TOOLS FOR DESIGN AND EVALUATION OF PHOTOVOLTAIC SYSTEMS

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ABSTRACT

This work describes two tools developed to design and evaluates of photovoltaic installations. They were developed as an agreement between our Institute and the public power utility (UTE) in order to make rural electrification in areas far from the network using alternative power.
In order to design this kind of installations here we describe the simulation software P_SOLAR developed by the Electrical Department. The mentioned program is an energy simulator by which it is possible to define different stages in a friendly way. This tool is useful to evaluate the future system performance, giving, as a result, indicators as the service quality.
In order to evaluate these kinds of installations it is described a data acquisition system development of low cost and consumption, which allow to measure the principal parameters in a hybrid installation.
The data obtained with each of these tools are showed and compared.

INTRODUCTION

The public power utility decided to supply electrification to schools, rural clinics and police stations placed in rural areas far from electric net. For that reason they subscribed an agreement with the Engineering Faculty for system design and specification (IIE, 1994). Nowadays there have been made this kind of installations in more than 30 rural schools, and it is foreseen to continue with the photovoltaic or wind systems installation (or the combination of both) according to each user demand characteristic.
As a help tool for the design of these systems, the Electric Department decided to develop an energy simulator called SIMENERG, that permits to foresee the system behavior. P_SOLAR is a software pack that, from the SIMENERG permits to simulate many years of a hybrid system operation.
In order to make a supervision of these installations it was decided to incorporate in some of them data acquisition equipment. In the market we have much acquisition equipment, almost none of them fulfills the requirement of being a very low consumption equipment (less than 1 Watt), indispensable characteristic according to the power supply nature. Taking into account what we mentioned above, and valuing the fact of having an equipment custom made of the system needs, it was decided that Electrical Department design and makes the mentioned equipment.

ENERGY SIMULATOR: P_SOLAR

The Simenerg Software Tool

Simenerg (R. Chaer, 1991) is a set of software tools specially designed to help the evaluation and the design of autonomous electricity systems.

Having a system to study, Simenerg allows the easy building of an efficient simulator for it. One can evaluate the service quality and others' aspects of the system by simulating many years of its life. Also by leaving free some of the design parameters and choosing a cost function one can carry out an optimization on the unconstrained parameters, to minimize the cost function guaranteeing a giving energy availability of the system with a given confidence.
Simenerg is an open set of tools, so ones the user has understood its general philosophy, he can modify and add more refined tools without limit.

P_Solar Description

The P_SOLAR software package is a specific implementation of a hybrid system simulator with power coming from wind and sun, made with Simenerg tools.
The principal menu allows to manage different layouts, permitting to save or read them from files or create and save a new one. Once the layout is selected it is only necessary to decide the amount years or period of time to simulate and then go on to the simulation itself. For this kind of systems it has been chosen a fixed simulation step of one hour.

Data input: layout. The software allows to assemble the hybrid system selecting components and their corresponding function parameters in a very easy way. The elements to select are: wind resource, solar resource, windturbine, photovoltaic panels, batteries and consumption.

Wind resource. It selects a file with the wind data in the selected place. In that file we have hourly mean wind speed at 10m high.

Solar resource In this case we have different ways to define this resource entry. The most basic case is to have the information about daily accumulated irradiation for each simulation day. In order to be able to make small simulation steps we have a method to obtain the hour distribution based upon the historic information of the area. Then, to obtain the energy in the inclined panel plane it is necessary to make the corresponding transformation, for which different methods are used, as Liu-Jordan, Pérez (IIE, 1994). These methods use the same historic information of the pace to have the hour distribution in the inclined plane.
In most general case, when it is necessary to simulate many years and have in that way statistic system information it has been developed a continuous solar irradiation source based upon the information of 8 years recorded in a certain place in the country, which is modulated by the meteorological data for all the country. In all these cases it is used the transformed mentioned above to convert to the inclined panel plane.

Windturbine. It allows to select a file with the speed-power curve at a certain height of different windturbine. To obtain the generator power, the wind data are corrected by the speed-up coefficient of the place and by the height of the tower.

Photovoltaic panels. In this case it is selected the quantity of units with a determined generating peak power. It is also determined the tilt angle of the panel with respect to the horizontal.

Accumulators. The battery model adopted considers the battery as an energy reserve in which it gives energy only limited by its discharge current, then it admits energy with a charge efficiency and limited by the maximum recharging current. They are also capacity corrections with the temperature. The cycled battery factory data are used to estimate the battery life, and then it's recharging period. The software asks for the maximum discharge depth allowed during the simulation in order not to exceed that limit.

