AEROSOL - a micro-scale domestic autonomous solar and wind power generation unit in an urban environment

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Abstract: Over the last few years wind and solar power generation units have had a widespread development, not only in remote areas but also in many modern cities. However distant may the dream of a 100% renewable electricity generation be, the fact is that everyday environmental worries and fuel costs have turned micro-scale generation units into a viable solution. A monitoring system developed on a commercial power generation unit is thus presented, with special emphasis on the viability of autonomous systems in today's cities.

Keywords: Wind Power, Solar Power, Disperse Generation, Microgeneration, Autonomous Power Systems

1. Introduction

The widespread development of new, cleaner energy sources and the paradigm changes in the power generation industry have led to the outcome of small and very small-scale electricity production units.

Fig. 1 – Small commercial wind turbine used inthis project.

A city building rooftop can easily accommodate a small wind turbine and a number of solar photovoltaic panels which are available commercially at a reasonable price.
Such a system can provide a good starting point for studying the specific characteristics of this system, both on a component-by-component basis and on a global system basis.

Like most renewable energy sources, wind and solar energy are intrinsically dependent upon meteorological events and specific land characteristics, the study of which may provide more accurate prediction data regarding the amount of energy produced and the reliability of such a supply considering autonomous connection or backup.

This paper describes a complete, step-by-step monitoring system integrated in a wider range on-going project consisting of this particular system, other similar systems and a weather station distributed over a small geographical area.

2. Equipment and field measures

The scope of this monitoring system and subsequent measurement campaign was to evaluate the power generated by the mentioned generation unit.

The unit was installed on the roof of an educational building belonging to the Technology and Management School in the city of Leiria, Portugal. This is also a privileged spot for the wind turbine, as it is located on the top of a hill, without any obstacles in a considerable distance.

Fig. 2 – Wind speed and solar radiation sensors.

The system used is a commercial system comprising a 500W wind turbine and two 120W photovoltaic panels with load regulators, batteries and a battery charge regulator/inverter (VSI).

The wind turbine can rotate 360º, automatically adjusting to the predominant wind direction. The solar PV panels are fixed and heading South, with 40º inclination.

On the same place a small weather station is installed, consisting of a solar radiation sensor and a static wind sensor. The solar radiation sensor is capable of measuring diffuse radiation as well as direct.

Measures were recorded for several weeks over the summer of 2005, in 10-minute intervals. However, for displaying purposes in some cases, hourly and weekly averages are considered.

The idea behind measuring in an integrated system is that intrinsically variable events like wind speed or solar radiation may be quantified and compared to the electric power output of such a system. Some "quick" conclusions or observations, even if disputable, can be withdrawn and tested again in the future for "safer" knowledge.

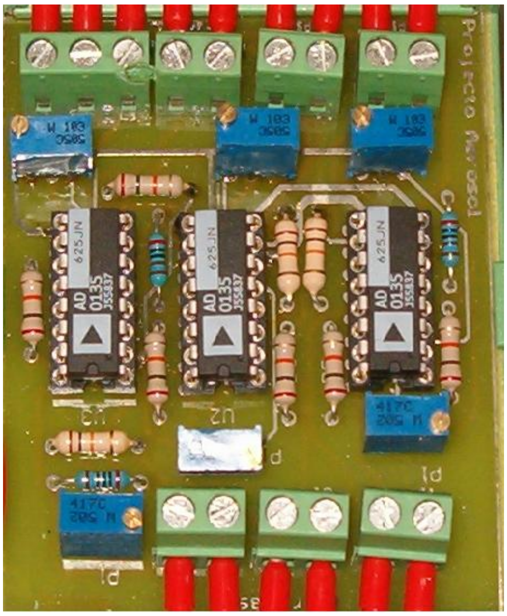

Fig. 3 – Data acquisition circuit board (designed for the project)

A system had to be designed and built so as to accommodate measurements from various sources and in many formats. A Siemens S7-200 PLC unit was used, with the adequate analog inputs modules and signal conditioning circuit boards.

All signals were therefore converted into voltage 0-5 V DC before being fed to the analog inputs. Several data acquisition circuit boards were designed and built, such as the one depicted in Fig. 3.

