euspen's 15th International Conference & Exhibition, Leuven, Belgium, June 2015

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Experimental characterization of a miniaturized underwater hydro-generator energy harvester

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Abstract

Networks of underwater sensors are used in watercourses for measuring and wirelessly transmitting, among others, pollution levels. To ensure constant work, each sensor node requires a power source. In this frame, energy harvesting devices based on miniaturized hydro-generators appear a viable autonomous powering option whose concept is described in this work. The harvester is based on a DC generator and a 3D printed propeller driven by the river flow. A suitable energy management electronics is also developed. Measurements on the innovative hydro-generator are carried on in real-life river conditions, as well as in a flow tunnel. The measured generated power levels correspond to values needed to constantly power a sensor node.

Wireless autonomous sensor networks, pollution sensor nodes, energy harvesting, miniaturized hydro-generator

1. Introduction

Networks of underwater sensors are an emerging technology commonly used in water flows for measuring parameters such as water temperature, flow velocity, pollution or other environmental conditions. In fact, each sensor node is composed of sensor(s) used to measure the parameter(s) of interest, a processing unit and a wireless communication unit. A common problem associated with the use of such devices is related to their power consumption, i.e. they usually need a continuous electric power source. Batteries are still frequently used for this purpose, but their usage proves often to be inadequate due to limited power levels, limited lifetimes and problems associated with accessibility. To overcome these restrictions, energy harvesting devices, such as miniaturized hydro-generators, may represent a viable, rather cheap and reliable solution [1, 2].

Based on previously presented considerations [2], a river flow energy harvesting concept aimed at powering river pollution sensors and relying on an underwater miniature turbine is thus designed and manufactured, as is a suitable energy management electronics. Measurements on the hydro-generator are carried on in real-life conditions at the Rječina river near Rijeka, Croatia, as well as in the flow tunnel at the Naval Research Institute in Zagreb, Croatia. The measured values allow establishing that the necessary power levels are achieved.

2. Miniaturised underwater hydro-generator and its management electronics

The design of the miniaturised underwater hydro-generator is based on considerations related to the required levels to power the load constituted by the sensor(s), the processing unit and the communication unit, as well as the expected river conditions with the highest anticipated water velocity of approximately v_{r_max} = 4 m/s. In this frame, the estimated average power consumption of the foreseen loads is at about P_{av} = 100 mW, while in the measurement mode, considering a measurement-to-sleep duty cycle of about 1/10, short power bursts of up to P_{max} = 300 mW can be expected [3].

Based on these considerations, all the components of the conceived underwater hydro-generator are iteratively modelled in a 3D modelling software. The final design, depicted in Fig. 1, is based on a Faulhaber DC generator (indicated in Fig. 1 with 1), which can generate up to U_g = 12 V and P_g = 2 W. The generator is connected with the propeller shaft (2) via an elastic coupling (3). The 3D printed propeller (4) with a diameter d = 150 mm is connected and centred to the propeller shaft with a bearing (5). A radial jacket (6) is mounted on the propeller shaft and it ensures sealing between the shaft and the brass generator enclosure that contains slots with silicone gel in order to ensure its watertight sealing (7). A cable feedthrough (8) completes the assembly. The manufactured components of the underwater hydro-generator, with overall dimensions of 150 mm x 180 mm, are shown in Fig. 2. These dimensions could ultimately be shrunk for higher water-flow velocities or reduced power requirements.

