NORIA DATA MANAGEMENT SOFTWARE FOR PV MODULES CHARACTERIZATION IN THE OUTDOOR ESTER TEST FACILITY

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ABSTRACT: The software named Noria, conceived and realized on purpose by the Environmental Technical Physics group of the University of Rome Tor Vergata, is presented. Noria has been built to manage the data coming from the outdoor ESTER test facility for PV modules of various technologies. In the facility, irradiance and meteorological parameters as well as maximum power of the PV modules under test are collected every minute while every ten minutes complete IV curves are traced and stored in the database. This large amount of data requires a powerful software tool structured with high flexibility architecture and user friendly interface in order to retrieve the information needed. The basic idea was to reproduce via software the PV modules arrangements on the outdoor stands during the monitoring activities. The information given by the stand configurations are used to retrieve the data. Logical queries allow to filter and extract data according to a wide variety of possibility selecting by radiation level, wind intensity, PV modules model, PV modules current or voltage, date and time etc.
Keywords: PV modules, monitoring, software

1 INTRODUCTION

Nowadays outdoor PV modules monitoring is taking more and more strength owing to the high demand of reliable and durable devices. Moreover energy production of the PV modules during long term exposure to the real environment is a highly requested information for a more aware choice of the PV device. Europe is a very active country in the field due to the high impulse given to photovoltaic especially by the German market. Since few years Italy is tremendously increasing the demand of photovoltaic installations due to the recent state incentives. Moreover some Italian regions as Regione Lazio is funding new emerging technologies for solar energy conversion. In this scenario the new ESTER (Energia Solare Test e Ricerca) facility for monitoring of standard and innovative (especially organic) PV technologies has been designed and built. The facility allows to monitor PV modules performances under typical Central Italy climatic conditions and stands together with other outdoor facilities in the Italian area [1], [2], [3].

Large amount of data are necessary to evaluate PV modules energy production and past experiences [4] have shown how is important to build software tools that accurately manage with them. The ESTER station has been built with a high flexibility and interchangeability of the hardware. The objective of the presented work has been to create a software that was able to keep track of every action is made on the facility hardware configuration in order to make the right data recognition and extraction through a user friendly interface.

2 THE OUTDOOR FACILITY

A detailed description of the facility has been presented elsewhere [5]. Here a brief overview of its capabilities is presented. Part of the outdoor station is showed in fig. 1.

Figure 1: Fixed stand and meteorological station at the ESTER facility.

It consists of a meteorological unit and a PV module test unit. The meteorological unit collects global radiation data on a horizontal plane as well as its separate components (direct, diffuse and reflected irradiance) together with air temperature, humidity, wind speed and direction, rain rate and pressure. Averages over 1 minute, 1 hour and 1 day of all parameters are downloaded every 30 minutes and stored in a dedicated database via Ethernet connection.

The PV modules monitoring unit consists of two stands, a south oriented one with variable tilt that can host up to 6 PV modules and a sun tracker system that can host 2 PV modules. In plane irradiance is measured by a pyranometer for each unit and by various technologies reference cells. Each PV module under test is connected to a MPPT provided by ISAAC – SUPSI, Lugano, CH. The module is constantly taken at MPP and every minute Pmax together with in plane irradiance, ambient and PV modules temperature, wind intensity and direction are collected by a CR1000 data logger by Campbell Sci. Every 10 minutes a complete IV curve is traced for each of the modules under test. The data are downloaded into the same database as the meteo data.

3 THE DATABASE

The database has been built using MySQL platform and it consists of 26 tables. Two of them are dedicated to the storage of the meteorological data, three of them are used by the PV modules monitoring unit while the remaining ones have been created to support the Noria procedures.

The table named DATATABLE contains all data acquired by the AD converters used for the measurement of the environmental parameters together with the TMPSTMP field used for the date and time storage; the table named UMIM contains the Imax and Vmax data coming from the modules under test, the TMPSTMP field and the MPPT_ID field addressed to the module under test. The IV_CURVE table is used to store data coming from the IV curve tracing for each module under test. Each record contains 512 values of current and voltage together with the TMPSTMP field and the MPPT_ID field. Every minute 53 values from the monitoring station are stored into the data table while every 10 minutes 512 values of the IV curve traced for each module are collected only during daytime, together with 4 control values; considering one PV module under test, this means that every hour 6276 data are saved in the database producing approximately 40 millions data per year.

It is important to note that the fields into the data table are referred univocally to each AD channel and sensor but not automatically to the kind of measurement made by each sensor. In this way no hardware constrains limit the sensor cabling. When the monitoring scenario is defined Noria is able to register all the constrains related to it.

Among the Noria tables the configuration table is the most important. It collects all the information related to the modules under test and to the configuration of the station stands. Noria tables are necessary in order to keep track of all the modifications that during the time can be made to the hardware composition of the monitoring stands. These modifications are essentially due to the changing of modules under test during time and to the standard maintenance procedures.

4 THE NORIA SOFTWARE

4.1 General description

Noria has been conceived in order to simplify data recognition and interpretation and it has been written in Visual Basic software language. As already mentioned, it is important to check on the PV stands configurations to correlate the data to the referred test. In Noria this is possible through the set up of a "virtual" configuration of the stands.