The PLC unit periodically reads the inputs from the analog cards, performs the adequate calculations and monitors the process, updating the outputs and saving the relevant data.

3. Data analysis

It is common knowledge that meteorological factors such as sun and wind have considerable variations throughout the days. As an example, figures 4 and 5 depict the variation of solar radiation and wind speed in the four hottest hours of a typical summer day.

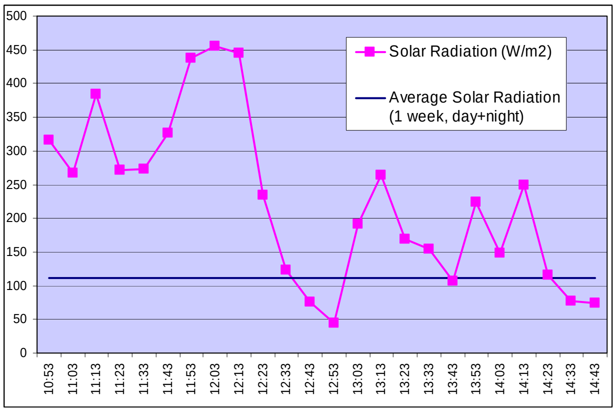

Figure 4 – Solar radiation in a typical summer day (10:45-14:45)

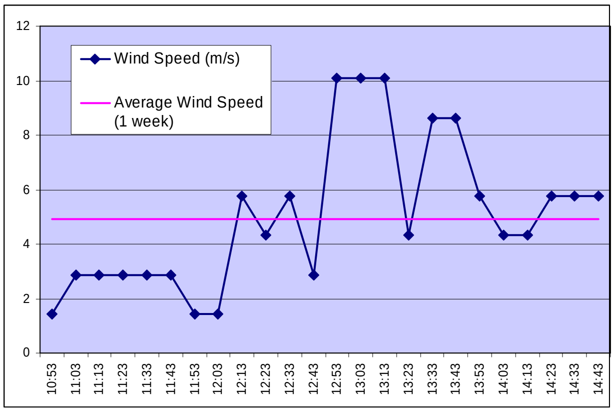

Figure 5 – Wind speed in a typical summer day (10:45-14:45)

In the project, an attempt was made to focus on specific load connection situations that may occur in a autonomous power generation system, namely:

- no external load (battery charging only);
- "small" external load (battery charging and load supply);
- "big" external load (load is supplied by the batteries as well as by wind/solar energy).

When no external load is connected, the only significant event is the charge/discharge cycle of the batteries. Nevertheless, wind turbine charge regulators are usually equipped with power sinks, in order to avoid overheating and damage to the wire connections and the wind turbine itself. Power sinks also dissipate energy when there is an external load which is smaller than the actual instant power generated.