Energy consumption. The energy demand of the system (the consumer) is being introduced by the daily demand profile hour per hour, which is affected by the monthly stationary coefficients that are necessary to supply as input data. The software allows to save or recover the demand data to use them in different simulations.

Simulation Results

During P_Solar run it can be seen on the screen the battery charge state and its evolution hour per hour. It is also shown how are the energy deficit and excess histograms' evolution. The final screen is shown in Fig 1. In the left lower extreme it can be seen the cycled histogram at which the battery was submitted during the simulation.

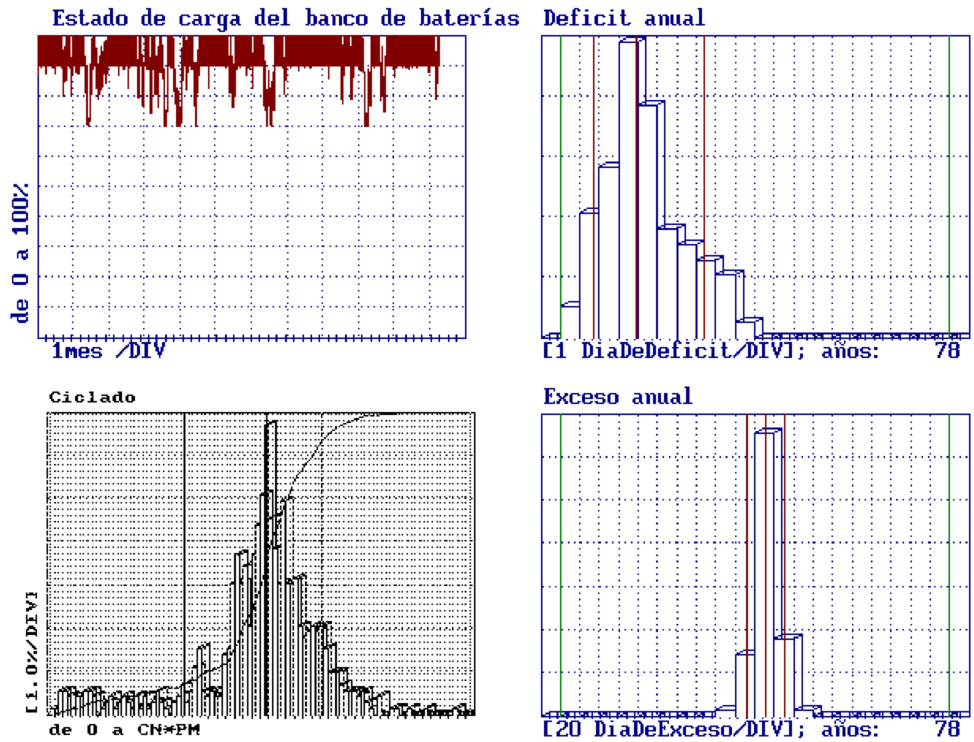

Figure 1. P_Solar screen output

Finally the following information is saved in a file:

Excess. Medium value: 290.00 [Days]
Excess 90% : 298.00 [Days]
Battery Annual degradation: 0.0067 [p.u.]
Battery life [u]: 6.92 [years]

Deficit 10% : 0.10 [Days]
Deficit mean value: 0.50 [Days]
Deficit 90% : 0.90 [Days]
Excess 10% : 282.00 [Days]

Battery cycling histogram [AH,weight]

DATA ACQUISITION SYSTEM: ADQ_SOLAR

The data acquisition system was designed to be installed in a housing or in a farm in which the only electric energy sources are photovoltaic panels or wind generator. The general basic installation layout, as well as the ADQ_Solar connections are shown in Fig 2.

The equipment built was configured to acquire the following magnitudes: 4 currents (2 from the photovoltaic system and 2 from the windturbine), battery bank voltage, solar radiation (piranometer), 2 temperatures (PV and environmental) and wind speed (anemometer).

Shunts' S1 to S4 are to measure currents I1 to I4 respectively, from these currents and voltage V1, the user power consumption is obtained, as well as the power supplied by the PV and the wind-generator to the battery bank.

The solar radiation measurement is made with a piranometer, which would be places near the photovoltaic panels.

