Photovoltaic Powered Data Acquisition Systems in Semi-Arid Areas

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Abstract

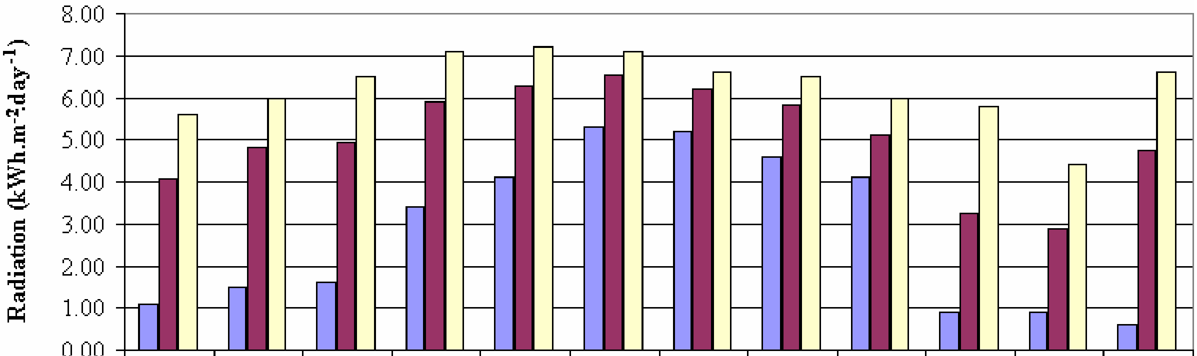
Continual progress of development in the photovoltaic (PV) field has in the last years reached a stage making decentralised utilisation of solar energy technically and economically feasible. This is true mainly in the state of Ceará, Brazil, with a yearly average temperature of 28 ºC and a yearly solar potential of about 2,000 kWh/m^2. The present project has as main goal the development of a PV powered data acquisition system adapted for the semi-arid conditions of the Brazilian Northeast region. Data acquisition systems (DAS) for agricultural and environmental monitoring very often are placed on remote sites, where eletric power grid is not present, and if the parameter being monitored requires a very high sampling rate, even bateries do not provide a reliable energy supply. Thus the need for PV power supplies.

Keywords: Stand-alone PV system – 1; Humidity sensors – 2; Rural data acquisition – 3.

1. Introduction

Due to necessity of innovating development in the agriculture with the goal of improving the production in quality and amount, it is necessary to monitorate the metereological and geological aspects. Therefore, technologies to determinate the variables that influence the production are in high demand. As an example, the water quantity required in each irrigation and the moment of this application are governed by the climatic local conditions.

Due to the climatic characteristics, the use of PV systems has great potential to supply the crescent electric power demand of the Northeast region in Brazil. The state of Ceará, for instance, it is characterized by irradiance up to 2,800 hours/year and a daily average value for the solar irradiation on a horizontal surface of circa 5,4 kWh/m^2/day. Due to the proximity of Ecuador, this solar potential is available every month of the year, being despicable the climatic changes caused by the seasons.
As it is show in the Figure 1, the data collected in Fortaleza, Ceará, show the constant solar irradiation, reafirming that the semi-arid Area of Brazil is a good location to implement those Data Acquisition Systems.



	apr/03	may/03	jun/03	jul/03	aug/03	sep/03	oct/03	nov/03	dec/03	jan/04	feb/04	mar/04
Minimum	1.10	1.50	1.60	3.40	4.10	5.30	5.20	4.60	4.10	0.90	0.90	0.60
Average	4.07	4.84	4.95	5.92	6.28	6.56	6.22	5.84	5.13	3.25	2.87	4.73
Maximum	5.60	6.00	6.50	7.10	7.20	7.10	6.60	6.50	6.00	5.80	4.40	6.60

Figure 1 – Solar Radiation in Fortaleza/CE.

The continuous development of the photovoltaic technology has reached in the last years a status that has made possible the use of the technology through decentralized facilities. This viability is translated so much in technical terms as economical. A system fed by photovoltaics panels eliminate the costs with the grid connection, since the data acquisition is made in remote places of the semi-arid area of Brazil. The implementation of a such low cost robust system would be viable for the reality of this area.

The automation of systems of data acquisition for agricultural purposes and other applications is still incipient in Brazil. Using microprocessing techniques, microelectronics and sensors it is possible to revert this picture and to search instrumentation alternatives pursuing the involved data control, acquisition, transference and storage in the measurements.