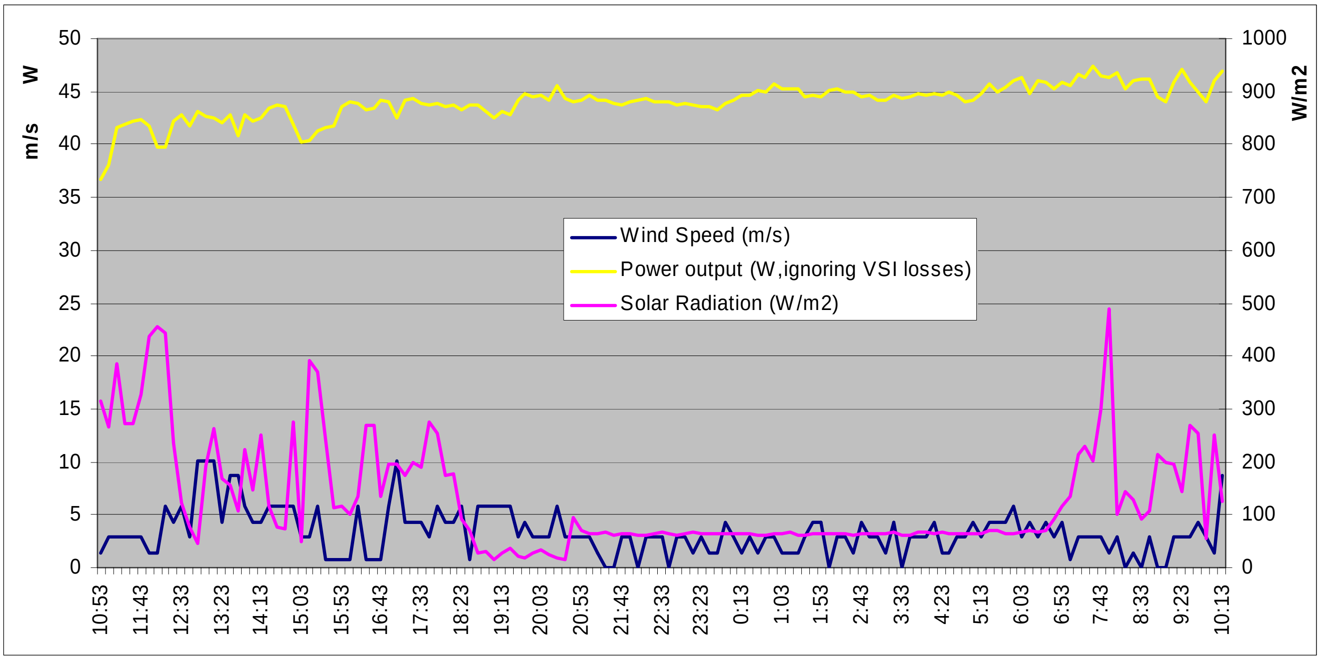

Figure 6 – Wind speed, Solar radiation and Power output over 1 day for a “small” load

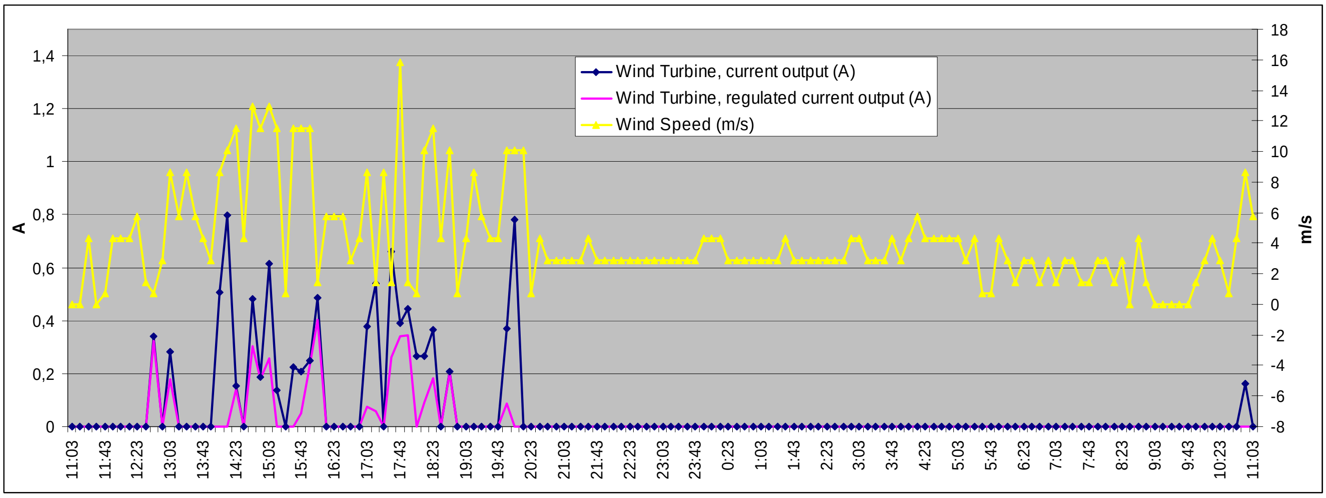

Figure 7 – The wind power generation threshold – wind turbine current output before and after regulation, and wind speed (1 day)

