Poster Abstract: Enspect—Simplifying the Design of Energy Harvesting Systems

Nick F. Tinsley, Stuart T. Witts, Jacob M. R. Ansell, Emily Barnes,
Simeon M. Jenkins, Dhanushan Raveendran, Geoff V. Merrett, Alex S. Weddell
Electronics and Computer Science
University of Southampton
{ntinsley, switts, jansell, ebarnes, sjenkins, draveendran, gvm, asw}@ecs.soton.ac.uk

ABSTRACT

The design of sensing systems powered from energy harvesting can be complex. Design decisions are required concerning the properties and parameters of energy harvesting, conversion, and storage devices. The quantity and properties of environmental energy are typically both temporally and spatially variant, while the current consumption of the load electronics also changes dynamically. In this paper we describe Enspect, an open-source hardware/software tool which simplifies the design of energy harvesting sensing systems by assisting in the specification of harvesting and storage devices. It does this by enabling the long-term collection of data on energy availability, and modeling and simulating the performance of a complete system.

Categories and Subject Descriptors

B.8.2 [**Hardware**]: Performance and ReliabilityPerformance Analysis and Design Aids

Keywords

Design tools, Energy harvesting, Modeling

1. INTRODUCTION

Energy harvesting offers a variety of attractive features to wireless sensing devices [1] but, due to significant differences in deployment environments and application requirements, every new system is typically completely redesigned. This is necessitated by the interdependencies between parts of the system, ranging from the spatial and temporal variation exhibited by different environmental energy sources, the multidimensional parameter space of energy harvesters and circuits, and the requirements of different applications.

Existing tools can capture data on energy availability from a single energy harvesting source. Ekho [2] captures data on the performance of a photovoltaic (PV) cell and allows it to be later replayed, while [3] is a portable device which measures the spectral composition of light and predicts available power from different PV cell chemistries. However, system designers may be unsure which energy harvester is most appropriate for a certain load and application; e.g. they may be considering either PV cells or thermoelectric generators (TEGs), or perhaps plan to use a combination of harvesters.

Here, we present Enspect, an open source[1] tool comprised of two parts: (1) a logger which collects long-term in-situ data on environmental energy availability from a variety of sources, and (2) analysis software that models the performance of a complete system to evaluate component choices.

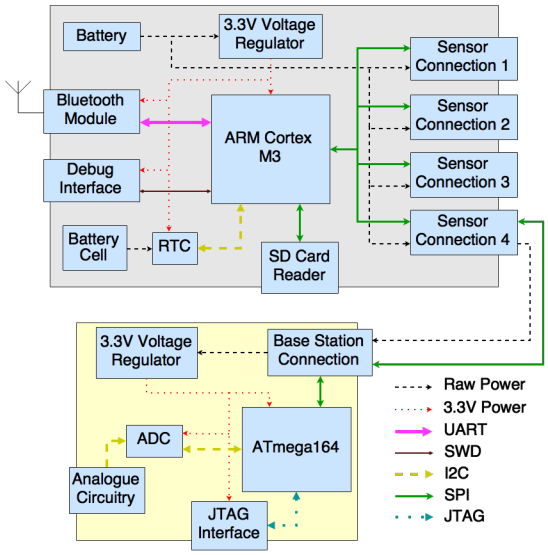


Figure 1: Block diagram of Enspect's data collection unit (DCU) and sensor module.

2. ENSPECT

To enable data on environmental energy availability to be collected, Enspect's Data Collection Unit (DCU), shown in Figure 1, can interface with up to four independent sensor modules. These may be used to evaluate different types of energy source (e.g. light and temperature difference), or the availability of energy in multiple nearby locations or different orientations. In the example shown, the PV sensor modules is capable of logging light intensity as well as its coarse spectral composition (RGB + infra-red). Intelligence

[1]Obtain schematics, embedded software, and PC analysis software from `http://www.enspect.ecs.soton.ac.uk`

SenSys'15, November 1–4, 2015, Seoul, Republic of Korea.
ACM 978-1-4503-3631-4/15/11.
DOI: http://dx.doi.org/10.1145/2809695.2817887.

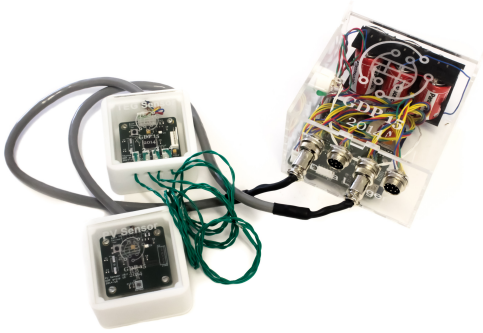


Figure 2: Enspect DCU with PV and TEG sensor modules.