2. System Description

The DAS used in the project monitors data from soil moisture and temperature sensors. Soil moisture is the basic parameter to conduct the water balance in the soil-plant system, and to establish the irrigation scheduling in irrigated areas, as well as the planting date for rain fed areas. It is also essential to monitor the transport of water and, indirectly, contaminants into the soil profile. Temperature sensors are being used to monitor air temperature around the DAS and remove any distortion caused by temperature changes on the response on the DAS and on the moisture sensor. The sensor system was previously developed by Coelho (2003) and uses a differential pressure sensor, as a tensiometer sensor to obtain the soil matric potential that, in conjunction with the soil-water retention curve will provide the actual soil moisture content. The system is being validated in a remote grazing field located in Pentecoste, state of Ceará, in an area characterized by limited water supply and semi-arid climate.

The system consists basically on: soil humidity and moisture sensors, photovoltaic (PV) array, battery bank, charges controller, sensor-DAS interface system, voltage-current signal converter and a Datalogger.
Basically the system works this way: the sensors collect the soil data and send it in analogic format, the voltage-current converter turns the voltage signal to a current signal and then sends to the interface system responsible to the analogic-digital conversion, finally the data

reaches the datalogger where is stored and analysed. The DAS system is fed mainly by the battery bank which is fed by the PV array. The charge controller connects the array to the batteries and these to the load, monitoring the energy supply.

2.1. System Feeding

The PV array would be sufficient if the necessity of nocturn data collection were not necessary. The DAS requires a battery bank to maintain the procedures at night. In addition to the nocturn advantage, the use of batteries minimizes the problems caused due to the potency variation supplied by the PV array. The battery bank is the main economic factor in a stand-alone PV system (e.g. Markvart et al., 2001). The system is being implemented aiming the maximun battery lifetime which reduces the maintenance costs. The lead-acid type is the most common battery used in PV systems. Despite of the good performance shown in direct connect with PV arrays, the floating potency caused by the variation of solar irradiation causes problems for the battery (e.g. Potteau, 2001). In addition to this problem, several days with low solar irradiation would force the battery to operate in low state-of-charge (SOC), sulfating the electrolyte present in the batteries, diminishing, also, their lifetime. The charge controller acting in the battery bank prevents those problems and in a full SOC, the controller disconnects the battery to the load and feeds the load with the PV energy.

2.2. Charge Controller

The PV stand-alone system operation depends not only on the individual quality of the component elements, but also of the interaction between them. In this way, the charge controller achieves an important role. The charge controller focus mainly in the batteries bank protection (constituted by lead-acid batteries). The energy generated in the PV array feeds the batteries bank which feeds the load. The charge controller acts in both actions by preventing an overcharging on the batteries due to an excessive voltage provided by the array and avoids a battery overdischarging caused by long feeding of the load and low solar irradiation for extended times.

The charge controller operation is based, mainly, on the SOC of the batteries. The overcharging and overdischarging can be prevented if the battery SOC is known. Determining the actual SOC in a certain time is the most difficult assignment of the controller. The most common strategy uses the battery voltage, depending on the SOC, the voltage on the battery terminals variates, from a lower value in high discharge state, to a higher value which indicates full SOC. Although that is a very used method, there are several variables that reduces the SOC determination precision like, for example, the temperature (for a single battery cell, a 10°C variation causes a 0,3 volts change on the cell terminal). This variation correspondes to 20% of the total voltage value. Due to the climate of the semi-arid area of Brazil, the temperature variation is a important variable to considerate, so a termical compensator is necessary in the charge controller.

Once the battery's voltage strategy is chosen, there is the control characteristics to analyse. The control is based on four adjustable set points: the end of charging point (in full SOC), restart of charging, end of loading (in low SOC) and restart of loading. Each set point is based on the battery characteristics and the points should be chose in a way to prevent problems such a repetitive cycling. When the battery reaches a full SOC, the controller disconnects the PV array to the bank, causing a 10% to 15% reduction of the battery's voltage, a careless choice of restart of charging would reconnect the battery as soon as it was disconnected, causing an endless cycle.

In the present study, a charge controller is to be developed and implemented in the DAS, but, for testing purposes and technical information, a controller available in market (solar charge controller model C30A) is used as reference (e.g. Trace Engineering Company, 1992). This is a simple controller designed without semiconductors resulting in minimal voltage losses, eletrostatic discharge protection, an operating mode LED indicator and some other features.

2.3. Data Acquisition

The present study aims, in a first phase, collection of soil humidity data. These data are fundamental to any agricultural culture. Manipulating and interpretating of those data brings a great improvement in the production, with this tool in hand, is possible to determine the best way to cultivate and to automatize the production. To make these possibilities real, the data required pass for a process that begins with the collection and ends with the storage in the Datalogger.

