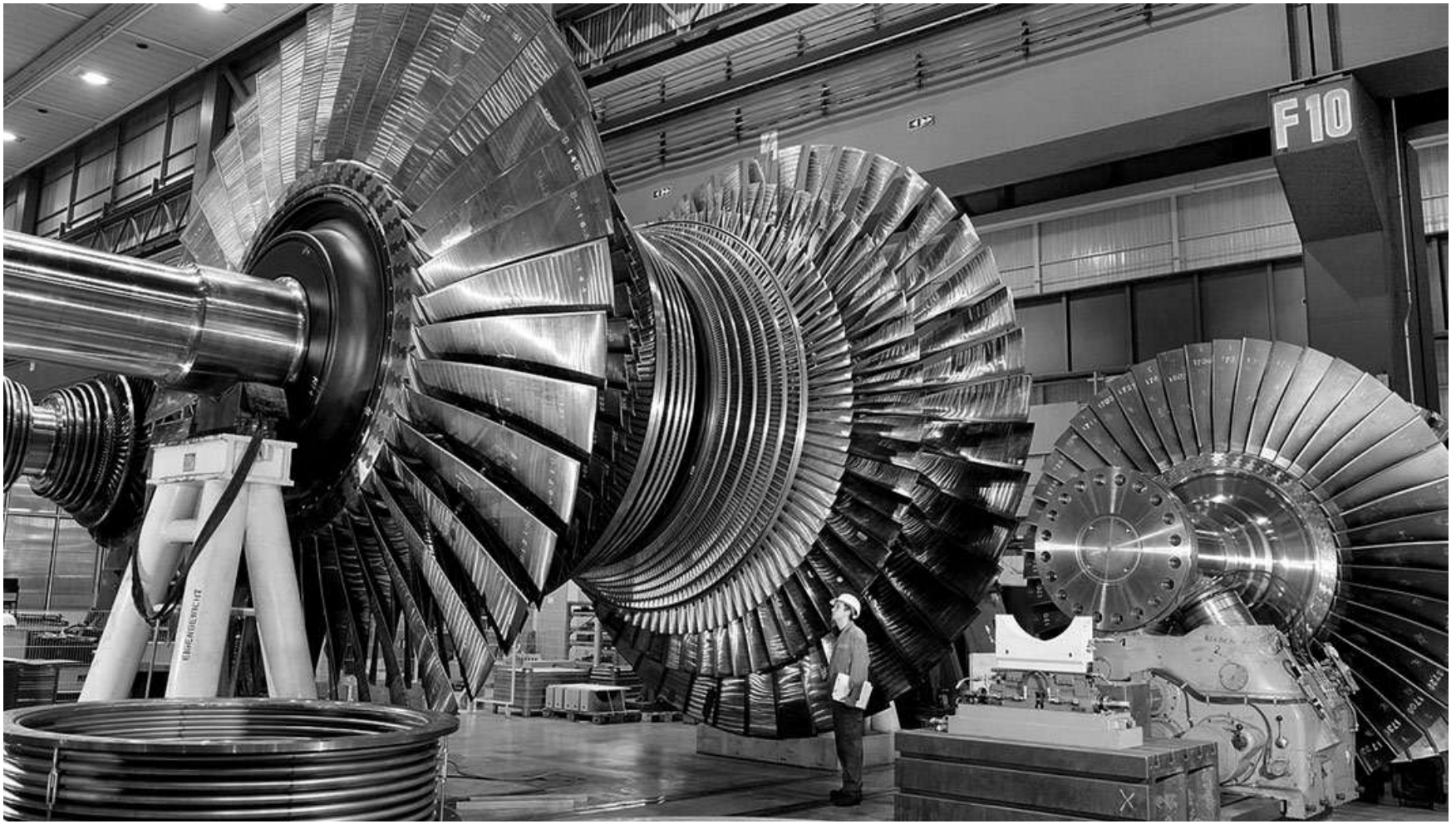

Energy harvesting based sensor network for industrial monitoring

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CTS | Ferroperm, Denmark

21st November 2013, Energy Harvesting and Storage USA 2013, Santa Clara, USA

Outline

1 Company introduction

2 System architecture

3 Piezoelectric technology for energy harvesting (EH)

4 Sensor nodes and Wireless Sensor Network (WSN)

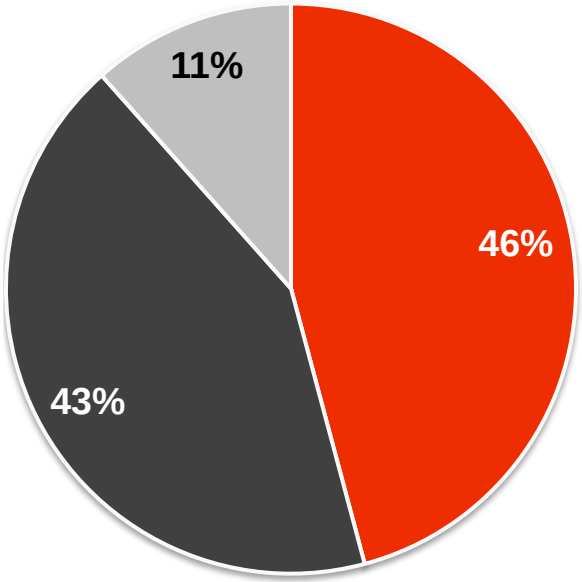
5 Climatic chamber and real industrial environment tests

1 Company introduction



Overview

- Provides high technology products and systems for the aerospace, defence and other specialist markets, including: medical, industrial, energy, test and automotive
- 60 years experience in extreme environment engineering
- Annual sales (2012), £1,605.8 million, 10% growth in comparison to 2011
- Listed on London Stock Exchange (MGGT)
- FTSE100 company



OE 52% / Aftermarket 48%

- Civil aerospace
- Military
- Energy and other

CTS | Ferroperm Denmark

- We are a manufacturer of piezoelectric materials, components, devices
- 2-3 million units produced annually
- Major markets
  - Medical ultrasound
  - Underwater acoustics
  - Acceleration sensors
  - Flow meters
  - Energy Harvesting

