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Data Acquisition System for Performance Monitoring of Solar Photovoltaic (PV) Power Generation

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ABSTRACT---*A computer based data acquisition system to monitor and control photovoltaic power generation systems using a novel method, based on Campbell scientific data acquisition board (CR3000) and graphical programming software (PC 400), has been designed and implemented. Prior to designing the data acquisition system, a small sized PV power generation system, consisting of a 6.4kw Solar panel, a charge controller and a DC to AC inverter, has been assembled. At the same time, Data-acquisition systems are widely used in renewable energy source (RES) applications in order to collect data regarding the installed system performance, for evaluation purposes. In this paper, the development of a computer-based system for RES systems monitoring is described. The proposed system consists of a set of sensors for measuring both meteorological (e.g. temperature, humidity etc.) and electrical* parameters *(photovoltaic voltage and current etc.).*

Keywords---Wind sensor (speed, direction), Temperature sensor (Ambient, module), Campbell Scientific data logger CR3000, PC 400s 1.5 Data logger software, Elmeasure web software.

I. INTRODUCTION

Most energy projections show that current and expected future global energy demand patterns are not sustainable. Long-term projections indicate that the world energy demand may increase dramatically, with most of this increase taking place in developing countries. For instance, according to projections made by the World Bank and the International Monetary Fund, Asia and South America are believed to present higher growth rates than the rest of the world within the next decade. The population of these regions must continue to grow faster than other countries and at the same time, there has to be an improvement of economic conditions, whereby creating a greater demand for more household appliances, industries and services, and hence, an increase in energy consumption. Today, at an overall world level, RE sources account for 13% of the primary energy demand (80% comes from fossil fuels, 7% from nuclear power), 18% of the electricity generation and 26% of the heat supply. In developing countries RE plants, characterized by a low impact on the environment, can play a greater role in order to achieve low-carbon intensive energy systems to supply the increasing energy demand.

II. SOLAR TECHNOLOGY

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar radiation along with secondary solar-powered resources such as wind and wave power, hydroelectricity account for most of the available renewable energy on earth. Solar powered electrical generation relies on heat engines and photovoltaic. Solar energy's uses are limited only by human ingenuity. A partial list of solar applications includes space heating and cooling through solar architecture, potable water via distillation and disinfection, day lighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes. To harvest the solar energy, the most common way is to use solar panels. Not only installation of these technologies but also monitoring and controlling of these systems are very important. A study by solar experts concluded that about half of all solar power systems aren't working as they should, and this leads to around 20% of a year's solar electricity to be lost.

Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar

techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. PV solar panels last at least 25 years, whereas inverters only come with an 8-10 year warranty. That means that sometime in the 8-10 year range the inverter will die and the system will stop producing energy. With a monitoring system in we can know immediately that the system has been compromised. Otherwise it could be weeks or months before that we realize that the solar electricity system is no longer producing energy.

Decentralized electric energy generation, whereby generators are placed closer to consumption areas in order to overcome transmission loss which inherently increases with cable length, is a sustainable alternative. When this kind of power generation uses RE sources, there is a possibility to make use of local resources and even increase employment and income. Systems that are less centralized and less capital intensive may produce more job opportunities, thus the equation of available labor with the specific needs of each nation assumes great importance as erroneous planning could generate large scale social problems, especially in developing countries whereby there is a requirement for a large number of new jobs at the lowest possible level of investment .Decentralization should be stressed to help promote a fair and desirable level of technological, economic and social development in these countries.

III. COMMUNICATION PROTOCOL

The DAS communication channel is a TTL/RS-232 transceiver that permits the serial interfacing between a data logger and a computer (RS-232 voltage levels), executing the electronic load variation, the analog-digital conversion from the solar irradiance, the communication with the 1-Wire temperature sensor and the data transmission to and from the computer via RS-232 interface. By using different buttons on a computer graphical interface, it is possible to visualize the results of the module characterization.

The measurement system uses a silicon-cell Pyranometers as a solar radiation sensor. The sensor data is collected by an internal micro logger and stored in a serial flash EEPROM until uploaded to a portable computer. Keeping the DAS/data logger in a low-power mode, which is only interrupted when measurements are to be taken or when a computer is connected to retrieve the stored data, it is possible to minimize the power consumption. At the end of each data collection period, the acquired data is transmitted to the computer through a RS-232 serial interface. A DAS applied to a PV plant that is capable of delivering 6.75kw of electrical power was described. Temperature, irradiance, array voltage and current data are acquired, processed and then transmitted. For voltage acquisition, a voltage divider was used, which means 10 mV for every one volt of solar panel output.

IV. WIRING PANEL

The CR3000 module integrates electronics within a sealed stainless steel clamshell, making it economical, small, and very rugged. The wiring panel provides terminals for connecting sensors, power and communications devices. Internal surge protection is incorporated with the input channels. These terminals can be disconnected from the CR3000 wiring panel when necessary for maintenance or troubleshooting operations.

