SATELLITE MONITORING OF REMOTE PV-SYSTEMS

Stefan Krauter, Thomas Depping
UFRJ-COPPE-EE, PV-Labs, C. P. 68504, Rio de Janeiro 21945-970 RJ, BRAZIL
Tel: +55-21-2562-8032, Fax: +55-21-22906626, E-mail: krauter@coe.ufrj.br

Abstract

A major part of autonomous renewable energy applications - such as PV - are electricity supplies in regions with no grid, no telephone coverage, and often with difficult accessibility. Commonly systems in such regions are supervised by yearly visits in conjunction with a data logger. Over the lifetime of a system the costs for supervision often significantly exceeds the cost of the system itself. Response time for maintenance, repair and product improvements is poor.
To overcome these disadvantages a data satellite transmission system using Brazilian satellites was set up in this project: It is compatible to the ARGOS protocol, facilitates small transmitters and has a full equatorial coverage. The satellite data is transferred via ftp from the ground station in to the Internet server of the PV-Labs at UFRJ in Rio, and is published from there worldwide via WWW. The advantages are manifold: Sponsors (NGOs, World Bank, national foundations, public etc.) have an immediate access to the projects ("Where did my money go?"), manufacturers can use the data to improve their products, and - last but not least - the online monitoring system provokes more public interest in the PV area.

1. INTRODUCTION

A major part of PV applications are autonomous electricity supplies in regions with no grid, no telephone lines, no cellular phone coverage, and often with difficult accessibility by common transport. Commonly in such regions PV systems are supervised by yearly visits in conjunction with a data logger. During the lifetime of a system the costs for that type of supervision significantly exceeds the cost of the system, e.g. monitoring for Northeast Brazil: Travel expenses, personnel: each yearly read-out of the data logger costs 600 €, so for 20 years this results in 12000 € just for minimum system lifetime. These high service costs often inhibit to install new systems. Also response time for maintenance, repair and product improvements is very long. So the necessity to constantly monitor PV-systems is evident. To transmit the data over long distances from remote sites the use of satellites is appropriate. As a first project for monitoring PV-power-stations via satellites a remote fisher village called Beleia, in the North of Brazil , State of Ceará, was selected.

2. MONITORING BY SATELLITE

2.1 The ARGOS system

The satellite system has to transmit approximately 10 bytes of measured data every 15 minutes. For this purpose a common telemetry-satellite-system called ARGOS is used. ARGOS was set up in the Seventies for scientific purposes to collect environmental data and is used for atmospheric and oceanic measurements or even is applied for telemetric purposes in zoology. The transmitters, called PTT (platform transmitter), are very small and can be interfaced with sensors to collect data (see Figure 1).

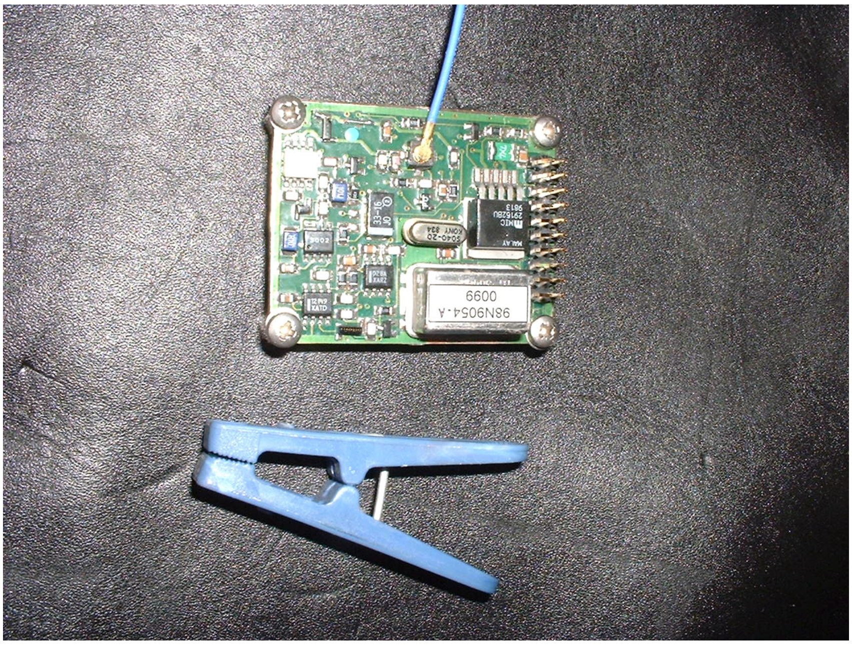

Figure 1. ARGOS Platform-Transmitter (PTT).

