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An autonomous sensing system for monitoring dissolved carbon dioxide of natural water for geochemical application

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Abstract: During seismic events (2009-2016), the groundwater systems of central Italy have registered changes both in terms of flow and in terms of chemical composition[1]. The main limitation of current studies is the frequency of the measurements, the absence of a continuous measurement network has prevented investigating the possible occurrence of these phenomena before the seismic events and therefore their relevance in terms of seismic monitoring. In this project, an energy autonomous wireless sensing system has been developed for continuous water chemical-physical monitoring, in real time and in high frequency.

Dissolved CO_2: Realization of the Prototype

Study the realization of a prototype, with the purpose to understand how realize a sensor with low consumption, low costs and powered by energy harvesting. Final system will be self powered and stand-alone.

Infrared Core sensor:

- Very low power/low energy consumption- 3mW
- Suitable for wireless, portable, wearable and self-powered systems
- >15 years lifetime

Stand-alone and self powered system: The dissolved CO2 is measured through a low-power (<3mW) infrared sensor that detect the gas spectral radiation. The IR- sensor is integrated in a special box with a e-PTFE membrane [2] that separate a gas chamber exchange by water. The data-logging and communication includes an Arduino mega module, a clock, an SD and SIM900 module and batteries (3.7V, 9900 mA) to power the system 3G. The energy harvesting system that recharge the batteries consist of a micro vertical axis hydro-turbine coupled with a commercial mini generator that provide the energy for water flow.

Consumption of the system for one measuring cycle (data acquisition, write file in SD and sending data via GPRS):

- Energy ~ 0,01 Wh
- Power ~20 W
- Electric current ~ 3,9 A

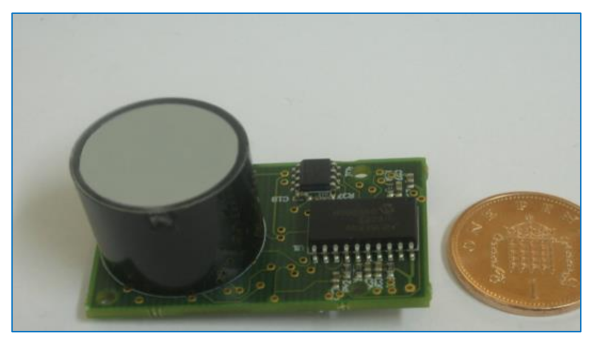

Figure 1 – Infrared core sensor

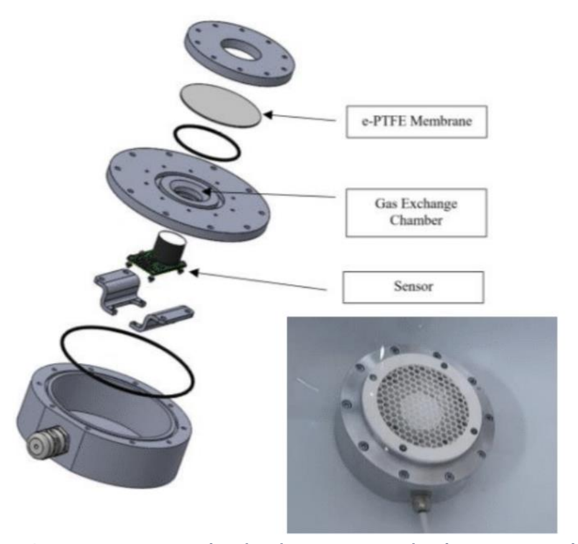

Figure 2 – Exploded view and photograph of the sensing system.

Figure 3 – Sensing system in water

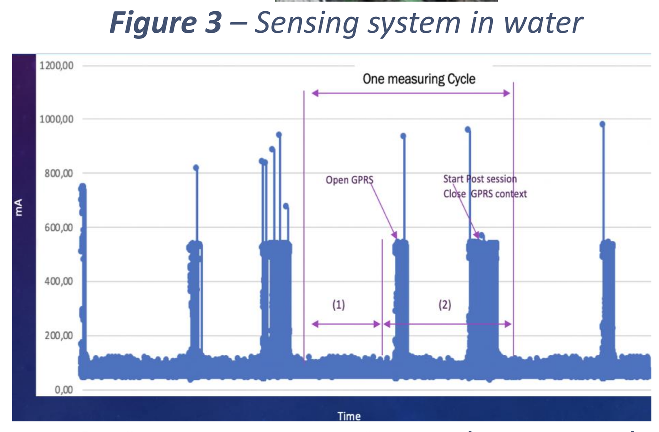

Figure 4 – System consumption analysis per cycle (reading, writing and transmitting data)

Energy Harvesting system

In the contest of Energy Harvesting, has been used a water loop bench at NiPS Lab in Perugia. The experimental apparatus consists in pipe where water flows at different flow. Vertical axis turbine (Gorlov) coupled with permanent magnets NdFeB 2-phase Halbach generator is immersed in water. A device that converts vibrational energy from flowing water in a pipeline, in electrical energy, to power water quality sensors.

A fundamental step for supply sensor with energy harvesting is choosing a right generator to include in the setup of energy harvesting. In this context fundamental measurements have been carried out, with the purpose to characterize different generators.

In order to characterize various generators, for each generator has been analysed behaviour of Input and Output Voltage in relation to the variation of revolution per minute (RPM). After careful analysis, commercial generator turned out to be the best, because provides immediately 5V with only 190 RPM.