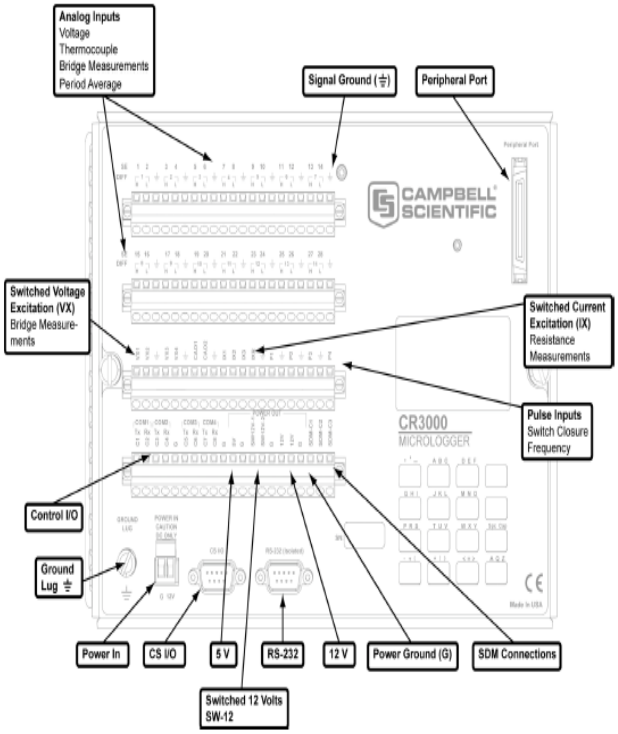

Fig.1. Wiring panel

Most electronic sensors, whether or not manufactured or sold by Campbell Scientific, can be interfaced to the CR3000.

V. SENSORS CONNECTIVITY TO PC:

Met One 10409 temperature sensor with sensitivity of 10 mV/°C is used to measure the ambient temperature of the solar panel. The irradiance is sensed using **Kipp** & **Zonen** CMP11 **pyranometer**.

A set of sensors are used to measure atmospheric as well as quantities regarding the electricity produced by a hybrid PV/wind generator power system, such as PV array voltage and current, the wind generator speed. The collected data are further processed, displayed on the monitor and stored in hard disk. This section describes a low cost concept for DAS/data logger applied to decentralize RE plants for use in developing countries, based on free software and an USB interface. Considering

that most of DAS found in literature use a serial TTL/RS-232 transceiver for the connection to a PC, the proposed DAS represents a new use of low cost USB based systems. The motivation is that currently USB represents the most diffused peripheral-to-PC connection standard thanks to its flexibility, expandability and ease of use. In this way, there are two possibilities for data collection: data can be locally collected with the USB channel or remotely by GPRS, aiming to be stored on a data base, making possible a posterior analysis.

In most of the mentioned references, the data storage is done on a PC hard disk, whereby there is a requirement to provide constantly, a dedicated powered PC on-site only for this purpose, which makes the monitoring system more expensive. In the proposed DAS, the variables are stored directly in the DAS EEPROM, making the complete monitoring system cheaper. Although DAS EEPROM has a smaller capacity than the PC hard disk, other EEPROM can also be placed in parallel in order to increase the storage capacity. Equipment's designed and built for specific applications tend to be less costly, enhance performance and to provide user-friendly environment for control and communication. It is clear that a commercial data logger has a greater operation range, but for specific applications, it makes sense to use a cheaper developed version.

VI. DATA LOGGER

A. *FEATURES:*

- Compact, self-contained data logger
- Built-in alphanumeric keyboard and display
- 2M Flash memory for operating system
- 4M battery-backed SRAM for CPU use, program storage, and data storage
- Table data format
- Available operating systems: PakBus®
- Software support: requires Logger Net 3.2 or higher (not included)
- Three Year Guarantee

B. *SPECIFICATIONS:*

- Analogue inputs: 28 single-ended or 14 differential, individually configured
- Pulse counters: 4
- Switched voltage excitations: 4
- Switched current excitations: 3
- Control/digital I/O ports: 8
- Continuous analogue outputs: 2
- Serial I/O port (CS I/O): 1
- RS-232 Port: 1
- Scan rate: 100 Hz
- Analogue voltage resolution: to 0.33 uV
- A/D bits: 16
- Baud Rate Maximum: 115200

Campbell Scientifics' CR3000 Micro logger® is a self-contained, rugged data logger that includes battery-backed, real-time clock and nonvolatile data storage. It has an on-board keyboard and 128 x 64 backlit LCD for accessing information on-site. The CR3000 features removable Input / Output connections, a CS I/O port, peripheral port, and RS-232 port. The functional components of a basic data acquisition are: -Transducers and sensors; -Conditioners or circuits standardizing the level of transducer signal to the range of the input voltage of the analog-to digital converter (ADC);