2.4 Sensors

The humidity sensors utilized in this Project determine the soil amount of water utilizing the tension method (e.g. Coelho, 2003). This sensor type has a porous membrane filled with water. The functioning principle is based in the balance between the soil water and the sensor water. The balance occurs when the porous capsule reaches contact with the soil. In beginning, the water inside the sensor is under atmosferic pressure. If the soil water is under tension, it creates a suction that takes water from the porous capsule, reducing the internal pressure of the sensor. The instrument is sealed, so a vaccum is created inside the sensor. The negative pressure reading shows the soil water potencial.

Although this method is a confiable one, there are some factors that reduces the sensor precision like the temperature, for an example. The temperature variation ocasionates problems that results in misreadings of the pressure due to the equipment and fluid dilatation.

2.5 Signal processing

The interface system is responsible for the analogical-digital conversion of the signals sent by the sensors, besides the processing and storage of the humidity sensorials data. In a first moment, the study are focused in the use of TD40 as the interface system. It has the following specifications:

Measuring 4.8 by 3.4 by 0.5 inches, the 40 MHz TinyDrive (TD40) offers a complete C/C++programmable computer system with a 16-bit, high performance CPU (Am188ES, AMD), operating at 40 MHz system clock with zero-wait-state. The TD40 supports 35 high-voltage I/O lines, 24 TTL bidirectional I/O pins, 11 channels of 12-bit ADC, two channels of 12-bit DAC, three channels RS-232/RS485, a real-time clock, battery backup, watchdog timer, PWM, three timer/counters, a 512-byte serial EEPROM, up to 512KB SRAM, and up to 512KB ROM/Flash.

The system has a serial input. This way, dipositives (laptops or others) can be connected to download the stored data in the internal memory of the board. The sensors send to the interface system an analogic signal of voltage. For instance of grand distances, there is losses caused by the resistance present in the wires. A voltage-current conversor is present between the sensor and the analogic-digital conversor, diminishing those losses and making the data more confiable.

The XTR106 is a component used in the system that converts the analogic signal sent by humidity sensors reducing the losses caused by the distances between the sensors and the storage system. The XTR106 is a voltage-current conversor that transmits currents from 4 up to 20 mA. It receives a 0-5V voltage signal and converts to a 4-20mA making the losses caused by the wires resistances or external noises do not disturb the signal. The component is supplied by a 0-40V source (solar panel and bank of batteries). The component circuit is shown in Figure 2.

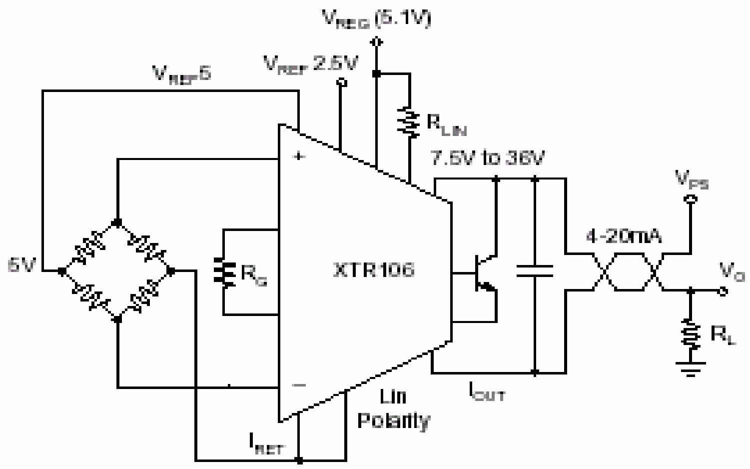


Figure 2 – XTR106 schematics.

3. Conclusion

The implementation of the DAS is still in progress. The strategys and equipments are still being chosen aiming the minimum maintenance cost. In this first phase, the tests executed show the viability of the project in the agriculture of semi-arid area of Brazil. The data collected contribute to a better culture management. In future phases, the system will have sensors collecting a series of geological and metereological data, like air and soil temperature, air humidity, wind speed.

The charge controller showed goods results in tests. Knowing that the controller is a important component to protect the batteries and that the bank has a major importance in the economic factor of the system, the next phase is to implement a controller designed specifically to this system in question. The data system is being tested and analysed. Future analysis of data collected, specially the temperature data, will allow to use the information to reduce the losses in the sensors and in the charge control benefiting the entire system.

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