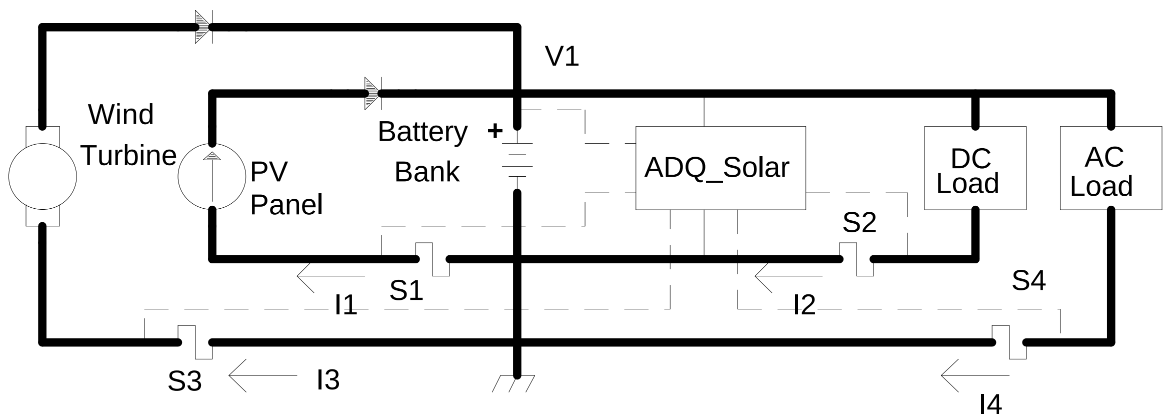

Figure 2. General layout

The temperature sensors and the piranometer give a voltage proportional to the magnitude to measure. The wind speed is taken by an anemometer with frequency output, this is the only digital input to the data acquisition system.

Using the recorder measures it is possible to do an energy balance of the system, and then deduct its real efficiency. It can also be obtained the demand curve of the user.
As it can be seen in Fig. 3 the acquisition system is fed directly from the battery bank, being its only power supply.

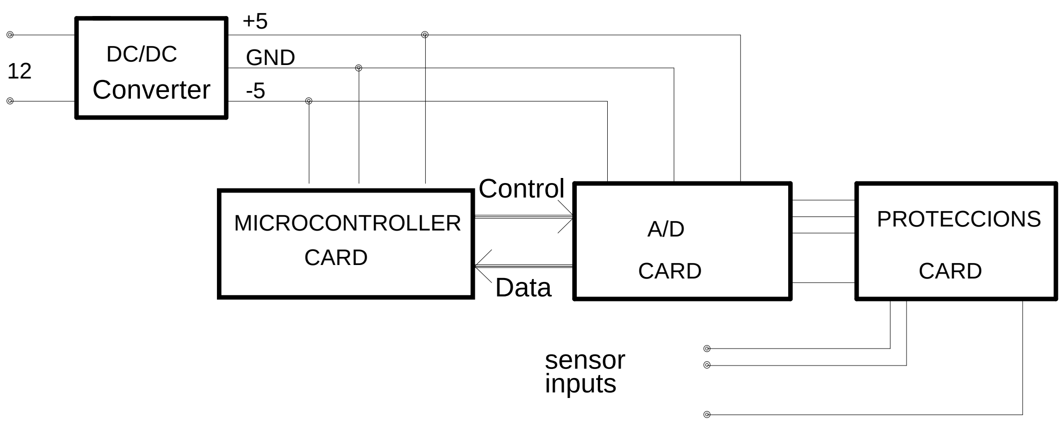

Figure 3. ADQ_SOLAR layout

Each of the analog signals mentioned is acquired once per minute, each hour the average is storaged. So the final data are the hour average of the mentioned magnitudes.
In the case of wind speed measurement the pulses sent from the amemometer are counted in a continuously way during the first 10 minutes of each hour.
The equipment has an "autonomy in memory" higher than a month and a half. In order to collect the data in the acquisition system memory it is necessary to go to the system installation place with a compatible IBM computer with an RS232 interface and the specific communication software. By this software the operator will be able to collect, in a friendly way, the storaged data.
It is important to remark that the equipment is absolutely flexible, as much in the kind of signals to get as well as in its storing format and the way of averaging the data.

Data acquisition system costs

The ADQ_Solar net cost (including box, temperature sensors and shunts) was USD 500, a piranometer USD 1,500 and USD 300 an anemometer. The design and construction of a prototype take about 400 Engineer hours and 400 hours of a Technician.

RESULTS COMPARISON

In order to compare the simulated results and the measured data we use a real system.