The devices can also be localized up to an accuracy of 130 m by calculating the Doppler shift - for example to observe the movements of animals. They permanently send their data-messages (identified by the unique PTT address) without feed back from the satellites.

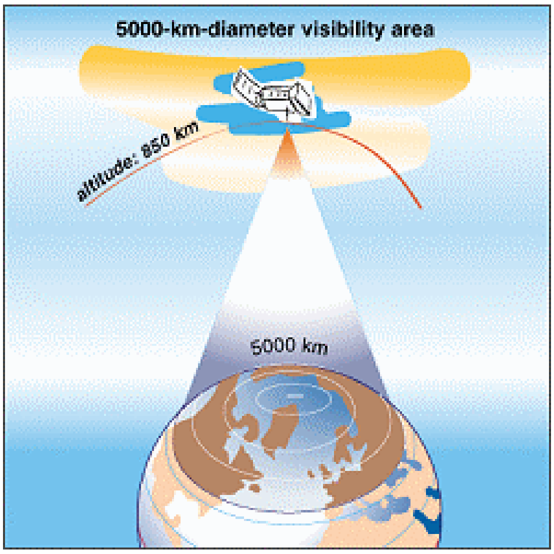

Figure 2. ARGOS low orbit satellite system.

The system works together with low-earth-orbit satellites orbiting in an altitude of 850 km (see Figure 2). Their orbital planes rotate about the earth from north to south, one complete earth-revolution takes about 100 min. About 14 satellites work for the original ARGOS, always two or three at the same time, transports the received data and sent them to France (Toulose) or the United States (Wallops and Fairbanks). The satellites have a visibility circle about 5000 km diameter, covering the whole size of Brazil. Contact time is between 8 and 12 minutes and with a transmission-rate about 32 Bytes. Because of the near-polar orbit, the number of daily passes over a transmitter increases with latitude. At the poles, each satellite passes about 14 times, at the equator about 4 times during 24 hours.

2.2 ARGOS-SCD

The Brazilian ARGOS-SCD system is compatible to ARGOS, but the satellites have a different orbital plane. Brazil uses two satellites (SCD-1, SCD-2), which fly equator-parallel and cover the whole of Brazil. The system permits up to 14 contacts per day. The satellites send the received data directly to the ground-stations; the main ground station is in São José dos Campos near São Paulo. From there the data will be distributed with a time stamp of receiving-time by Internet to the user. For this project, the use of the Brazilian ARGOS-SCD-System is for free. The ARGOS-SCD system is controlled by INPE (Instituto Nacional de Pesquisas Espaciais).

Nominal uplink frequency:	401.65 MHz
Message length:	up to 32 bytes
Repetition period:	45 to 200 sec
Transmission time:	360-920 ms
Transmission power:	1 up to 2 W

The quality of the transmission is depending on the location; often the transmitter-data interferes with other transmitters. To avoid errors, redundancy is necessary: the rate of transmission repetition required varies and depends on the location. To overcome the limit of 32 bytes per contact it is possible to use more than one address (multi-ID), maximal up to 4 simultaneously. In Brazil the satellites are sending the received data directly to ground-station, which consumes very little time. This makes it possible to send more than 32 bytes via one address by using a small repetition time allowing several transmissions during one contact time (e.g. 60 s). This allows to send e.g. two different 32 byte-data-packets (coded with an address in the data to differentiate the packets) during one contact. But in general it is safer to use more addresses to transmit packages containing more than 32 bytes because the transfer of the PTT-ID has a higher reliability than the data.

2.3 Transmission

The analogue sensor signals are digitalized, averaged over 15 minutes, processed (see below) and then sent to the send-buffer of the transmitter. The transmitter sends the content of the buffer, independent of the measuring time, every 30 to 40 seconds. When the measuring-time is over, the new measured data will replace the oldest measuring data sets. The satellite data is transferred via ftp from the ground station in São Jose dos Campos to the server of the PV-Labs at UFRJ in Rio, and is published from there worldwide via WWW (see Fig. 3). The system permits 12 to 14 satellite contacts per day, at the transmission rate of 32 Bytes per contact.

