THE PIERRE AUGER PROJECT AS A MACRO-GRID OF STAND-ALONE PHOTOVOLTAIC SYSTEMS

ÁNGELES LÓPEZ AGÜERA, IAGO RODRÍGUEZ CABO
Departamento de Física de Partículas & Instituto Galego de Altas Enerxías, Universidade de Santiago de Compostela, E-15702, Santiago de Compostela, ESPAÑA

Abstract: The Pierre Auger Observatory, PAO, has been created to detect highly energetic cosmic rays, with a macro-grid of stand-alone photovoltaic systems (PS) as a power source system. The control of this system is essential for the proper performance of the detector. The Observatory's grid offers the largest source of statistics for stand-alone PS, creating the possibility of performing unprecedented research in this field. In this article we will present some of the results obtained in this field.

1 Introduction

The Pierre Auger Observatory may be considered one of the most ambitious high-energy cosmic ray detection projects, hoping to describe the energy spectrum around and beyond the cut-off of Greisen-Zatsepin-Kuzmin, GZK [1]. The experimental setup required the construction of two giant detector grids, one located in the northern hemisphere and another in the southern hemisphere, in order to reach a large part of the celestial space. The grids in the southern hemisphere, in an advanced stage of construction, are located in the Argentinean region of Mendoza, and will be completely operational by the end of 2006. They will cover a total area of 3000 Km^2 with a hexagonal matrix of 1600 Čerenkov water placed at intervals of about 1.5 Km (surface detectors). The detection is performed by means of the characterization of the energy and the arrival time of the secondary particles of the atmospheric cascades, with these parameters one can reconstruct the primary cosmic ray. The detection is also performed with four fluorescence detectors that examine the atmosphere over the tanks, collecting the fluorescence light produced by the cascade while passing through the atmosphere and using it to reconstruct the primary. The combination of both, Čerenkov and fluorescence techniques, improves the precision of the final measurements. The lifespan for data taking is 20 years.

Each Čerenkov tank uses 12 tons of water bacteria-free as its sensitive material. With the aim of eliminating redundancy, the produced signal is received by three photomultipliers placed symmetrically on the upper part of the tank. Due to its "isolated" geographical location, each of the 1600 tank surface detectors are on a stand-alone system with its associate reading and acquisition electronics applications, and thus, its own photovoltaic power systems.

Overall, the photovoltaic systems (PS) have been designed as a grid of 1600 stand-alone PSs of 100 W each. Each of the systems includes two photovoltaic modules (Isofoton W53) in series, two 105 Ah batteries connected in series (Clean Moura, Pb-acid) and a MPW regulator (Mode Pulse Width, Morning Star Sunsaver 10) which ensures the stable charging and discharging process of the battery.

The PS is fundamental for the proper performance of the Pierre Auger Observatory, since the failures in this system translate into data acquisition losses, which may be serious while capturing interesting events. Therefore, it is of the utmost importance to maintain a precise control of the PS. In this article we glance at some of the first research results on the PS of the Pierre Auger Project, specifically at those regarding the preliminary proposals for the Quality and Ageing Control of the system.

Finally, while scientific aims of the Pierre Auger detector go much beyond the mere technical aspects, a study of its power system constitutes a unique experimental setup in the realm of Solar Energy because of the number of monitored stations, being the largest ever projected source of statistics referring to the stand-alone photovoltaic systems.

2 Quality Control of the PS

As it is already well known, a Quality Test consists of a series of procedures that ensure the proper performance, or quality, of each of the components, in this case the photovoltaic system. One of the largest advantages of the Pierre Auger PS is its statistics. This allows for the defining of performance standards criteria without the need for modeled simulations of the PS [2, 3].

For the PS of the Pierre Auger Project, a three stage control is proposed: previous to installation; once installed; and for the detection and identification of the possible anomalies during normal performance.