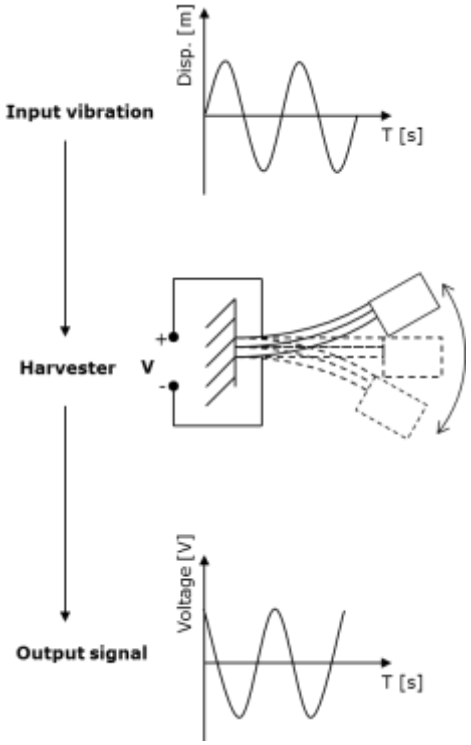
2 System architecture



Kinetic energy harvesting – basic principle

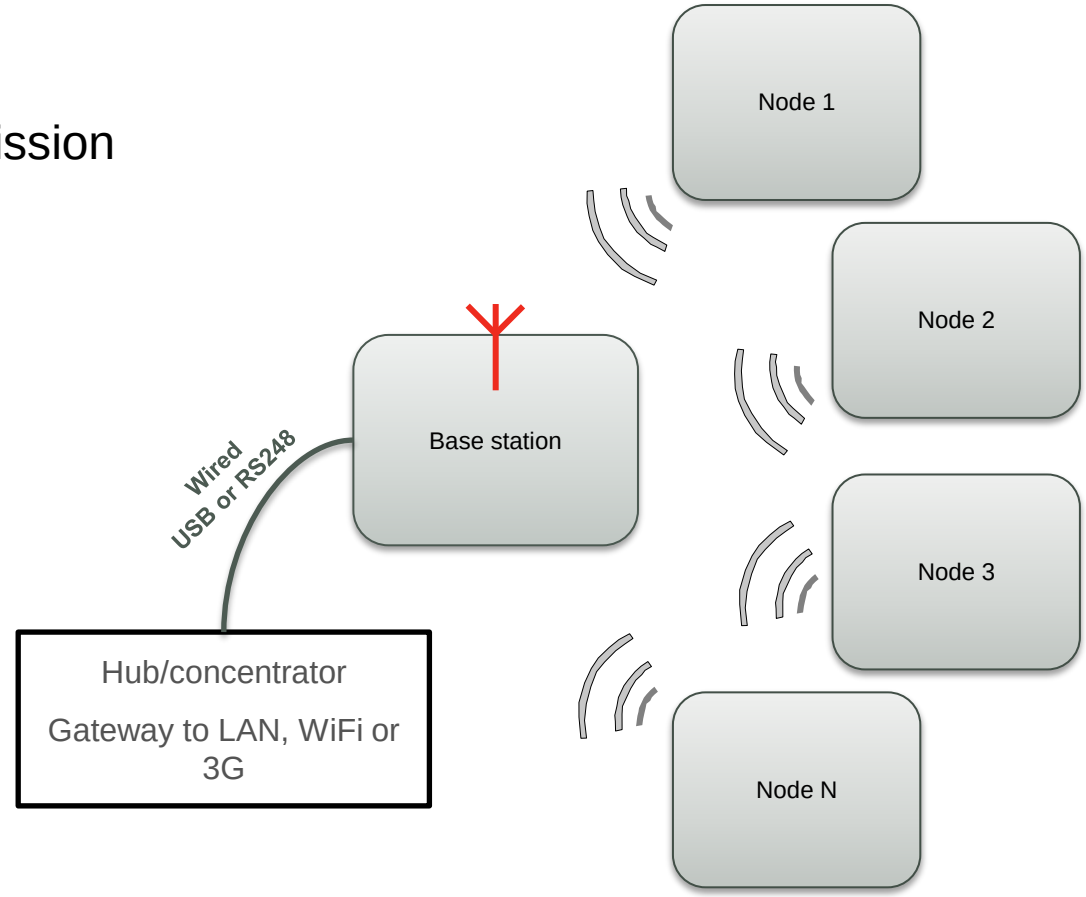
Energy Harvesting - transforming low grade energy into usable electrical energy enabling an autonomous, wireless operation of electronic devices

- The kinetic energy is transformed into electrical energy