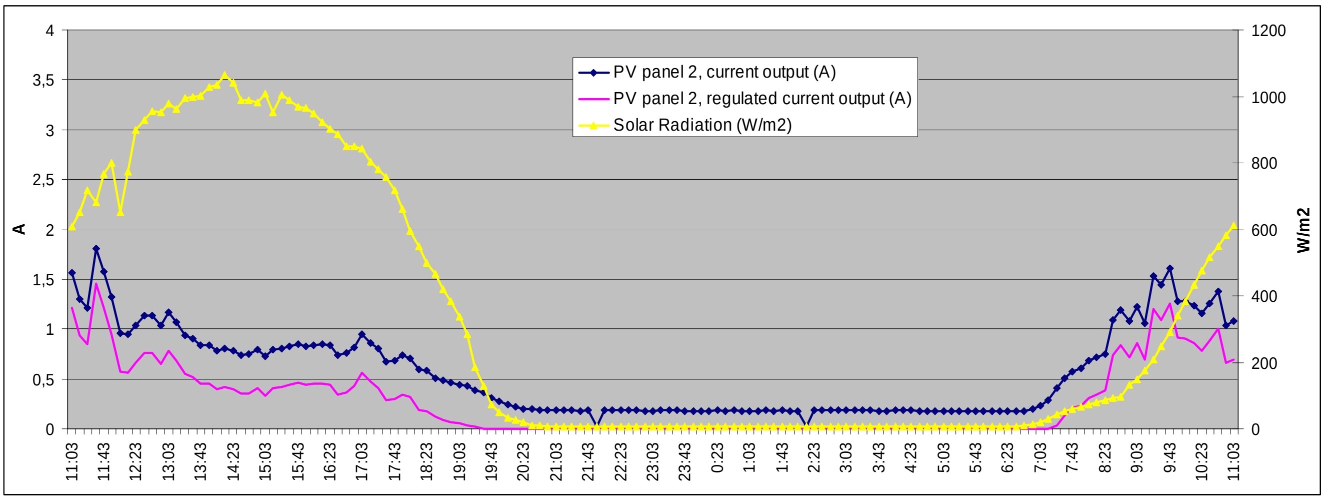

Figure 8 –Regulator as a “load” – PV panel 2 current output before and after regulation, and solar radiation (1 day)

Figure 6 shows a typical “small continuous load” situation, for which a system like the one in study is appropriate – despite the absence of sun during the night, and (in this example) the low wind speed the load is continuously supplied by the energy stored in the batteries.

This shows that battery storage size in autonomous systems is as important as the power generation capacity itself – not just for night periods but also for non-windy days.

It is adequate to state at this point that whereas solar photovoltaic panels generate power with nearly any amount of radiation, wind turbines typically have a wind speed threshold under which no power is generated.

Figure 7 has a good example of the previously stated, showing one day of wind power generation and wind speed. From 9 p.m. to 10 a.m. of the following day, the measured wind speed is roughly between 2 and 6 m/s. However, both the current straight from the wind turbine and the current through the regulator are zero. A quick look at the figure situates the generation threshold near the 8 m/s wind speed.

Apart from that observation, there is a visible regulation action – the regulator smoothes the wind peeks, but also consumes much of the power generated. Only in some small points does the regulator follow the current flowing out of the wind turbine. Note that the flowing current is being taken as representative of the power generated, which is usually accepted as valid for a PV equipped with a set-point voltage regulator.

Figure 8 shows one day of solar power generation and solar radiation. Where solar radiation has the normal behaviour of a typical sunny summer day, current flowing through the PV panel is steadier than in the previous example. Unexpected results show power production not increasing with the higher solar radiation of around midday, which may mean there is something wrong with the regulator. It apparently behaves like a steady load, consuming part of the power produced.

4. Conclusions

The first difficulty encountered when dealing with this system had to do with integration. Being designed as stand-alone systems, both the wind turbine and the solar panels have separate charge regulators, which in this case are connected to the same bus where the batteries are.

This caused that sometimes, when both solar and wind power were available, only one of the resources was actually supplying the load/charging the batteries, while the other was cut-off by its own voltage-based regulator.

Also, low-quality regulators included in these units may explain some of the poor behaviour observed in this study – it is well known, for instance, how much solar PV efficiency depends on the set-point voltage.

In summary, wind and solar power production vary considerably in time, even when comparing ‘similar weather’ days or day periods. In addition, incomplete battery charge cycles and power quality issues add up to the limitations created by the intrinsic uncertainty of systems based on renewable sources. Significant questions on the sustainability of systems as the one described still remain, as well as on the quality of the parts involved.

Acknowledgements

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