Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 00 (2012) 000–000
Procedia Engineering
www.elsevier.com/locate/procedia

Proc. Eurosensors XXVI, September 9-12, 2012, Kraków, Poland

Practical Implementation of a Novel Wind Energy Harvesting Network

N.R. Harris, N.G. Grabham, J. Tudor, S.P. Beeby, N.M. White.

Electronics and Computer Science, University of Southampton, Southampton, UK

Abstract

This paper describes a demonstration wireless sensor network consisting of 24 self-powered nodes that harvest energy from airflow, utilizing a novel wind energy harvester. Although the main application for the technology is for fitting to ducted air systems for building health monitoring applications, this demonstrator showcases the various technologies in a more direct manner, by using energy harvested throughout the day in intensive periods of high power operation, (as sensor networks would), in this case by lighting LEDs. This provides a visible and dynamic introduction to the nature of wireless networks and makes it easy to see the operation of the network. Further we can report on the long term testing of this network, as it has been running continuously for over a year.

Keywords: energy harvesting; wind; sensor; wireless

1. Introduction

This paper showcases the practical development of several strands of topical research into a visible and dynamic demonstration system. The exercise was to produce a demonstrator for a novel wind energy scavenger with application to wireless sensor networks, and investigate the performance of such a system, by creating a highly visible self-contained long term test bench. Each node is individually addressable and contains a microcontroller and 802.15.4 radio transceiver. In addition there is an energy storage and conversion sub-system that stores electrical energy in supercapacitors, and allows a low power step-up regulator to power the system continuously. The network is self-synchronising and self-starting and, for demonstration purposes, each node is fitted with two bright LEDs, under node control. The LEDs provide a visible indication of node operation and enough energy is harvested and stored in 24 hours at a windspeed of 3.5m/s to allow high power operation (LED on) for about 20 minutes a day, and this is

* Corresponding author. Tel.: ++44 2380 593274; fax: ++44 2380 592901.
E-mail address: nrh@ecs.soton.ac.uk.

utilised to provide a synchronized light show. In more practical systems, this energy would be available for powering any sensors that might be attached, such as smoke detectors or temperature sensors etc. and is also available for powering the radio and processing systems.

2. Structure

The system consists of two parts – a base station and a remote node. Both the base-station and the self-powered node are based on a Chipcon CC2430 system-on-a-chip. This consists of a 2.4GHz 802.15.4 compliant transceiver and an 8051 based microprocessor core. There is 128kB of FLASH program memory. The node is controlled by a Real Time Clock (RTC) separate to the microprocessor, to minimize power consumption.

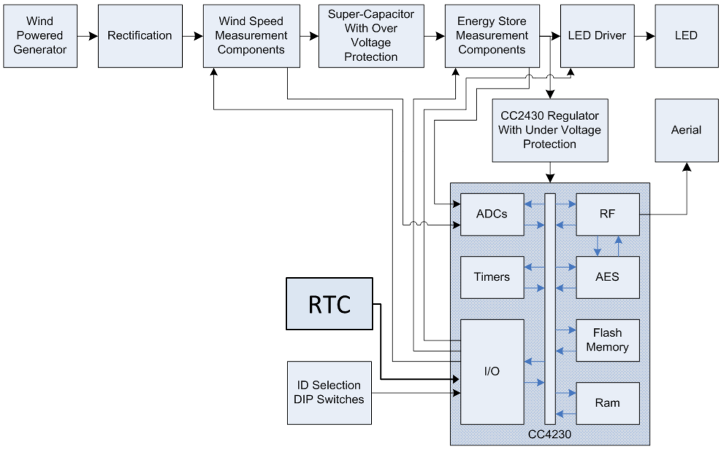

Fig.1 Self-powered node architecture

The microprocessor can program alarm events into the RTC, which is then able to wake the system from deep sleep. Likewise the basestation can use the RTC to send timing information across the radio link to the nodes. Figure 1 shows the system diagram for the node structure. When asleep, the RTC consumes 24µW of power, but the regulator (a MAX 1674) uses about 120µW under low load conditions. When the system is operating the LEDs, at a 5% duty cycle, consumption is measured at 0.75mA (2.25mW at 3V). Although the generator produces 1mW at 3.5m/s windspeed into a matched load [1], this is the best case as the load presented to the generator varies with the state of charge of the system, and how much energy it is using. It is therefore more convenient to measure the change of voltage on the supercapacitors as a proxy measurement for power generation and consumption. The energy generated from the generator is rectified to DC and charges a supercapacitor of 3.6F. Due to the large capacitance and slow rate of charge (fig. 2) care has to be taken in starting the system. Under normal conditions, the voltage regulator attempts to start up at an input voltage of 0.9V. However, the slow rate of rise on the shutdown pin means that the regulator will fail to switch on correctly and will enter a mid-state which consumes all available power, so it is necessary to inhibit the regulator until a suitable voltage has been achieved. Experimentation showed that a switch-on voltage of 1.7V gave good results. However, it is also required that the system doesn't shut down again when the voltage drops just below 1.7V – the regulator can maintain its output at 3V even if the input voltage falls to 0.3V, once its active. The architecture of the MAX1674 allows voltage pass-though when the regulator is not active, and so this can be used to bootstrap the shutdown pin. The regulator is maintained in shutdown, until the supercapacitor voltage reaches 1.7V, whereupon it will start to turn on. As the output voltage rises, the shutdown pin is driven higher thus reinforcing the startup. The regulator will now stay on until the input drops to 0.3V. In addition, it is arranged that the rest of the system is disconnected from the regulator until the output voltage rises about 2.2V. This ensures a" no-load" start up for the regulator. Bootstrapping the regulator in this way allows maximum use of the stored energy in the capacitors. When the system eventually shuts down at 0.3V, there is 1.1 Coulomb of charge left in the capacitors, which means that only 11% of the capacity of the capacitors is unavailable for powering the system. The generator used has been previously reported [1] and a picture (fig. 3(a)) and a schematic (fig.2(b)) are given, but we report on its use to power a system here.