- The kinetic energy can be in the form of the following:
  - Harmonic vibration
  - Non-harmonic vibration
  - Rotation
  - Displacement
  - Torque
  - Acoustic wave
  - Etc.



Energy harvesting based wireless sensor network

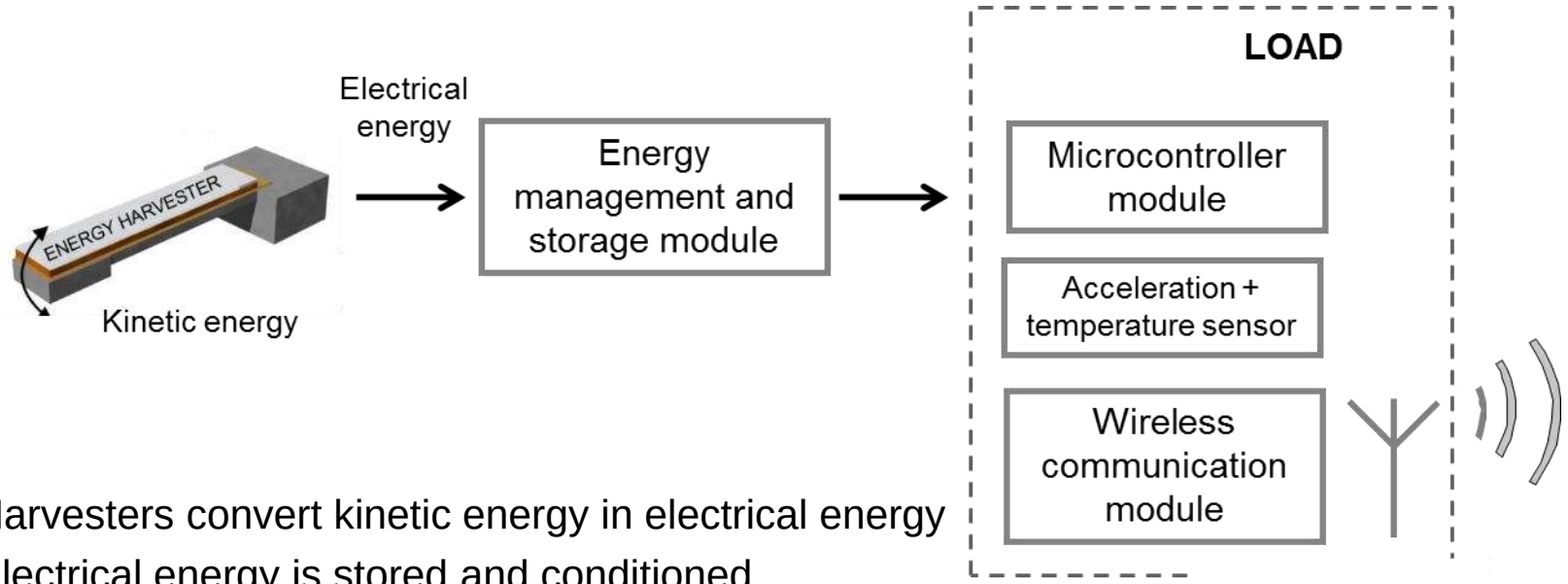
- Star topology
- Unidirectional transmission
- 16 sensor nodes
- 2.4 GHz radio link
- Proprietary protocol
- Distance (3-10 m)



