Metrology for energy harvesting

European Metrology Research Programme

e-newsletter • Issue 3 • Autumn 2011

UK measurement strategy launched at NPL's energy harvesting stand

On 6th July 2011, David Willets, the Minister for Universities and Science, launched the UK's National Measurement Strategy for 2011–2015 at the Royal Society's Summer Science Exhibition. The strategy is designed to exploit the Government's investment in measurement research to support economic growth and improve the UK's competitiveness and scientific excellence across all areas of business and government.

The Government will invest around £240m over the next four years in developing the UK's scientific and legal measurement infrastructure.

The strategy will be led by the National Measurement Office and delivered through the world leading research facilities at the National Physical Laboratory (NPL), LGC and NEL.

David Willets generates power on an energy harvesting bike

The rational for the strategy is the strong return on investment consistently provided by funding of measurement:

- An independent survey of businesses found that in a single year the NMS infrastructure helped businesses introduce products and processes that increased profitability by more than £700m
- Case studies carried out to quantify the impact of specific National Measurement Strategy projects typically show a return on investment of between 10 and 30 times
- Each year in the UK, around £340bn worth of goods are sold on the basis of the measurement of their quantity. In addition £280bn of industrial goods are weighed or measured
- One project carried out by NPL explored how mobile antennas behave. Evaluations showed that the calibration data improvements supplied by NPL could have equated to a 1% one-off saving in network capital costs, or around £50m

Visit our blog at http://tinyurl.com/MetrologyForEH

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Project news - research updates

Determining Seebeck coefficients

PTB, the German national measurement institute (NMI), has installed a measuring system to determine the Seebeck coefficient of thermoelectric (TE) materials. This was initially tested using a nickel sample of known Seebeck coefficient with a complex temperature dependence of the coefficient. This was found to be less suited as reference material. The group therefore used a nickel-copper alloy, which has given good reproducibility, and has the advantages of the coefficient being larger and the temperature dependence more straightforward and linear.

PTB is currently testing the system and making improvements such as a calibrated thermometer to ensure that the reference temperature, which is close to the sample temperature, is traceable to National Standards. Once these improvements are complete, the group will start to investigate and characterise different TE materials as candidates for reference materials for Seebeck coefficients in the temperature range 300K–900K.

TEG characterisation

NPL, the UK's NMI, has designed and built a system to reliably characterise the efficiency of commercial thermoelectric generators (TEGs) between room temperature and 150°C.

There are two individual challenges to determining the efficiency of a TEG: the measurement of the electrical output power and of the heat flow. This system uses an absolute method for the measurement of the heat flow, by measuring the power dissipation of an electrical heater. A shielded heater avoids any parasitic heat flow.

Consistent results have shown NPL's system to be reliable. TEGs measuring up to 40 x 40 mm can be characterised – this is the most common industry standard size – but smaller and slightly larger TEGs could also be analysed.

The system is currently set-up in an insulated enclosure to reduce heat loss, but it will be placed in vacuum to reduce radiation losses even further. With some minor design alterations, the temperature range of the system will also be increased.

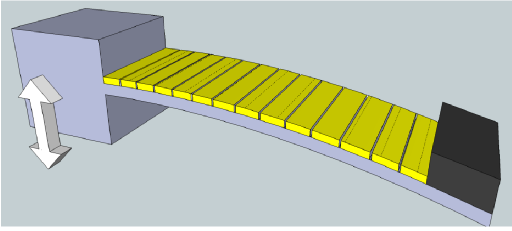
Electrostatic MEMS

LNE, the French NMI, has designed the first electrostatic energy harvester based on comb-drive MEMS. The device architecture has been optimised to maximise the electrical power converted from mechanical vibrations in the frequency range 1 kHz to 4 kHz.

VHDL (Very high speed integrated circuit Hardware Description Language) simulations on these systems indicate that they are capable of harvesting electrical powers ranging from 6 µW to 60 µW. The harvesters are fabricated through an industrial SOI (silicon on insulator) wafer process and will be distributed to the project partners for full electromechanical characterisation.

Piezoelectric power outputs

Piezoelectric energy harvesters are typically cantilevers with an inertial mass at the end. The base of the cantilever is excited by ambient vibrations and the inertial mass exerts a force on the cantilever which generates a stress in the piezoelectric (yellow).



NPL has developed a model that predicts the output of the beam based on the force at the cantilever tip. In order to investigate the effect of the coverage of the beam with piezoelectric elements they have made a cantilever with 30 elements along its length, and measured the power output.

Upcoming events

ISAF-PFM 2011
24-27 Jul 2011
Vancouver, Canada

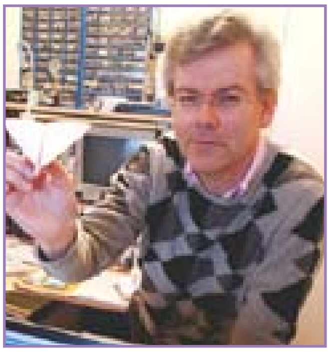
ISIF 2011
31 Jul – 4 Aug 2011
Cambridge, UK

ECT 2011
28-30 Sept 2011
Thessaloniki, Greece

Metrologie 2011
3-6 Oct 2011
Paris, France

View from industry:

Prof Pierre Nicole, R&D Project Manager, Thales Group



With operations in 50 countries and 68,000 employees, Thales is a leading international electronics and systems group addressing defence, aerospace and security markets worldwide. The company's leading-edge technology and software is supported by 22,000 R&D engineers who develop and deploy mission-critical information systems.

Thales provides world-class expertise in UAV Systems and technology, onboard electronics for civil and military aircraft, and air transport solutions for cleaner, quieter and more efficient aircraft that fly safely and securely.

What is Thales' interest in energy harvesting (EH)?

We are particularly interested in EH for two key areas – aeronautics and wireless sensor networks (WSN). The first has huge constraints compared to other applications because it involves safety critical applications such as airplane sensors and 'black boxes' (flight data recorders).

There's also great scope to tie these applications – particularly WSNs – to markets that are new for Thales, such as the building industry.

What do you see as the main barriers to industrial development of these devices?

There were four main challenges associated with developing WSNs:

- Reducing power consumption to ultralow levels
- Reducing power required for radio frequency communication
- Developing processing capabilities to successfully network sensors
- Guaranteeing that enough energy will be harvested/ generated for self-sufficiency

The first three have been successfully addressed – only the last one remains. No one can confidently state that their EH device or WSN will generate enough energy in a given environment with given conditions over the required period of time.

Better metrology is essential to ensure that WSNs have autonomy in terms of power generation. We must be sure that the energy source – whether light, temperature or vibration – is sufficient to guarantee that the network will work. This is particularly true for safety critical applications such as monitoring aircraft parameters. If even one sensor has less power available to harvest or is less efficient than expected then it could result in a false warning to the pilot or an unreported critical event.

We also need to be able to guarantee that the devices will operate for the conditions and the lifespan that is required – passenger aircraft have a lifespan of around 40 years. Metrology is key, but as well as the technical issues there are procedural issues.

For example, vibrations of the riveted plates of a plane can be measured with accelerometers. The centre of the plate is the optimal place for an energy harvester, but there's no guidance or standard method to determine placement. Even if you are off by just a few centimetres the level of vibration available to harvest, and thus power generated, is significantly different. In some sectors the end-users are not accustomed to procedures – they put the sensors where they can, not where is best.

We therefore need accurate, standardised measurement and procedures and education for users to provide customer assurance about the minimal level of power that will be generated.

What will successfully addressing these challenges mean for Thales?

It will help develop our business at every level and improve customer confidence.

There are plenty of products available – particularly from the US. However, it's one thing to prove it works in the lab, and another to take it into the field.

Airbus, Boeing, EADS are all interested in EH but have valid concerns about there being enough energy generated. We need standards and procedures to give assurance and security that the devices will work under real life conditions for the necessary period of time. We need ways to compare and contrast efficiency, and methods that take into account different environmental factors. We need measurement, modelling and software tools.

Some EH products are already commercially available – has the lack of a traceable metrology methodology had an impact on these?

Yes – it's been blocking development and market growth for several years because there's not enough customer confidence. The building industry wants to use wireless sensors, eg thermoelectric EH devices to measure constraints in concrete walls. However, they are very sceptical because no one has produced information about how the power generated is affected by the thermal flow through, related to the thickness and the configuration of the wall.

The US particularly has pushed EH products through to market, which has raised interest in the technology, but still relies on customer satisfaction and word of mouth to spread uptake. This isn't enough to grow the market to its full potential.

Who are the main players in developing EH technologies?

Europe is slightly ahead in R&D but the US is ahead in technology. Europeans have ideas, but don't seem to trust in them. The US is more willing to take a risk by making products and taking them to market. Europe is more risk-averse – we wait until a market is identified and then offer a solution.

The Japanese outlook is similar to Europe. The Chinese are becoming more aware of EH's potential and there's a real possibility that within a few years they will have become the world leaders. They take every initiative and have a huge potential internal market.

What impact will the Metrology for Energy Harvesting project have on Europe's position?

Projects like this can make a real difference to Europe's ability to capitalise on its ideas and commercialise the technology, because it will help industry provide customers with the information they need to make decisions and invest more in EH technology.

The predicted 2020 global market for EH devices is \$4.4bn (up from \$605m in 2010)* – do you think this is feasible?

Globally yes, although I'm not sure that Europe will match that level of growth. It's about psychology – if we build customer confidence then the market will explode.

** IDTechEx, Energy Harvesting and Storage for Electronic Devices 2010-2020*

***We welcome feedback, opinion and suggested articles. Please send your comments to** markys.cain@npl.co.uk **and** james@proofcommunication.com*

This project is funded by the EMRP and national metrology research programmes.

EMRP
European Metrology Research Programme
Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union