3. Charging Results

The target windspeed for this system was 3m/s for sustained operation. Extensive testing of the generator configuration was carried out, and it was discovered that the generator wing was sensitive to the angle of attack, and that the generator could therefore be 'tuned' to give a maximal response at a given windspeed by fitting a leading edge to the wing.

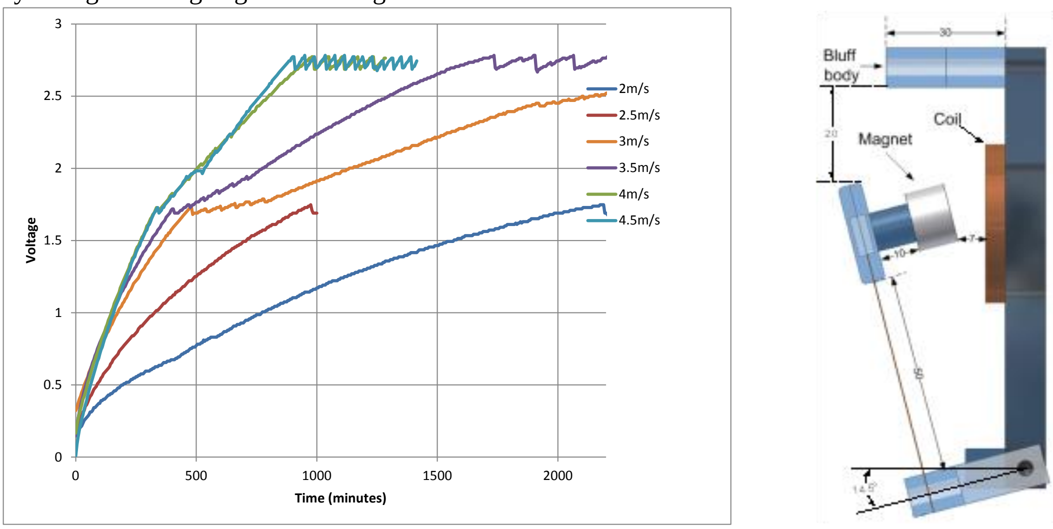

Figure 2(a) Charge rates of the system (b) Schematic of the generator (side view)

Figure 2 shows a typical set of results for a node under different windspeed conditions. It can be seen that the voltage on the supercapacitors rises slowly, but at a rate linked to the windspeed. For low speeds, although the generator is capable of charging the capacitors, when the electronics turns on, the charge rate is not enough to support charging and use of the system, even when asleep. However, for windspeeds of 3m/s and greater, the charge generation rate is capable of supporting autonomous operation, as the voltage on the capacitors continues to rise even with the electronics active. For these higher wind speeds, it can be seen that the supercapacitors are able to reach their maximum voltage and the overvoltage protection system is activated.

4. System

24 nodes were constructed and installed in a custom wind tunnel, in an array of 4 columns by 6 rows. The airflow was arranged to flow from the top to the bottom of the cabinet, whereupon it was recycled and

returned to the top. A PC running a control program allowed the base-station to upload timing and scheduling information to the nodes, acting as a 1 second beacon. As the nodes charge up and switch on, they listen for radio messages. On receipt of a message they are able to set their RTC to the time code in the message, and then set an alarm to indicate an operation. At this point they go to sleep and wait for the alarm. In this way, nodes can charge up at different times and still become synchronized. At the scheduled time, the nodes all wake up and execute the event, which is in this case a light display. At the end of the display, they set their RTC for the next event and go to sleep, allowing the capacitors to recharge.

Figure 3(a) A single node in operation (b) A photograph of the complete array of 24 nodes

Thus even if nodes become depleted and turn-off, they are able to self-start and self-synchronize. This network has been running for 1 year continuously, and has had no failures to date, but this is expected as the mechanical system (beams) has been designed to have a fatigue life of 25 years.

5. Conclusion

A wireless network, powered by a novel airflow energy harvester airflow, consisting of 24 nodes has been constructed and has performed very well for a period of 1 year. The electronic design of such a system is not trivial, and problems with slow voltage rises has lead to problems with cleanly turning on electronic components and a novel bootstrapping system has been developed to overcome these limitations. The generator has been shown to reliably power a commercial system on a chip, even when the load matching is not ideal and demonstrates the robustness of simple system design. The generator has thus proved its capability and further development for use in the built environment is currently underway.

References

[1] Zhu, D, Beeby, S, Tudor, J, White, N and Harris, N A Novel Miniature Wind Generator for Wireless Sensing Applications. *IEEE Sensors 2010*, Waikoloa, Hawaii, USA, 01 - 04 Nov 2010.