The name "Noria" is got in association to the water wheel (Noria, in Italian language) showed in Fig. 2. The Noria lifts water from a river to the aqueduct at a higher level, as well as the software product pulls the data from the database to the user.

4.2 Storing the hardware configuration

The first step the user has to pass through is the transposition of the hardware configuration into Noria. This is done using an hardware depository where the channels of the AD converters, the number and types of

Figure 2: The water wheel called in Italian, Noria.

sensors and the properties of the PV modules under test are inserted. Stored configurations as well as cabling of sensors and PV modules are visualized as shown in Fig. 3. The fixed stand is divided in stand 1A and 1B since it is composed by two frames that can be differentially tilted. Fig. 3 shows stand 1A in the current configuration: a reference module Kyocera KC125GHT-2 has been mounted since October 2007 and is continuously monitored. When a configuration has to be changed because new modules have to be mounted or old ones need to be taken down, each modification has to be registered by the time period in which it was made. The essential feature of this procedure is the registration of the functioning period.

4.3 Data Query and retrieve

The data extraction is made by a driven procedure to edit the queries. The query is built using a dedicated graphic interface that allows to select the environmental parameters measured by the station and/or the PV modules properties, to assign a value or a range of values to search, and to combine them by Boolean criteria. The data sorted out by logical interrogations are presented by tables and by graphics in the case of the IV curves.

Fig. 4 shows a diagram that summarize the steps the program follows to extract the data. As presented in the diagram the data can be obtained, for example, combining the serial number of a PV module under test and a particular set of a generic parameter, R.

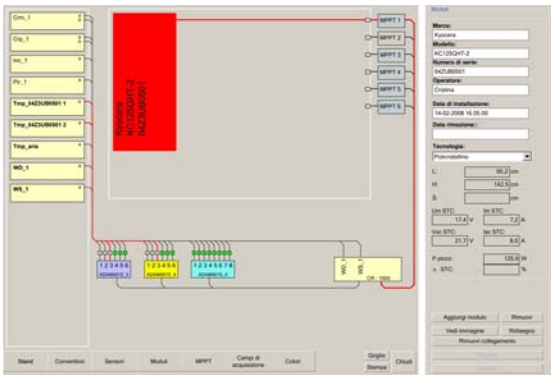

Figure 3: Screen print of the actual configuration of Stand 1A.

The Noria tables for modules and configurations are queried and the time and the PV module that fit that query are retrieved and used to filter the acquired data.

The program provides three output frames: a configurations list that meets the query criteria, a grid with the one minute interval data and a grid with the IV curves that correspond to that criteria. An export procedure allows the translation of the data in the most used file formats.

As an example of the capabilities of the software output fig. 5 reports the output grids for the interrogation that combines the module brand = Kyocera and the module temperature higher than 40°C.

Noria has been used, for example, to extract the IV curves that characterize the reference module Kyocera KC125GHT–2 and that are suitable for translation to STC. The translated values have then been compared to the reference data provided by ISAAC SUPSI to qualify the facility. As prescribed by IEC 60904–1 [6] the curves have to be taken at high in plane irradiance (> 800 W/m^2) and the device should be normal to the solar beam within ±10°. This prescription is obtained tilting the fixed stand at an angle perpendicular to the solar beam at noon and sorting out the data with Noria in a time interval between 11.30 and 12.30. Data can be grouped per month or can be selected from the entire data table.

Another example of application of the Noria capabilities is the Nominal Operating Specific Temperature (NOST) determination [7]. For our case the conditions of perpendicularity have been considered so that all data acquired between 11.30 and 12.30 has been selected. It has to be noted that the stand tilt angle has been varied during the test period (April-May 2008) to get perpendicular solar beam at noon.

For what concern the other restrictions to the data filtering the prescription of the IEC standard [8] have been considered i.e. Air Temperature, Ta = (20 ± 15) °C, wind speed, w = (1.00 ± 0.75) m/s and in plane irradiance higher than 400 W/m^2.

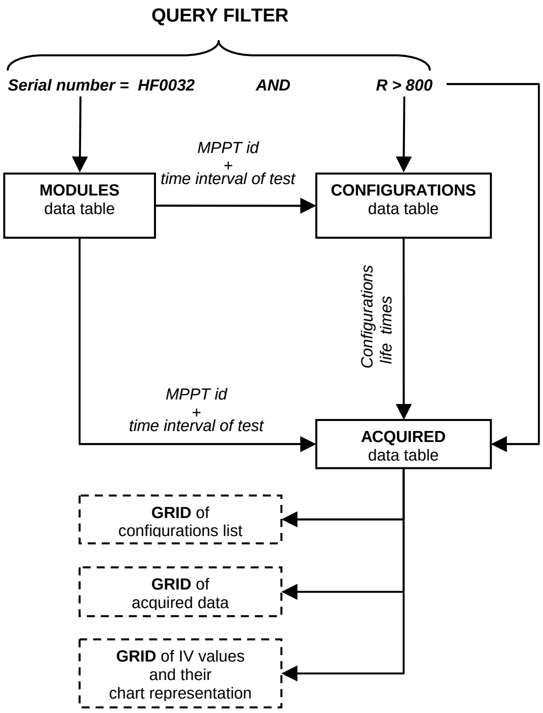

Figure 4: The scheme of the query filter.