Vertical turbine (Gorlov) coupled with permanent magnets NdFeB 2-phase Halbach Generator:

- Number of turns 400
- Magnetic Field max 0,11 T
- Poles Number 6
- Coil radius 1,65E-02 m

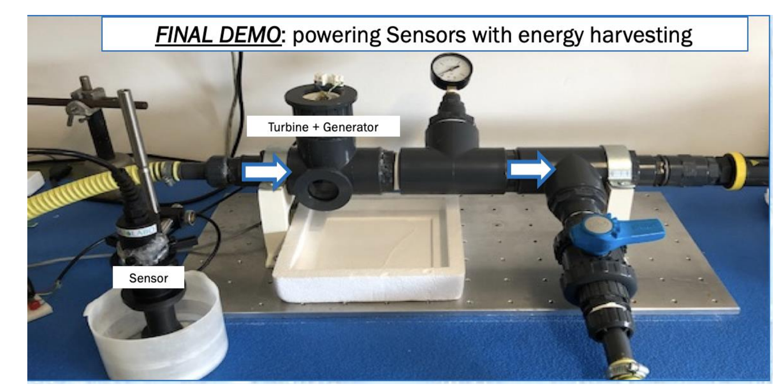

Figure 5 – Water loop test bench at NiPS Lab, Perugia

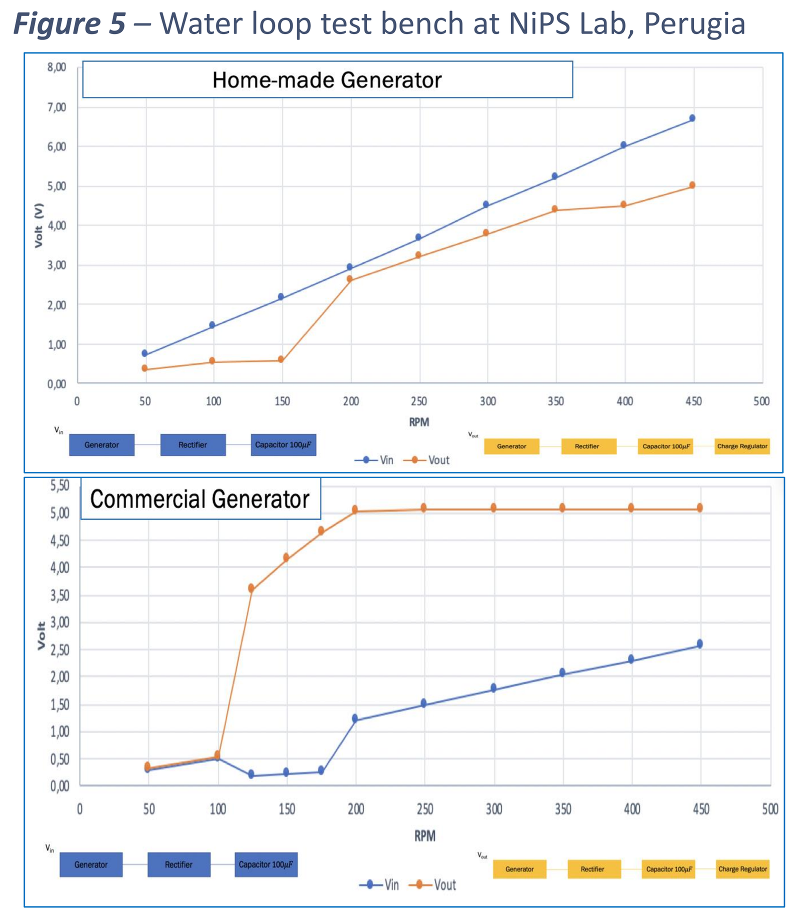

Figure 6 – Commercial vs Home made generator

Figure 7 – 3D printed water turbine

Summary

Different tests in field have been made in different place in Rieti: Canetra spring, Peschiera Spring and San Vittorino spring. These locations have been characterized by different contents of dCO2, and are located about 30 km far from the epicentre of the April 2009 L'Aquila earthquake. As shown in figure 8, measured values with Probe MiniCO2 are around 5.4% carbon dioxide, against 4.4% carbon dioxide before with the prototype. The difference in detected carbon dioxide is about 1%.

Developed prototype represents an excellent solution to use in all these fields of applications. This prototype, respect the state of the art of sensor on the market today, is autonomous thanks to energy harvesting, low-cost, and miniaturized. With this sensor, it will be possible to make a continuous monitoring, even if in the place difficult to reach. Prototype can be development further, and it can become an industrial product in short time.

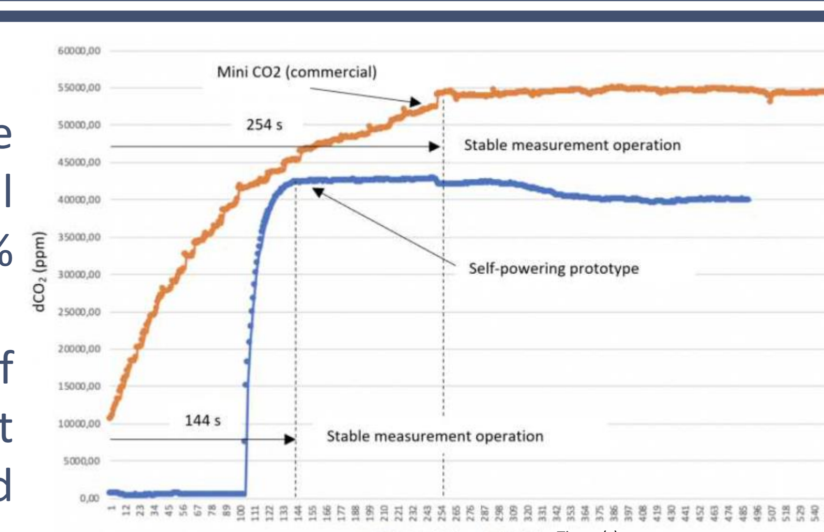

Figure 8 – prototype (orange) vs MiniCO2

Acknowledgements

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