General features of the system

- Micro generator level
  - Highly integrated
  - Small (millimeter scale)
  - Sourcing energy from vibrations
- System level
  - Low weight
  - Energy autonomous
  - Wireless
  - Long life
  - Wide range of working temperatures

Sensor node architecture



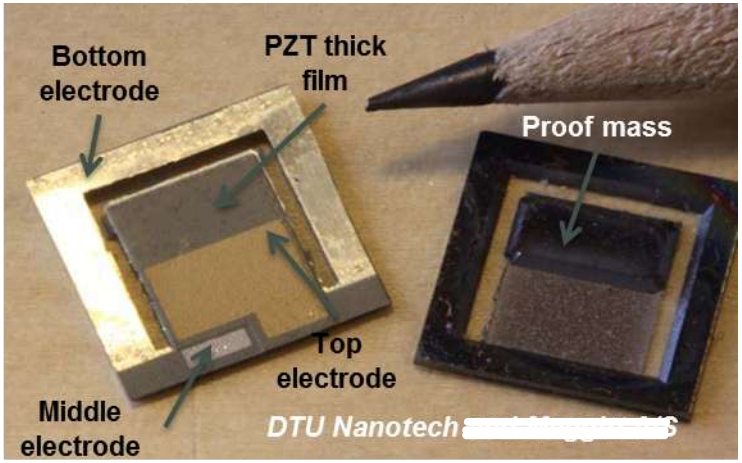
- Harvesters convert kinetic energy in electrical energy
- Electrical energy is stored and conditioned
- When electrical energy is sufficient the load is powered
- Microcontroller repeats acceleration measurement and data transmission at fixed time intervals

3 Piezoelectric technology for energy harvesting



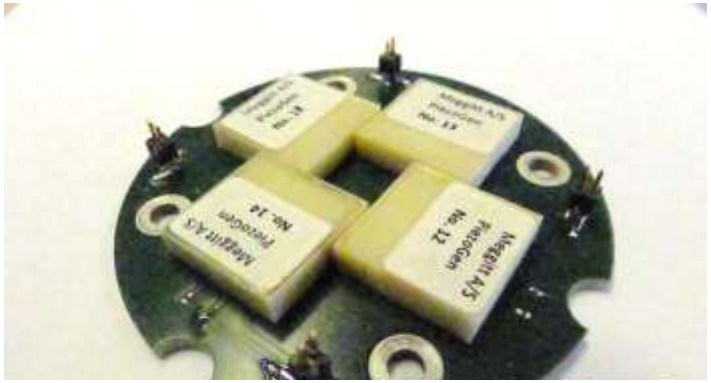
Energy Harvesting micro-generators – thick film based bimorph

- Realized with silicon micromachining technology and PZT thick films deposited by screen-printing technique
- Single clamped cantilevers with a silicon proof mass at the free end
- Bimorph configuration
- 10x10 mm^2 lateral dimensions
- Higher voltage and power compared to unimorph
- Si/PZT fabrication + middle electrode + 2nd PZT layer + Si membrane removal