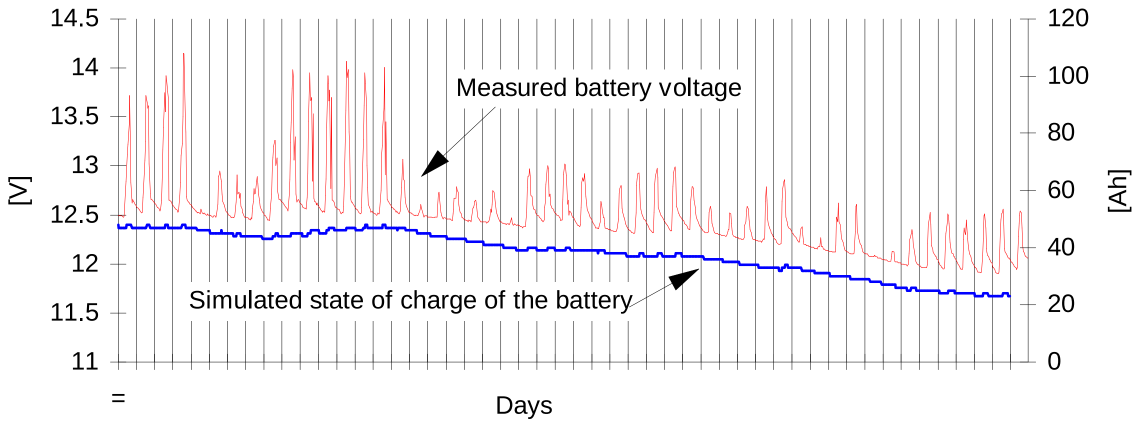

Figure 4. 50 days measured voltage value and simulated battery state of charge.

In Fig. 4 it can be seen the battery voltage measured and the battery state of charge situation obtained from the simulation of the system. The solar irradiation data used in this case were the daily irradiation accumulated during the 50 days of the simulation and it's shown in Fig. 5.

If we assume that the voltage during the night is proportional with the battery state of charge the results arrived are good enough for partial validation of the methodology.

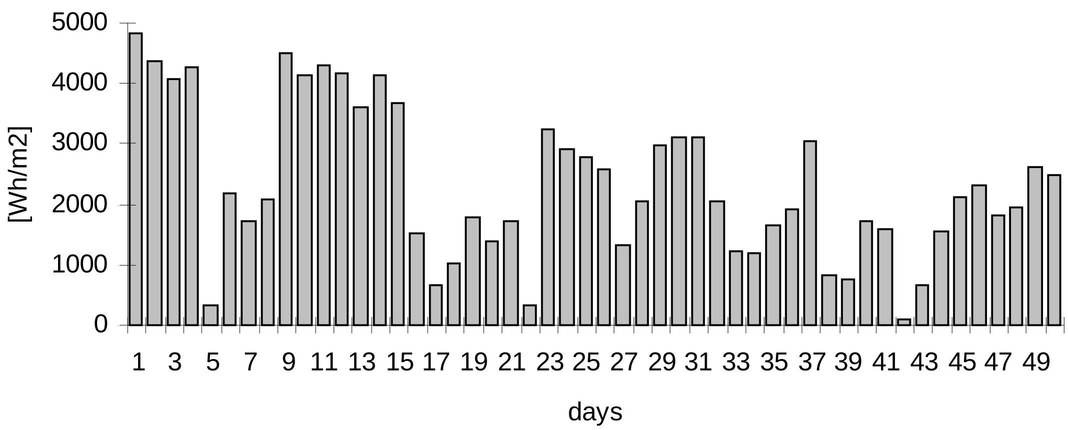

Figure 5. 50 days measured global irradiation used as simulates input.

CONCLUSIONS

Both tools were developed at the Electrical Department, so we have acquired the knowledge and the ability to adapt them to our needs.

The next task with ADQ_Solar is the development of remote data transfer, avoiding the hard work to visit the systems to collect data.

Is important to note that in the example shown in this paper we know all the data of the real system, so we can make absolute predictions of the behavior of the system. The results obtained from using P_Solar to design a new system are very useful to made relative comparisons. In case of demanded absolute predictions with certain accuracy, is very important to know exactly the system operating conditions (radiation, wind speed, consumption) and the characteristics of the components (battery, PV panels, windturbines, regulators, loads).

This is not usually so when a system is planned, but the help giving by systems like ADQ_Solar allows to have better predictions.

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