2.4 Processing

The poor data-transmission of 32 Bytes every 100 minutes (in average) can be overcome by using more than one transmission-channel (Multi-ID) and by using smart data pre-processing (e.g. nonlinear ADC-characteristics) extracting the information needed to supervise a PV system in terms of yield, usage, and battery state. Fig. 3 to Fig. 5 show schemes of the configuration using a multiplexer for the selection of a signal and a micro controller for processing. The nonlinear conversion characteristics means that the more relevant range of the values are coded with a relatively high resolution, while other parts a coded with less resolution. E.g. in the case of the battery voltage, the value range between 11 V and 15 V is the most relevant, while the ranges < 11 V and > 15 V are less relevant, so the resolution of the analog to digital coding can be reduced for operation points farer away from standard. Also the battery voltage does not change very fast, so a lower temporal resolution can be used. Other values, such as the load current can change very fast, requiring a higher temporal resolution to avoid loosing accuracy carrying out an energy analysis.

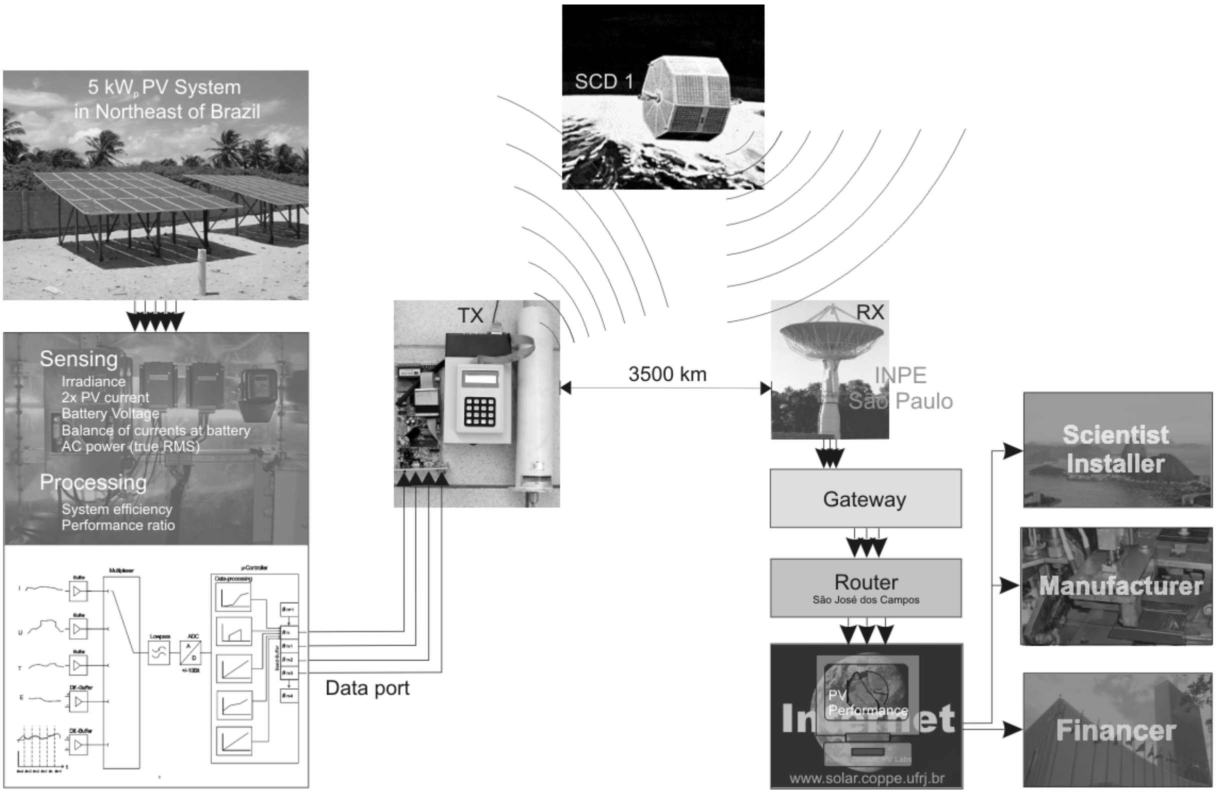

Figure 3. Scheme of PV Satellite Monitoring System: Uplink with data acquisition, Satellite-Data-Collection System ARGOS-SCD, Downlink with SCD, ground station, WWW publication.