The first of these consists in a check-up procedure of the different basic parts that make up the system: photovoltaic modules, batteries and charge regulators. The second stage checks the preliminary uniformity of the performance of these parts, once installed. Finally, the third stage consists in establishing the systematic method of detecting and identifying the anomalies that may appear in the PS, mainly with its batteries, since they are the weakest part of the system. This last stage is of utmost importance from the experimental point of view, due to the singular characteristics of the Pierre Auger Observatory (large extension, difficult access, etc.), with 20 years of expected performance during which the batteries must be changed at least 4 times. Our aim is to detect and understand the different types of anomalies that may appear and decide the necessary measures to adopt in order to ensure the proper performance of the system. The proposed method for detecting and identifying the anomalies consist in the use of the Voltage Function of the batteries, specifically with its probability distribution. This variable is sensitive not only to the presence of the most common anomalies in the system's accumulation, but also to any other in the PV system.

Figure 1 shows the standard voltage distribution of a battery. Here we can see the five basic regions of the regular battery performance:a deep charge regionbelow 11.8V, a discharge region between 12 and 13V,a charge-discharge region below 13.5V, a regulation region above 13.5V and the overcharge region above 15V. The first and last areas correspond to performance voltages that should not be reached in normal working conditions. Among the possible causes of PS performances at anomalous regimes are either working failures or accelerated anomalous ageing.

For batteries, the most frequent anomalies take place during performance and are: deep discharges, overcharges and regulation problems. The first is associated with an excess of sulfate in the terminals and an accelerated loss of capacity (and even irreversible); the second case is originated by elevated amounts of corrosion; and the last is due to stratification of the battery's electrolyte.

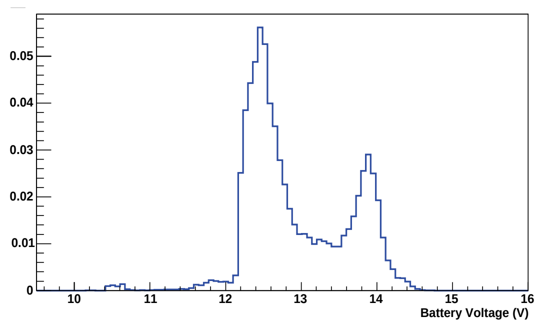

Figure 1: Generic Voltage Distribution Function of a battery.

For example, in Figure 2 we see the probability of performance in a deep discharge regime. In Figure 2b) we can see the Voltage Distribution Function of the batteries, showing one stage with an anomalous performance (see the red square in Figure 2a)). Notice how it presents a noticeable proportion of values (area) below 11.8V in one of its batteries. The decision of whether or not one station is a candidate for presenting an anomaly may be established by checking the range of statistical tolerance of the total sample.

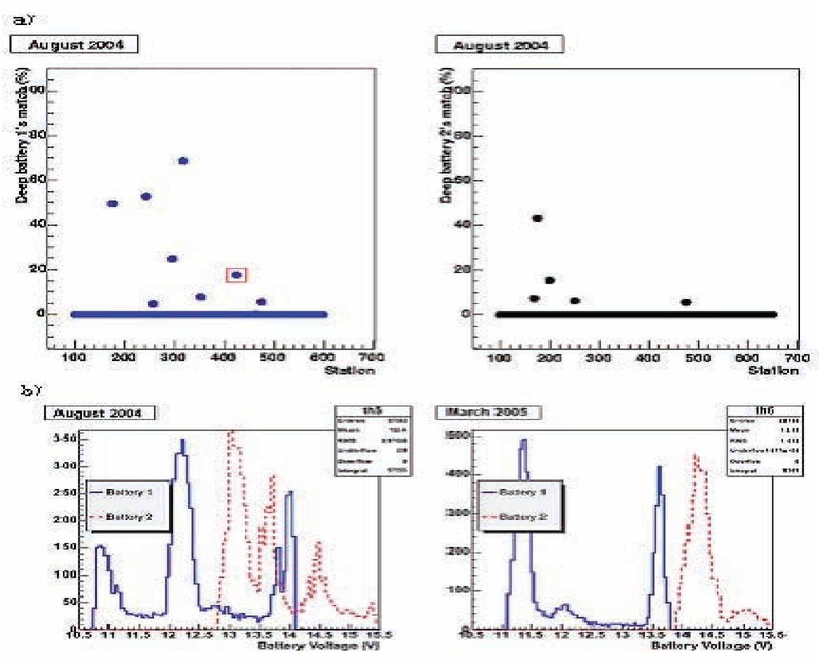

Figure 2: a) For each station (X-axis, station number) the probability of battery performance in the deep discharge region (less than 11.8V) in August, 2004. In red we can see station 425. b) Voltage distribution for the batteries at station 425 on August, 2004.