Fully assembled generator board

- Four EH devices are combined in order to assure the proper power level/bandwidth
- Fully assembled board delivers approx. 100 µW of continuous power at 0.3 *g* RMS, resonance (e.g. 300 Hz)

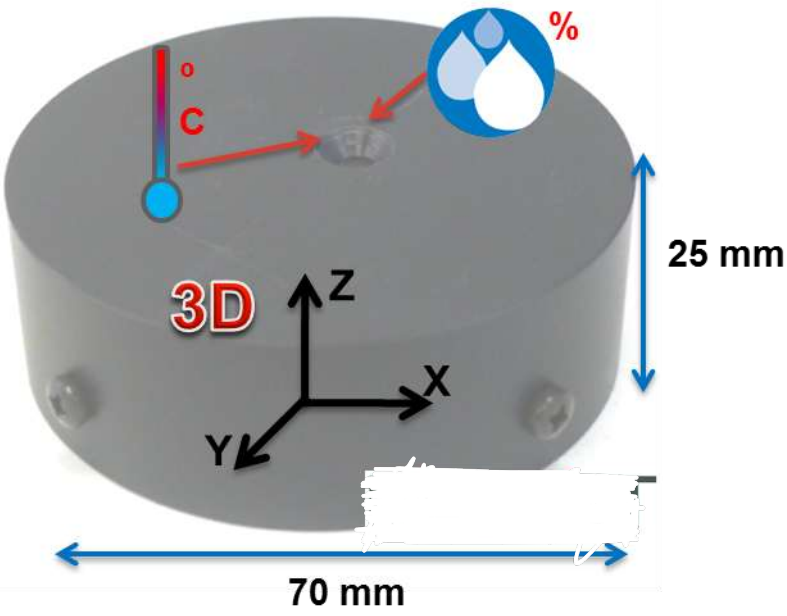


4 Sensor nodes and Wireless Sensors Networks



Sensor Node

- Operation temperature
  - Range: -40 – 70 ºC
- Acceleration measurement
  - 3D acceleration measurement
  - Sampling frequency = up to 3200 Hz
  - Resolution = 13 bits
- Ambient temperature
  - Accuracy ±0.4 ºC (10 ºC - 60ºC)
- Relative humidity
  - Accuracy ±3.0 %RH (20% - 80%)
- Sensor nodes are linked using 2.4 GHz wireless communication forming star-like network architecture