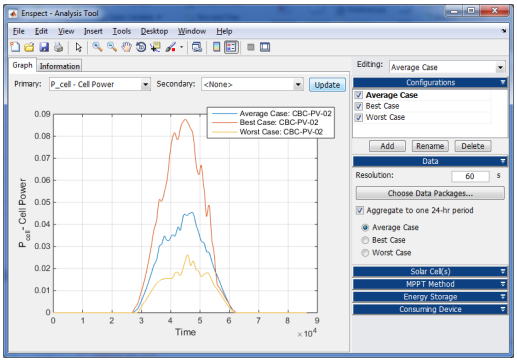
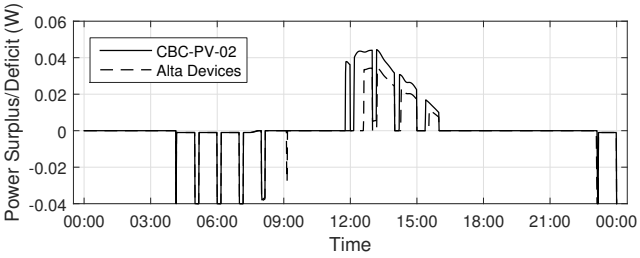


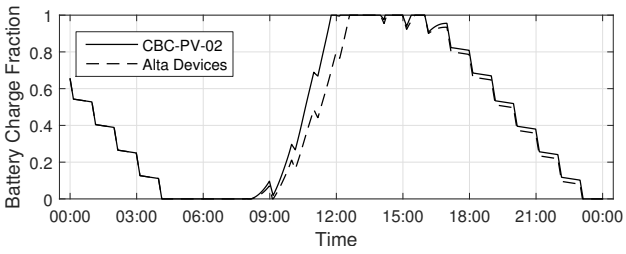
Figure 3: Analysis tool, predicting PV cell power output from average, best, and worst case data.

is devolved to these modules, with processing taking place on the on-board microcontroller to minimize the amount of traffic to the DCU; typically modules will report their readings at 2 Hz, but this can be reconfigured in software. The system is plug-and-play: it will recognize the sensor modules connected and configure itself appropriately. It can be configured over Bluetooth, and logs data to an SD card. The system has a minimum 24 hour operating lifetime. Figure 2 shows the DCU with two sensor modules (PV and TEG).

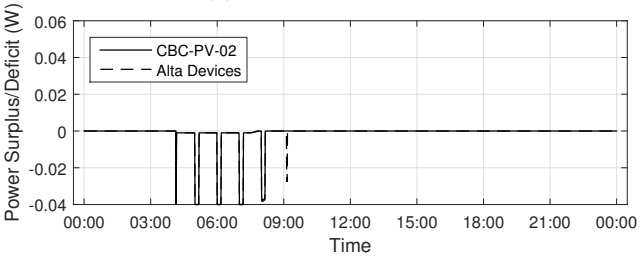
The MATLAB analysis software (Figure 3) takes data obtained by the DCU and models system performance. It uses models of energy harvester performance, which can be derived from datasheets or empirical measurements, and allows the system design to be manipulated to observe the effect of various component choices. For example, it allows various techniques for maximum power point tracking to be evaluated, as well as enabling the capacity of the energy storage device (battery) to be adjusted. The software is modular so its components can be exchanged.

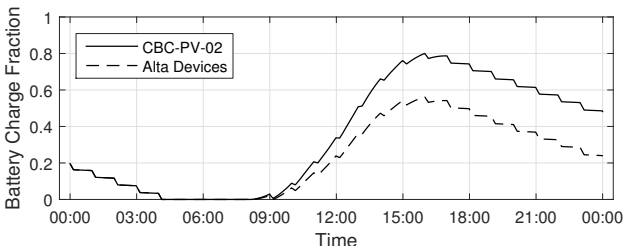
The tool introduces the concept of a power 'surplus' and 'deficit'; a surplus is when the battery is full and harvested energy is wasted; a deficit is when the battery is empty and cannot provide power to the load. If a system experiences both surplus and deficit, it indicates under-sized energy storage. If it only exhibits a deficit, it may be due to the harvester being under-sized. Figure 4 shows a complete system simulation, with a duty-cycled sensor node powered from a PV harvester: (a) with an under-sized battery (exhibiting surplus and deficit); (b) with an appropriately-sized battery.





(a) Under-sized battery





(b) Appropriately-sized battery

Figure 4: Simulation of system, with two battery capacities.

3. CONCLUSIONS

Enspect simplifies the development of energy harvesting systems. It allows long-term data to be collected, and allows decisions to be made on the design of an energy harvesting system. By illustrating the charge state of the system, and using energy surplus and deficit concepts, the robust design of energy harvesting systems has become more intuitive.

4. REFERENCES

[1] S. Beeby and N. White. *Energy Harvesting for Autonomous Systems*. Smart Materials, Structures, and Systems Series. Artech House, 2014.

[2] J. Hester, T. Scott, and J. Sorber. Ekho: Realistic and repeatable experimentation for tiny energy-harvesting sensors. In *Proc ACM SenSys'14*, pages 1–15, New York, NY, USA, 2014. ACM.

[3] J. Sarik *et al.* More than meets the eye - a portable measurement unit for characterizing light energy availability. In *Global Conf. Signal and Information Processing*, pages 387–390, Dec 2013.