

Contact: Faisal Mubarak (FMubarak@vsl.nl)

EM-fields

- Key comparisons:
  - VSL participated in the CCEM.RF-K24.F comparison on E-field measurements. The final report is published in the BIPM website in March 2013.
  - VSL participates in the EURAMET.EM.RF-S27 comparison on Antenna factor for Loop Antennas. The final report is published in the BIPM website in May 2014. During the comparison, at VSL a new approach using a one-turn air-core searching coil is developed. This approach has improved the LF magnetic field calibration facility considerably. The upper frequency boundary can now be extended from 1 kHz to 100 kHz.

- **JRP IND60-EMC Industry**
  The project started on July 2013 and will last for 3 years.

  - VSL has characterized five transducers by using S parameter measurement and LF measurement method. Two voltage dividers (single phase and 3-phase) and three current probes are measured. It is found that the influence resulting from the secondary side on the measurement of transfer impedance is of significant difference for low turns-ratio current probes.
  - The key issue is deriving the EUT and Grid impedance from measurement. A new approach to measure the grid and load impedance of converters in-situ has been developed. It is called the three-probe approach. This approach allows impedance measurements of power supplies and electric appliances without interrupting their normal operations. The measurement accuracy is guaranteed with proper Fast Fourier Transform (FFT) process to collect both amplitude and phase information in the measurement. With this proposed setup, the equivalent model consisting of both resistive and reactive components can be derived to represent the unknown grid and load impedance in 2k-150kHz frequency range. In the frequency range 150kHz-30MHz, two-probe approach can be applied. Paper is submitted to IEEE APEC 2015.
  - The conducted immunity test-setup is realized using bulk current inject probe. One smart meter is used as DUT for the conducted immunity test. The influences on the smart meter are determined by comparing the reading from the smart meter and from the reference meter. Although resonance will occur when the disturbance meets the

resonant frequency for the combination of an inductive source and a capacitive load, but such resonance has no obvious effect on the smart meter. The injected disturbance is injected in the 2 k-150 kHz range.

- VSL designed a conducted emission reference source for round-robin tests. A digital synthesizer is used to provide flexible output level. The phases of all frequency components are adjusted to achieve the lowest crest factor of the waveform. For frequency band above 30MHz, Crystal oscillator + Schmitter trigger + Coupling capacitor/RF transformer method is adopted. Preliminary result is presented in IEEE EMC 2014. Conference. Good number of interested people.

Project website: www.emc-industry.com

Contact: Dongsheng Zhao (DZhao@vsl.nl)