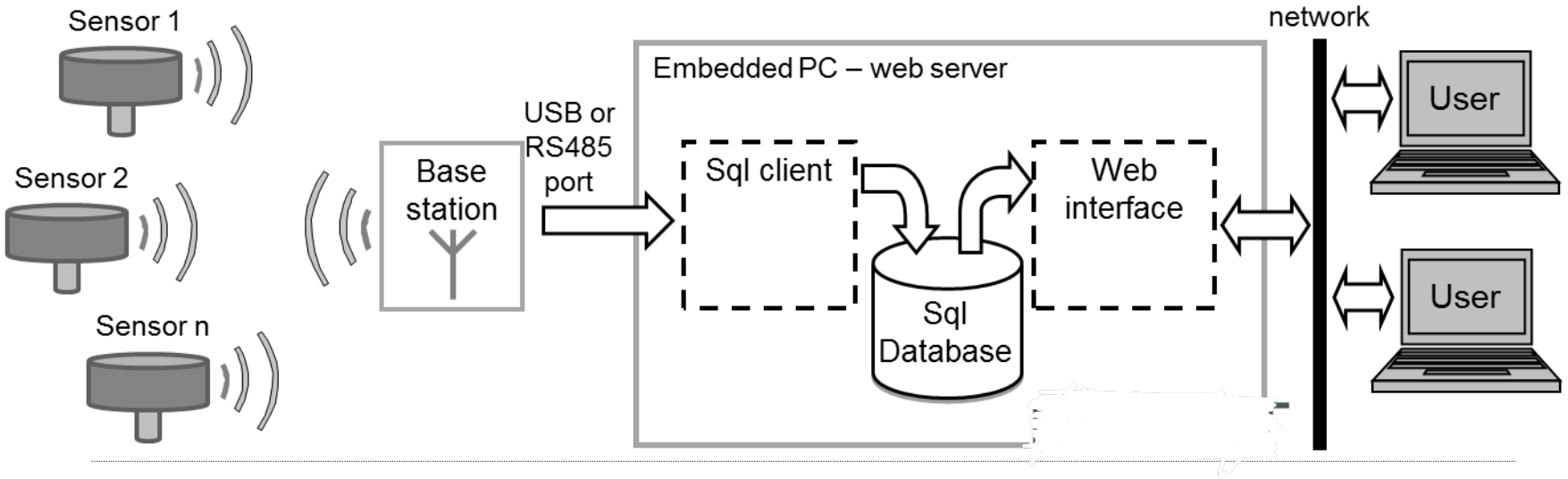


Operation principle of the sensor node

- Due to low energy level the nodes operate with low duty cycle
- The microcontroller alternates acceleration and temperature measurement and data transmission with sleep intervals
- The minimal acceleration level is approx. 0.3 *g* RMS, working frequency is tunable in a broad range

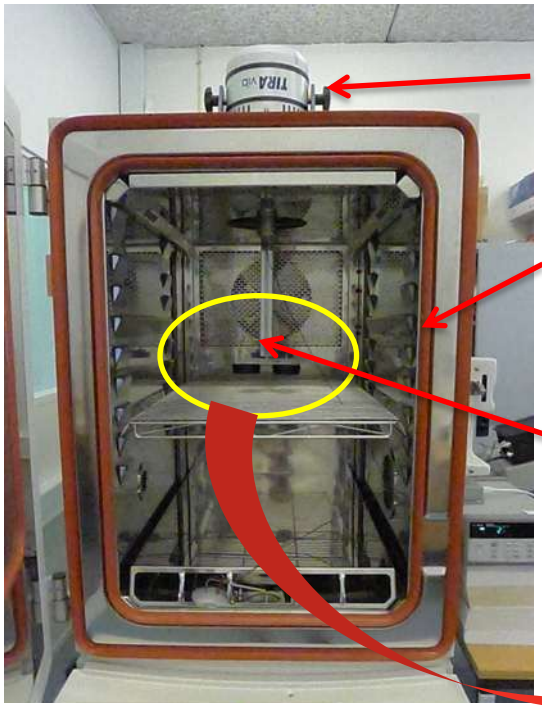
Working network of wireless and battery-less sensor nodes

- Several wireless sensor can operate at the same time
- Base station receives and forwards the incoming packets to the web server
- Sql client collects the incoming data and stores them in the database
- Web database interface shows the stored data to the users
- Intercompatibility of the different EH sensor nodes