2.5 Specifications

<u>Satellite-Transmitter</u>
Argos-PTTULT-01, 2 Watt, max. 4 addresses

<u>Analog input</u>
6 differential, 3 single-ended inputs

Voltage Range:	max. +/- 12V
Resolution 1:	max.10Bit/70µs or +/-9Bit each channel
Resolution 2:	max. 17 bit/133ms per channel

1 isolated, single ended, +/- 12Volt

<u>Digital input</u>
2 positive polarities, 2 inverted polarity

Range:	up to 220 V AC/DC
Isolation:	500 V AC
<u>Supply</u>	18 to 36 V DC
Consumption:	max. 3 Watts

2.6 Device Description

The device is designed to facilitate monitoring of different kind of renewable energy systems. It consists of a micro-controller including an EEPROM, an integrated A-D-converter, and an extra high resolution A-D-converter. It is be configured by a serial port and provides several analog inputs. All analog inputs pass the input-multiplexer before being conditioned by the differential amplifier and a low-pass-filter (see Figure 4). Therefore just one amplifier and one filter is necessary - the adjustment for each input is carried out by software. The main A-D-converter is a quad-slope high-resolution A-D-converter (17 bit plus sign), so for the maximum resolution used (11 bit) it is not necessary is to adapt each channel for the demanded input-range by additional hardware (e.g. potentiometer) - if they do not exceed the maximum input of 12 V. The integrated A-D-converter has just a 10 bit resolution and assists the main-converter for fast sampling demands (e.g. AC measurements); also it is for redundancy and to control the power supply of the device. The controller manages the measurements and controls the transmitter: during a sending period the measurements have to be interrupted. The micro-controller handles all analog inputs and also serves to combine measurements e.g. to determine power ($P=I \cdot U$).

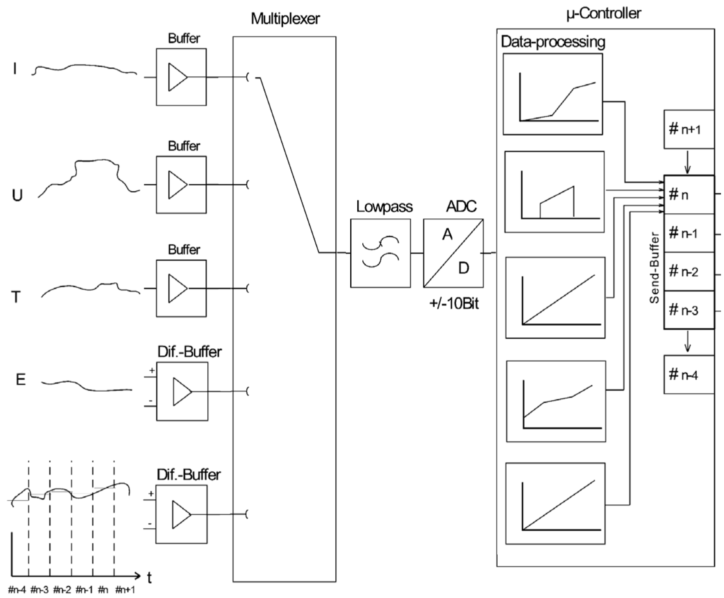

Figure 4. Schematic of sensing and processing unit.

3. PROJECT SITE

The first project using the satellite monitoring system is a 5 kW_p PV-System in Baleia (Federal State of Ceará), in the North of Brazil. The system feeds a ice producing unit to cool fish and is working completely autonomous. It consists of two PV panels (2.5 kW_p each, see Figure 5), two charge controllers (24 V, 50 A each), a 24 V battery system, and a DC-AC inverter (5 kW nominal).