3 Ageing

The battery's ageing process is much faster than that of the other components of the PV system. Moreover, its degradation may remain unperceived for a long period of time, therefore foreseeing its remaining lifespan is very important for the PV.

The preliminary method for evaluating a battery's state of ageing [5] is inspired from the original idea presented in [4]. Whatever the type of evolution the battery is having, (standard or anomalous), the passage of time creates a gradual loss of capacity or expected lifespan, intrinsically accompanied by an overall increase in internal resistance (see Figure 4a). This increase in resistance corresponds, in theory, to a faster discharge of the battery.

The method is based on the fact that the ageing is related with the expansion and slight retraction of the distribution in the discharge region (the first peak in Figure 1). In other words, the expected variations of the shape of the battery's voltage distribution. Naturally, we measure the ageing effect by fitting a RMSE between the voltage distribution of discharge of the battery with respect to itself in equivalent previous months, having corrected the effects of temperature and irradiation. The final results are independents of modelling. In fact, this method has already been preliminarily verified with the data, and the existence of batteries in advanced stage of ageing has already been detected at the Pierre Auger Observatory. For these batteries, the lifespan is 50 percent less than that stated by the manufacturer.

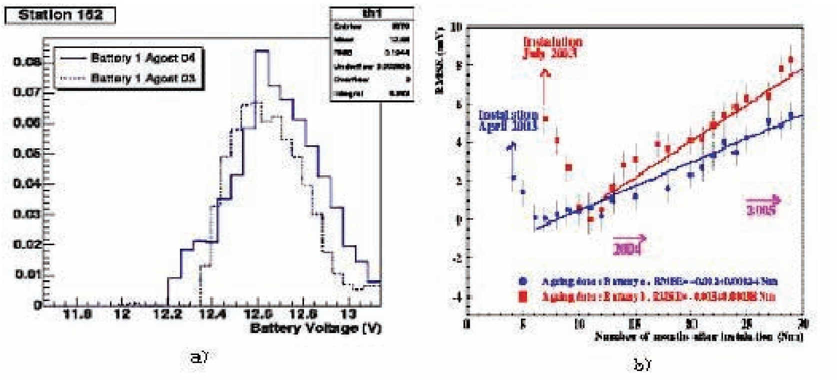

Figure 3: a) Voltage distribution of discharge of a battery at station 152 in August, 2003 (continuous line) and 2004, dashed line; b) Temporal distribution of RMSE for a standard station (station 152) and an anomalous station (146).

Figure 3 shows two types of observed evolutions in the experiment: standard and anomalous.

Notice the substantial difference in the ageing process between both batteries (one of them is probably suffering from stratification). The figure also shows that there is an evidence for a battery accomodation process that is seen after the first few months of performance (the RMSE reaches a minimum).

4 Conclusions

The ground detectors power system at the Pierre Auger Project with its 1600 stand-alone PV systems, its high number of statistics and the extreme meteorological conditions at the geographical locations is an unprecedented experimental setup for the study of stand-alone PV systems.

In this article we introduce the first results of the Quality Control methods and evaluation of ageing of this type of system. The results obtained can be easily extended to any grid of stand-alone PV systems in the world.

5 Future

The near future entails the systemization of the proponed procedures verifying the sensitivity of the method for controlling the system. Moreover, we hope to develop new estimation methods to evaluate the state of ageing of the batteries (for example, from viewing the mode of discharge of the batteries [6]). The comparison a posteriori of the different methods of treatment will allow us to optimize the quality control procedures of the PV systems. We also plan to study the effects of the meteorological conditions on the PV systems. We do not disregard the use of neuronal networks to extract data analysis conclusions.

At the same time, we will use the Pierre Auger PS as experimental setup for new system components characterisation. At this moment, different types of regulators have been installed and we are also studying the possibility of installing gel batteries.

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