5 Climatic chamber and real environment testing results

Climatic testing

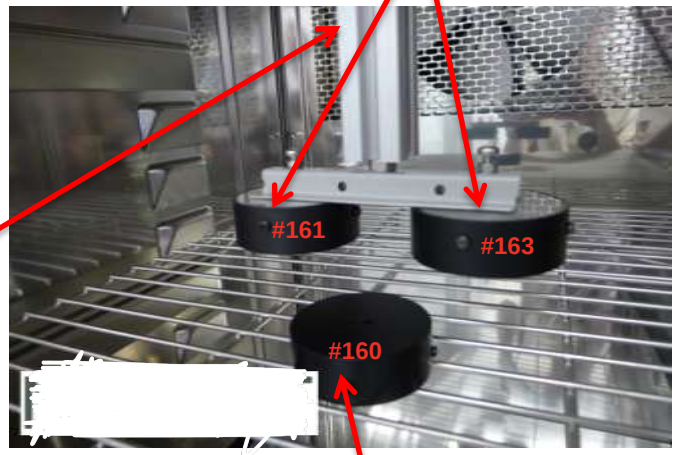


400 N Shaker

Climatic chamber
- Temperature
- Humidity

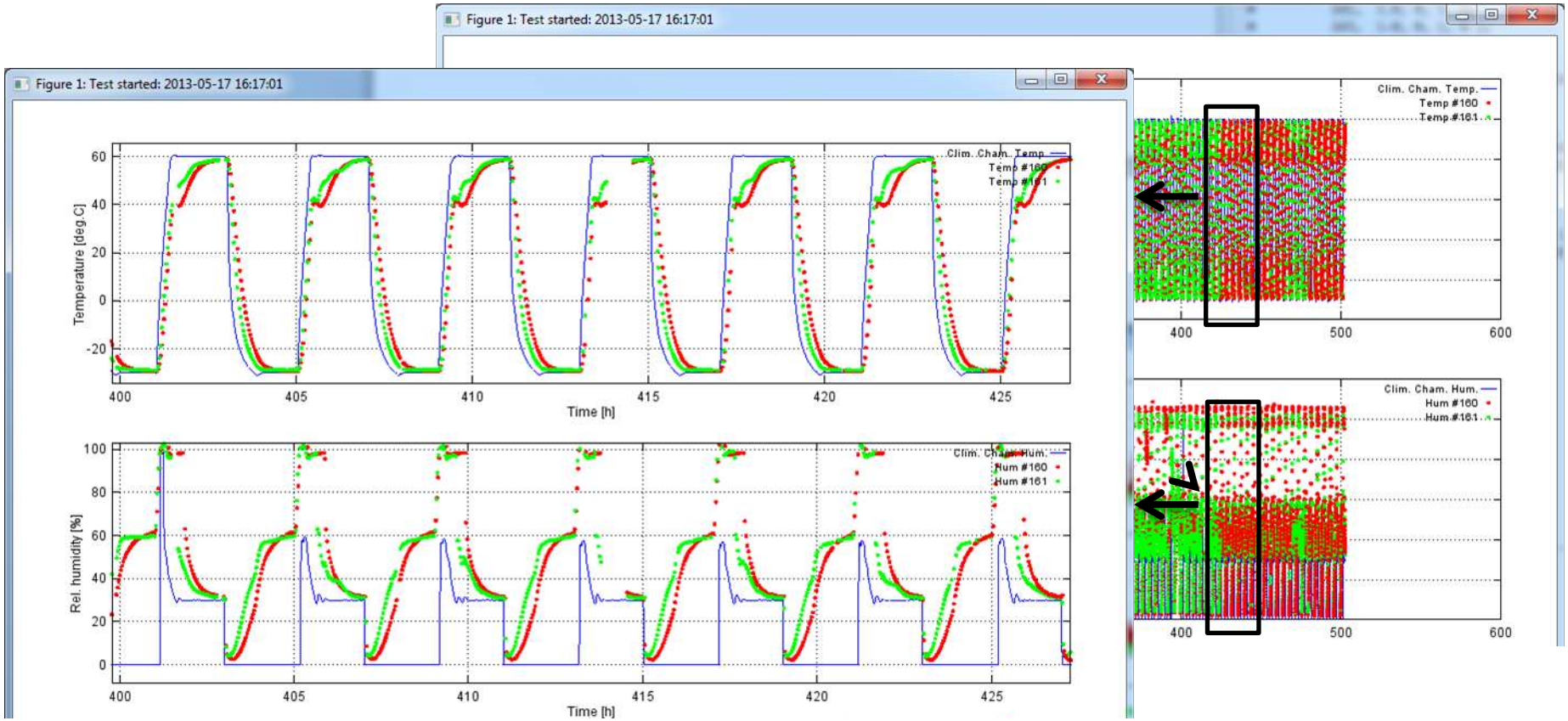
Shaker shaft

Energy harvesting based sensor nodes
Excitation: 300 Hz, 0.5 *g* RMS



Battery powered sensor node

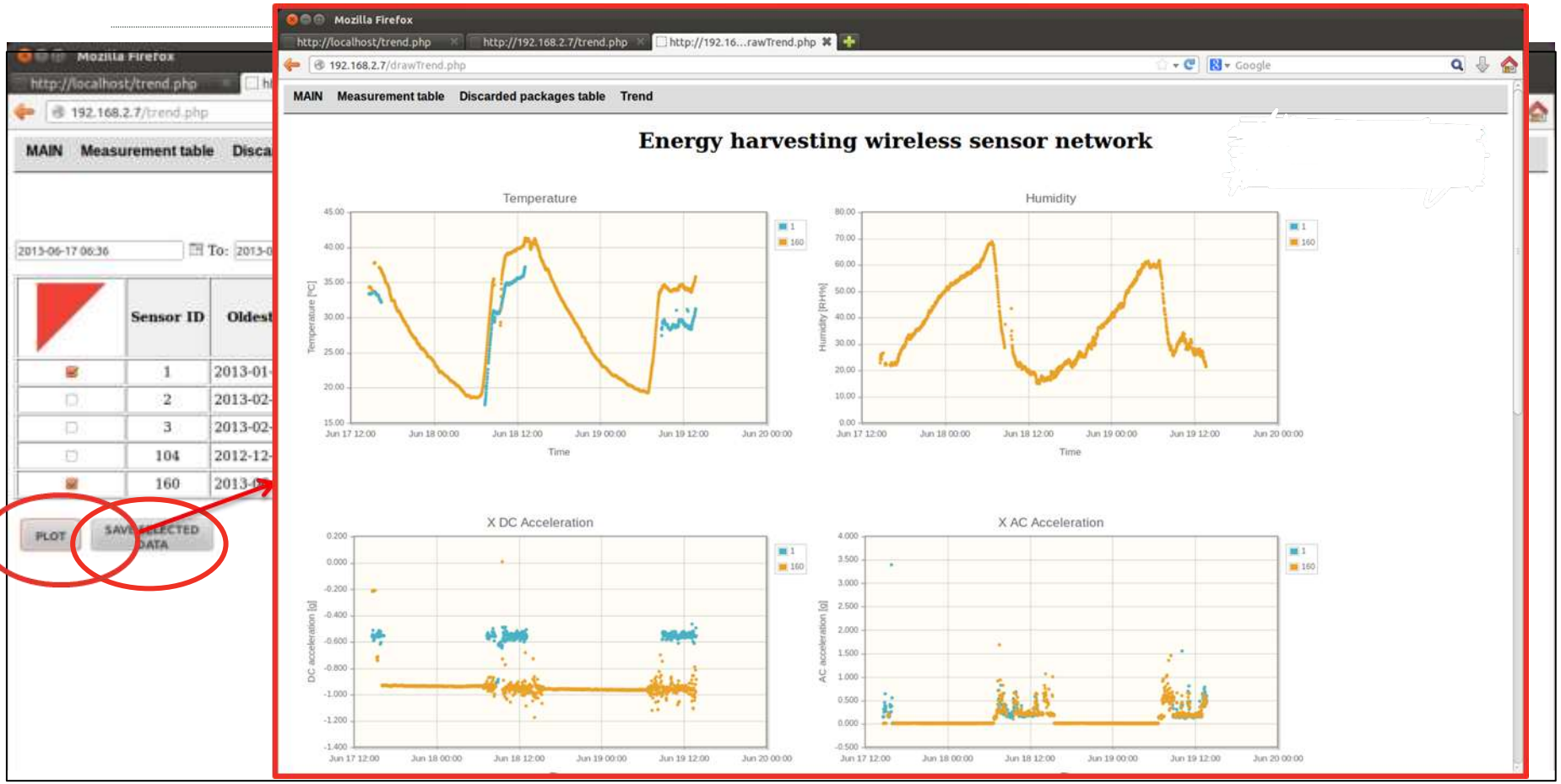
500 hours test



Industrial environment setup – an example

- Energy harvesting powered sensors have been placed on hydraulic pumps located outside of the factory building
- The base station together with the data server was placed inside the factory building
- Operating harvesting frequency was 220 Hz
- Battery powered sensor node was used as the reference

Results – example of data trends



Conclusions

- The EH devices are capable of generation of 15 to 20 μW of power at moderate accelerations of about ~0.3 *g* RMS
- The PZT thick film micro generators can successfully power sensor nodes, enabling energy autonomous, wireless measurement of acceleration, temperature and humidity at low levels of vibration e.g. 0.25 *g* RMS
- The data is easily accessible through number of standard network interfaces: LAN, WiFi, 3G
- The climatic testing indicated good performance in real environment conditions
- The wireless and battery-less sensor systems have been successfully applied in monitoring of industrial equipment
- The presented network of sensors can be applied in permanent as well as temporary monitoring in e.g. difficult to access locations
- Energy harvesting based sensor nodes enable systems that are:
  - Energy autonomous
  - Maintenance-free
  - Very easy to deploy

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ELBA

Thank you