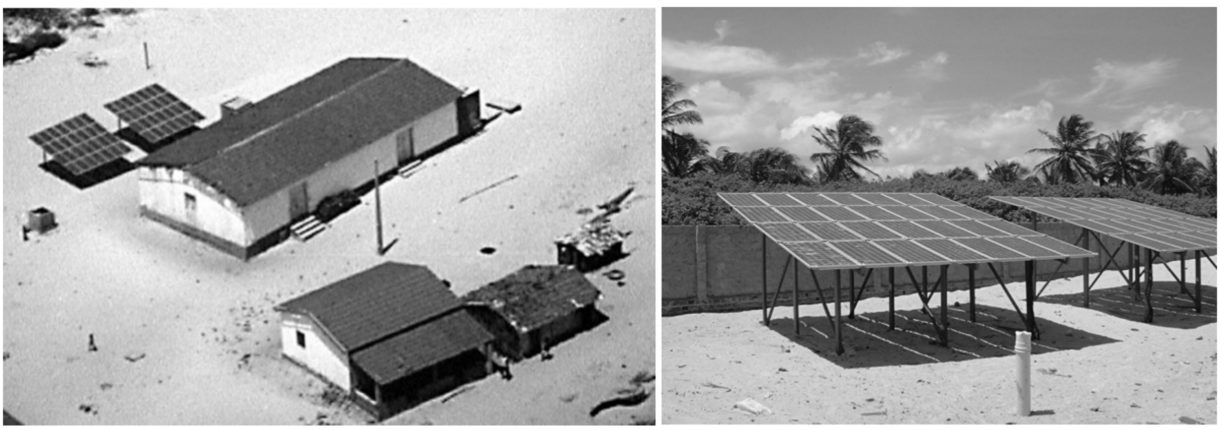

Figure 5. Photos of project site: PV generator with house containing ice makers for fish conservation.

The data ranges for measurements at this project are:

Irradiance:	0 - 1200 W/m^2	Battery voltage:	20 -30 V
PV power panel 1:	0 - 2.4 kW (30 V, 80 A)	Battery power:	0 - 9 kW (30 V, 300 A)
PV power panel 2:	0 - 2.4 kW (30 V, 80 A)	Inverter output:	0 – 12.5 kW (250V_{AC}, 50A_{rms})

The resolutions of the measurements are set to 8 and 10 bits, the transmitted temporal resolution used is 15 minutes, requiring two ARGOS transmitter addresses simultaneously.

4. COST COMPARISON

Initial costs for the transmitter (ca. 1,000 €) and the pre-processing unit (ca. 500 €) are already compensated after two years of usage by the saving of travel expenses for the yearly supervision of the systems. Table 1 is giving a cost comparison between the conventional approach via a data logger and satellite monitoring. Cost savings over lifetime are more than 10,000 €.

Table 1. Cost comparison of conventional monitoring (data logger) with satellite monitoring over a period of 20 years for a remote PV system in Brazil (without development costs).

Type of cost	Conventional Data logger	Satellite monitoring
Equipment	1* 1,000 €	1*1,500 €
Transportation	20* 500 €	1* 500 €
Personnel	20* 50 €	1* 200 €
Accommodation	20* 50 €	1* 150 €
Total costs	**13 000 €**	**2 350 €**

Data transmission costs do not occur for a limited number of systems to be monitored, due to an agreement between INPE and UFRJ. While the investment for the equipment is considerable, it is – aside from the scientific concern - more recommendable for bigger systems or for micro grids. A further application of the system is the energy metering and billing.

5. CONCLUSION

Monitoring renewable energy systems in remote areas is essential in order to guarantee reliable operation. A lack of infrastructure in these remote areas does not allow telephone or radio transmission of measured data. Periodic visits of the power plants or SHS are prohibitively expensive as in many cases even not practicable.

Transmission of data of remote PV systems via satellite is a feasible and efficient way to monitor renewable energy systems. The introduced system has a sufficient transfer rate to allow hourly monitoring. Recognizing failures early saves money and improves reliability and reputation of renewable energy power supply. Manufacturers can use the data to improve their products by adapting them to real operating conditions. Sponsors (NGOs, World Bank, national foundations, public etc.) have an immediate access to the projects (“*Where did my money go?”*), which creates more confidence in the carrying out of projects. Also, the online satellite monitoring system helps to attract more public interest in the PV area by promoting its usefulness via the WWW.

ACKNOWLEDGMENTS

The authors are expressing their sincere thanks for the support from INPE, Brazil and Würth Solar Ltd., Germany.