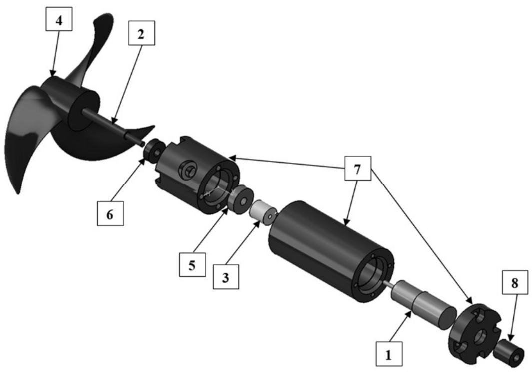

Figure 1. 3D final design of the miniaturised underwater hydro-generator

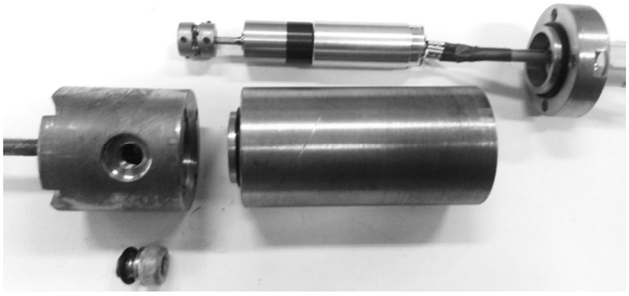

Figure 2. Hydro-generator and its brass enclosure

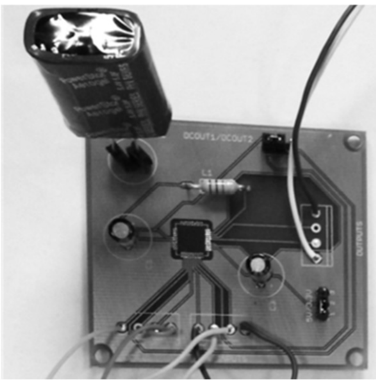

Figure 3. PCB with energy management electronics

Since the output voltage of the developed generator is a linear function of the river flow velocity, the voltage outputs must be kept constant and compatible with the expected loads ($U_l = 3.3$ V and $U_l = 5$ V respectively). A suitable energy management electronics, based on a Fujitsu harvesting chip, is thus designed and manufactured (Fig. 3). Besides maintaining the voltage at the needed level, the electronics has also the function of storing excessive energy, which can be used as a power source when higher power bursts are needed, onto a supercapacitor.

3. Measured performances of the underwater hydro-generator

Field measurements in real river conditions are conducted employing the above described generator at the Rječina river near Rijeka (Croatia) with a measured river flow velocity of approximated $v_{r1} = 1$ m/s (Fig. 4).

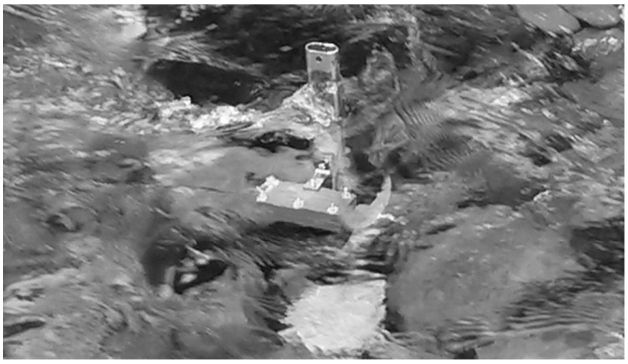

Figure 4. Underwater hydro-generator during field tests

The developed energy management electronics is used and a "dummy load" composed of LEDs, simulating the sensors and the controller and measurement boards, is connected to its output. A supercapacitor with a capacitance $C = 5$ F is used to store the unused energy. As shown in Fig. 5a, at the turbine (i.e. the input into the system) roughly $U_{in} \approx 10$ V and $I_{in} \approx 70$ mA, corresponding to $P_{in} \approx 700$ mW generated power, are obtained. The measured continuous voltage and current for the two foreseen load configurations are then, respectively, $U_l \approx 4.5$ V and $I_l \approx 110$ mA, i.e. $P_l \approx 500$ mW in one (Fig. 5b), and $U_l \approx 3.3$ V, $I_l \approx 35$ mA ($P_l \approx 115$ mW) in the other configuration (Fig. 5c).

A further set of measurements in controllable flow conditions is done next in a flow tunnel at the Naval Research Institute in Zagreb, Croatia (Fig 6). To obtain comparable results, the same energy management electronics and "dummy load" as in the river measurements, are used again. The obtained results allow establishing that the generated power is again $P_{in} \approx 700$ mW, while the continuous power outputs are up to $P_l \approx 220$ mW.

a) b) c)

Figure 5. Turbine voltage and current (a); electronics voltage and current outputs for the $U_l = 5$ V (b), and for the $U_l = 3.3$ V (c) load configurations

Figure 6. Flow tunnel (left) and hydro-generator in the flow tunnel (right)

4. Conclusions and outlook

The design of a miniaturised underwater hydro-generator and the respective energy management electronics, to be used for powering the sensors and the electronics aimed at measuring pollutants in rivers, are described in this work. Field experiments in real river conditions allowed establishing that roughly $P_{in} \approx 700$ mW of power can be obtained. An additional set of measurements in controllable flow conditions is carried out in a flow tunnel. The generated power is again at the level of $P_{in} \approx 700$ mW, while the continuous power outputs are up to $P_l \approx 220$ mW. A "dummy load" composed of LEDs, simulating the sensors cluster, is thus successfully powered.

In a further step, the developed hydro-generator energy harvester and its energy management electronics will be embedded into the final configuration of the system aimed at tracking pollution in remote watercourses using sensor network technology. Alternative concepts of energy harvesting based on piezoelectric eels, as well as a hybrid solution where a cam driven by the turbine is used to "pluck" a piezoelectric beam, will also be tested.

Acknowledgements

This work is supported via the EU FP7 ICT-2009.9.1 project no. 269985 "GOLDFISH – Detection of Watercourse Contamination in Developing countries using Sensor Networks – Enlarged".

References

[1] EU FP7 ICT-2009.9.1 project no. 269985 GOLDFISH Enlarged 2013 *Annex I – Description of work*

[2] Kamenar E, Zelenika S, Blažević D and Šamanić I 2014 *Proc. 14th Int. EUSPEN Conf.* **1** (Delft: Sieca Repro) 63-6

[3] Zelenika S, Kamenar E, Maćešić S, Blažević D, Gregov G and Marković K 2014 *Deliverable 4.4. of the GOLDFISH project* (Rijeka: TFRi)