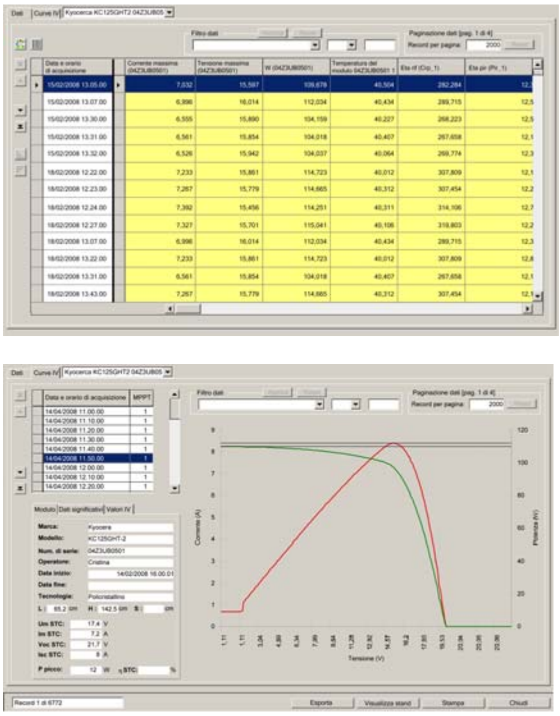

Figure 5: Example of data extracted with Noria with the query: brand = Kyocera and Tmod.> 40°C.

Fig. 6 shows the trend of the difference between the module temperature and the air temperature versus the in plane irradiance (POA irradiance in the graph) for the obtained data.

The calculated NOST value is 40.5°C. This value is preliminary since the amount of data gathered, especially in the low ranges of irradiance, is small.

4.4 Other features

Noria can be accessed by different users and their privileges are regulated by the user administration. User activity is constantly registered and also automatic and manual backup and restore of the configurations saved in Noria is foreseen.

The management of the meteorological data with Noria is also in the schedule. The various data tables could be combined since the two data loggers that provides the meteorological and PV monitoring data are synchronized.

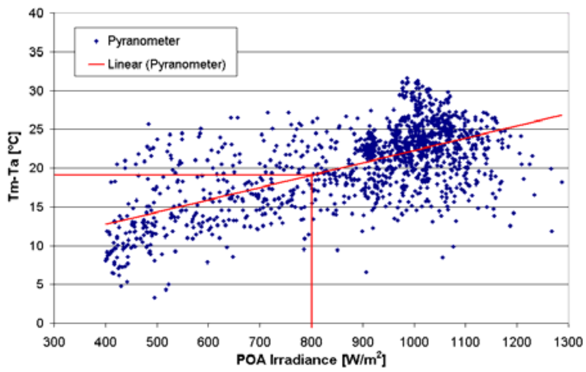

Figure 6: Preliminary evaluation of NOST for the Kyocera KC125GHT-2.

5 CONCLUSIONS

The capabilities of a new software conceived to manage the large amount of data coming from the ESTER PV monitoring station have been illustrated. The software allows to keep a high flexibility in the data acquisition system and station hardware providing an instrument that is able to upload the hardware configurations under test and to use them as a tool for data identification and selection. Multiple interrogations based on PV modules properties, environmental parameters ranges, date and time can be applied and combined by Boolean criteria to extract the dataset and a user friendly output interface allows to check the data and easily export them in the most common file formats. Future improvements of the software regards the implementation of a query task for the meteorological station data in order to integrate the information from the two units of the facility.

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7 REFERENCES

[1] F. Apicella, V. Giglio, M. Pellegrino, S. Ferito, F. Tanikawa, Y. Okamoto, Proceedings of the 21st European Photovoltaic Solar Energy Conference, Dresden, Germany (2006).
[2] G. Blaesser, Solar Energy Materials and Solar Cells, v 47, n 1-4, (1997) 167.
[3] D. Chianese, A. Realini, E. Burà, N. Ballarini and N. Cereghetti, 21st European Photovoltaic Solar Energy Conference, Dresden, Germany (2006).
[4] T. Zdanowicz, M. Prorok, W. Kolodenny, H. Roguszczak, Proceedings of the 3rd World Conference on Photovoltaic Energy Conversion, Osaka, Japan, (2003) 2497.
[5] A. Spena, C. Cornaro, S. Serafini, Proceedings of the 33rd IEEE PV Specialists Conference, San Diego (CA), May, 11-16 (2008).
[6] IEC 60904-1 Photovoltaic devices – Part 1: Measurement of PV current-voltage characteristics.
[7] R.P. Kenny, G. Friesen, D. Chianese, A. Bernasconi, and E.D. Dunlop, Proceedings of the 3rd World Conference on Photovoltaic Energy Conversion, Osaka, Japan, (2003) 1015.
[8] IEC 61215. Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval.