Highlights of Energy Harvesting & Storage Europe 2012

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Ever since we wrote the study 'Energy Harvesting for Remote and Wireless Sensing' back in 2008 we have made a point of keeping an eye on developments in the field. It has been interesting to follow the successes of some and the ongoing development challenges of others. Many of the issues and challenges remain the same. We attended last week's IDTechEx conference, Energy Harvesting & Storage Europe in Berlin so have provided some highlights below. Hopefully these will provide the reader with some leads for further investigation in their particular areas of interest.

The **conference** itself was, as usual, well organised and attracted a good crowd of around 300 delegates. The programme covered a range of topics from end user needs through to technology solutions. It is worth bearing in mind that this is a commercial conference. This was reflected in some of the talks being a bit too much of a sales pitch and revealing nothing of any significance on how performance was achieved. In an emerging technology area that is still trying to establish credibility this seems a shortsighted approach by some of the companies. The exhibition part of the conference was excellent and probably the highlight of the programme for us – a great opportunity to quiz companies in more detail and see some concrete demonstration of energy harvesting in action. This is the 3rd year in a row that the conference has been held in Germany. This has taken advantage of the concentration of energy harvesting expertise in the country but it may be time to move to another country now to access a new crowd.

User needs and experiences

We are always keen to hear the views of potential **end users** of energy harvesting technology. Their interest and efforts to explore the possibilities is a good indicator of the health of the sector and progress in demonstrating real benefit. Somewhat disappointingly there were no real indications of new applications or sectors – the usual sectors of automotive, aerospace, industrial machinery and smart buildings seem set to continue to dominate. In addition, in most sectors outside of smart buildings, the technology still appears to be at the demonstrator stage with volume sales yet to take off.

Volvo, the truck and bus company rather than the car company, gave an excellent account of the potential for energy harvesting and the challenges to be overcome. There were some very clear messages on the cost savings in all manner of areas from fuel consumption, manufacturing costs and workshop time but also some caveats in terms of the need to deal with a conservative business, long product cycles and the need for safety critical systems. Encryption of wireless signals was also highlighted as key to prevent vehicle hacking and packaging to survive harsh environments and protect against ingress of water and dust is important. Amongst the wish list of requirements were auto grade components, complete assemblies, high volume and low costs and the development of low power sensor communications standards for safety critical systems. Volvo have two energy harvesting demonstrators planned for the end of the year.

ABB presented on integrated and modular energy harvesting solutions for the process industry. Their interests appear to cover everything from field instrumentation to condition monitoring of machines, motors and power products. They have looked at kinetic, thermal and photovoltaic harvesting and have been field trialing solutions. There is a particular interest in true broadband vibrational harvesters should these become available. Intrinsic safety was highlighted as a critical need for some applications.

TRW Conekt presented on the needs of both the automotive and aerospace sectors. There were clearly a number of similarities between the two in terms of operating environment but some key differences include acceptable cost and regulation. In the automotive sector, particularly for tire pressure monitoring, it would appear that energy harvesting needs to become cheaper than batteries. In aerospace it is much less price sensitive as whole life costs are considered. Certification for automotive applications is by regional approval but for aerospace is worldwide. The case was made that holistic integrated design of hardware, software and power sources is required for optimum performance. The question was raised as to whether or not we have arrived at the right low power radio protocols yet noting that the most successful systems so far have tended to use proprietary protocols.

Product innovation

There were also a number of interesting technical developments presented in the area of product innovation.

A novel use of thermal energy harvesting was presented by **MSX Technology**. They are using a wireless acoustic sensor to keep a cooking pot at simmer temperature by detecting the formation of steam bubbles. The feedback wirelessly to the hob sensor control allows better control of heat and therefore significantly reduced waste heat. This has been pitched as a low cost solution with thermal harvesters supplied by Micropelt. Their hope is that demand will be driven by new EC directives on energy saving.

Micropelt and Texas Instruments have been working together and have developed a new microcontroller platform for condition monitoring sensors with local intelligence. They claim to enable lean wireless sensor networks powered by TI's new Ferroelectric RAM MCU and Micropelt's embedded thermo-harvesting power modules. The Wolverine platform claims to cut power consumption in half compared to the competition setting new standards for energy efficiency in microcontrollers.

G24 Innovations described their dye sensitized cells as the world's most powerful indoor photovoltaic modules claiming better efficiency than amorphous silicon and increasing efficiency with increased temperature (Si-based solutions have problems with reduced efficiency in hot climates). The advantages of flexibility of the cells and having the option of different colours will suit some applications. Several applications from electronic shelf labels, a wireless Bluetooth keyboard (developed with Logitech) and wireless blind and shade systems were described. Production capacity has been ramped up and a second line is in place and ready for commissioning. G24i claim a cost per kW/hr of $37 compared to that of $128-180 for batteries.

Solar Print and Analog Devices presented together on their glass dye sensitised cell solution for powering wireless networks.

The **Fraunhofer IZM** presented on the development of a prototype power supply for a Bluetooth music headset ski helmet with glove control using solar power. Most focus appeared to be on how to integrate high efficiency crystalline silicon cells into bendable modules for fitting to curved surfaces.

Technology developments

It was interesting to hear of developments in East Asia as these often get ignored in the usual focus on the traditionally strong energy harvesting centres in Europe and the USA. **Hanyang University** in South Korea has been carrying out feasibility studies on using piezoelectric energy harvesting. Case studies included using a waterflow driven propeller impacting a piezo strip to light up over 1,000 LEDs. Vibration in a Maglev train was harvested using a design that incorporated a box of ‘bouncing’ steel balls on top of a piezoelectric base. A further high-speed train application assessed vibrational energy available at various points in the cabin. The **National Institute of Advanced Industrial Science and Technology** (AIST) in Japan described thermoelectric conversion films fabricated through printing processes. They have developed new materials, a carbon nanotube-polymer composite with high thermoelectric conversion characteristics (a ZT of around 0.1) so avoiding the issues of high cost rare bismuth and tellurium. They have also developed suitable fabrication processes to produce large area flexible and low cost devices. They appeared to be targeting quite high temperature differentials getting several hundred microwatts per square centimeter off of a differential of 100 degrees. Questions of durability to high temperature breakdown were a concern although it was claimed that suitable polymer selection would address this. **IBULE Photonics** of Korea have developed a piezo generator based on a PMN-PT single crystal instead of the usual PZT material. The material is lead magnesium niobium along with lead titanium for the piezoelectricity giving a claimed 3x higher piezoelectric mechanical stress.

There was a good cluster of presentations on heat energy harvesting with some new technologies or advances in production capability.

Nextreme described their microscale thin film thermoelectric technology and high volume semiconductor manufacturing processes. They made the very strong case that the predicted large markets ($6bn by 2020) for thermoelectric devices will require very substantial cost reductions and widespread wireless sensor network deployment. Their process uses 400x less Te than conventional TEGs and this could become key with the trend to rapidly increasing Te costs. Interesting practical solutions e.g. harvesting off the hot and cold pipes under a sink or on the waste trap as well as turbine bearing condition monitoring were described.

ST Microelectronics described a completely new thermal harvesting approach using bimetals which snap up and down around specific pre-defined temperatures. A significant potential advantage is that the devices would be able to work without the need for a heatsink – usually a rather bulky element of a thermal energy harvester. The harvesting devices are constructed by combining the bimetal with a piezoelectric material in a shock layout or by direct patterning of the bimetal on the piezoelectric. The snap temperature does not change with scale and scaling laws seem to work in favour of scaling down in size – several small matrixed bimetals can replace one large on resulting in increases in power and be surface and shape adaptive at the same time. Concerns of fatigue lifetime were claimed to not be a problem having demonstrated thousands of cycles although this may still not address the issue of lifetime of the piezoelectric components. It was also claimed that the matrixed approach could be used to address different temperature ranges in a single device by coupling bimetal with different snap temperatures.

Marlow Industries also covered thermal energy harvesting and power management but the presentation was more tutorial in style so did not reveal much detail on their own developments.

Piezoelectric energy harvesting received a fair bit of attention this year.

Arveni work in the area of mechanical push button or vibration energy harvesting and their key USP appears to be a very high claimed conversion efficiency (some 13x better than their competition). No information was however supplied to explain how this was achieved. They demonstrated their usual batteryless TV remote control based on 2-way radio developed for Philips. This is still a prototype rather than having started achieving product sales. Arveni now also appear to be working on using their technology for powering industrial wireless sensor networks.

Meggitt Sensing Systems talked about the performance of fully integrated vibrational energy harvesters based on PZT. They have taken a thick film manufacturing approach by screen-printing on micro-machined silicon cantilevers. Through their internal spin-off company, InSensor, they offer various mass-beam geometries including unimorphs and bimorphs and can manufacture in high volumes. Their focus would appear to be devices that are designed to operate with relatively modest acceleration levels achieving something like 15-20 microwatts at 0.5g.

One of the main criticisms of piezoelectric materials is their brittle nature that results in failure after repeated bending. **Algra** have come up with a piezoelectric switch design that works without displacement. Greater than 5N pressure on the piezoelectric material is sufficient to activate the device as a handheld remote control. The use of a laminated multilayer casing with support rather than clamping for the piezo layer appears to be an important aspect of the design. It has been applied to light switching, garage door openers and other home automation applications. Further applications are envisaged in push stop buttons on buses, batteryless pH meters, e-ink display, various industrial push buttons etc.

Low power electronics and energy management was also a major area of focus.

Infinite Power Solutions, well known for their THINERGY Micro-energy thin film rechargeable cells, made the case that Bluetooth Low Energy is the protocol to enable personal sensor networks that are powered using energy harvesting. The claim is that it can increase battery run time up to 10x over traditional sensor network protocols.

Imperial College London focused on power electronic interfaces for energy harvesting devices. They criticised the approach of many researchers in measuring the power output of EH devices. Three research questions relating to power conditioning, adaptability (improving electromagnetic coupling of piezoelectric harvesters) and damper strength (electronics tuning of resonant harvesters) were highlighted with some (at least partial) solutions suggested.

There were a number of presentations on microcontrollers addressing various issues. **Anagear** presented a new controller for smart power management in both battery supplied and self-powered wireless sensor nodes. It was claimed that this could provide a solution to the ‘cold start’ problem. The circuit is in prototype form with manufacturing expected shortly. **Microchip** presented another family of microcontrollers that can operate with as low as 45µA/MHz @ 3V. **Energy Micro** presented on a new 32Bit microcontroller claimed to be the world’s most efficient at 32bit. By taking an industry standard ARM Cortex-M3 processor and integrating modules they have managed to increase its power efficiency by a factor of 4. The microcontroller is provided as a developer toolkit.

There were also a series of presentations that related more to the wireless sensor network aspects than energy harvesting itself.

Libelium described some quite largescale wireless sensor network deployments (up to 1,000 nodes) in a smart cities project. They have been taking a horizontal and modular approach and can accommodate over 60 sensors and interface all key protocols (ZigBee, Bluetooth, 3G, GPRS).

Linear Technology / Dust Networks claimed that the two major WSN challenges (battery lifetime and reliability) are no longer an issue. By using time synchronised channel hopping battery lifetime can be extended to 5-10 years and reliability to 99.99% for a network that has 50 motes, 7 hops over 3 floors exchanging 100,000 packets a day. With regards larger deployments, examples were given e.g. a 700 acre oil refinery of Chevron instrumented by Emerson. Also it was reported that NTT was able to cut significantly the energy costs in their data centres. They praised the arrival of WirelessHART.

EnOcean, who have developed their own ultralow power radio protocol and a very successful ecosystem of smart building product suppliers around this standard, addressed issues of security in their early systems. A rolling code has been proposed to offer fraud resistance against reply attacks. Encryption has been added as a protection against eavesdroppers.

Wibicom, a small technical consulting company in the field of wireless communications showed 'WibiSol' a concept antenna with an integrated dye sensitised cell which harvests energy from ambient light or the sun and simultaneously transmits and receives RF signals.

Poster sessions

There was more representation of the academic community in the poster sessions with academic groups from across Europe including Germany, UK, Sweden, France, Czech Rep., Poland, Latvia, Italy and Belgium presenting. The posters covered mainly basic research but several also had a clear focus on applications of energy harvesting. Some highlights include:

Riga Technical University, Latvia featured flat inductors for energy harvesting, investigated the creation of electromagnetic harvesters with flat architecture and evaluated their performance. The key advantage of such design is avoiding a rigid construction for the harvester, where an empty space for the magnet's motion must be ensured. The ultimate goal is to use such harvesters in wearable systems integrated in clothes. Theoretical results for 3 shapes (square, rhombic and circumference) of inductors were compared.

Newcastle University, UK presented a range of on-chip solutions for voltage sensing and voltage monitoring. Their work is motivated by the need to have non-invasive operations. Their voltage sensors and monitors avoid using conventional analogue to digital converters that are power costly, slow and occupy a large area. The proposed sensing method is based on sampling energy into storage and mapping this energy into a code. The implementation uses elastic digital circuits leading to a low energy solution because they only consume power when they actively perform conversions. Using UMC 90nm technology node the conversion time was 1.2μs, the dynamic power consumption 76μW with cell leakage power 7μW.

Università degli Studi di Modena e Reggio Emilia, Italy presented an autonomous wireless sensor to enhance safety in vehicles equipped with tow bars by taking into account if a trailer is connected to the vehicle. Overturning vehicles lead to preventable fatal accidents. The device scavenges energy from the vehicle's vibration using a piezoelectric module. Data are transmitted to the stability control algorithm running on the vehicles ECU so as to dynamically adjust the vehicle's model parameters to consider the current real operative conditions.

Cranfield University, UK presented the advances in self-powered wireless sensor nodes for structural health monitoring. The system is designed to harvest energy from wing vibrations of aircraft in active service and should be able to use that energy to measure aircraft wing fatigue and inflight loading. The system features a novel piezoelectric harvester based on a macro-fibre composite. A patent pending solution integrates impedance matching, power management and smart switching. The power harvested is 1.8-12mW at 1-10Hz and 230-570 µStrain representing one of the best performances reported.

The Best Poster award was given to **Erasmus University College**, Belgium for the topic Ambient Energy Powered Smart Meters. The poster presented initial yet promising results on a micro-turbine based energy harvester that could be added to water pipes in order to autonomously measure and transmit to the utility companies the amount of water used. The authors had used a 3D printer to produce models of the turbine and compared several ways to retrofit them on existing water pipe installations.

And that folks is the highlights as we saw them. If there are any inaccuracies in the above please feel free to let us know. If you would like to know more about what is reported here or would just like some help in finding out more about energy harvesting in general do get in touch.

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