VII. ANALOG-DIGITAL-CONVERTER RESOLUTION

From the point of view of the method of conversion there is a variety of different types of A/D converters used in data acquisition. The most commonly used A/D converters in today's data acquisition products are divided into:

- Dual Slope/Integrating - with a good attenuation of interferences during the integration process

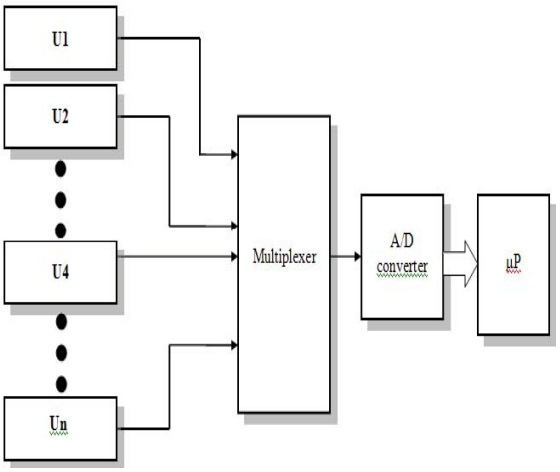

Fig.2. Multi-channel data acquisition system

- Successive approximation - provides resolutions in the 10 to18-bit range, and depending on the resolution, offers sample rates up to tens of Mega samples per second.
- Flash – characterized by the shortest conversion time Sigma Delta provides very high resolution, especially in converting continuous signals

Most multi-channel data acquisition systems are based upon a single A/D converter. A multiplexer is then used between the input channels and the A/D converter. The multiplexer connects a particular input to the A/D, allowing it to sample that channel. Figure.2 depicts a typical, multiplexed input configuration. The primary disadvantage of this system is that even if the switching and sampling are very fast, the samples are actually taken at different times.

The ability to sample inputs at the same instant in time is typically referred to as simultaneous sampling. There are two ways to achieve simultaneous sampling. The first is to place a separate A/D converter on each channel. They may all be triggered by the same signal and will thus sample the channels simultaneously. The second is to place a device called a sample & hold (S/H) on each input. When commanded to "hold", the S/H effectively freezes its output at that instant and maintains that output voltage until released back into sample mode. Once the inputs have been placed into hold mode, the multiplexed A/D system samples the desired channels.

The signal to be sampled will all have been "held" at the same time and so the A/D readings will be of simultaneous samples. A criterion applied to classify data acquisition systems is the transmission type of digital announcements (data, addresses, commands): serial transmission or parallel transmission.

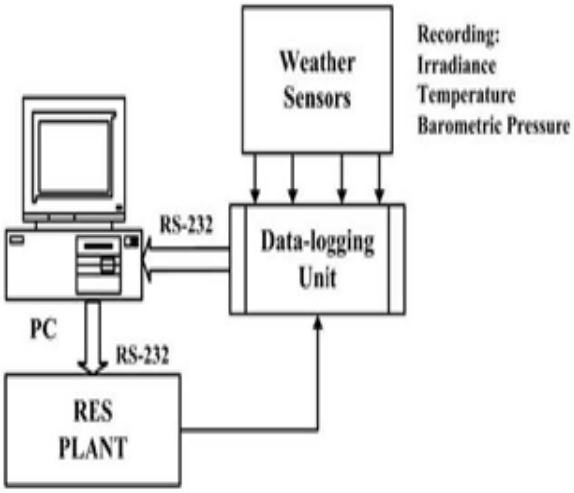

Fig.3. An example of data-acquisition system

The interface system assures equipment and adjustments of devices attached to the bus. The original PC-bus, ISA-bus, is a simple, robust, and inexpensive interface that has certainly stood the test of time. However, most of today's plug-in board business is based on the MOD bus (or variants such as MOD and PXI). The rapid evolution of renewable energy sources (RESs) during the last two decades resulted in the installation of man.

However, such an effort requires detailed knowledge of meteorological data of the site where the system will be installed and operational results from similar systems, if available. Many data-acquisition systems have been developed in order to collect and process such data, as well as monitor the performance of RES systems under operation, in order to evaluate their performance. A data-acquisition system used for monitoring the performance of both photovoltaic battery charging and water-pumping systems is shown in Fig. An A/D converter interfaced to Data logger-based unit records a set of sensors' signals, while the collected data are stored in a local EPROM. The data collected by the data logger are transmitted to a PC, with an RS-232 serial connection, where they are stored for further processing. The same architecture has been implemented in for solar irradiation and ambient temperature measurements. In all the above-mentioned cases, Windows or MS-DOS based software was developed specifically for each application, in order to process and display the collected data on the PC, but this approach is not flexible to changes, e.g. the addition of new sensors. A commercial data-logging unit has been used to measure a set of meteorological and operational parameters of a hybrid photovoltaic–diesel system. The collected data are transmitted to a PC through an RS-232 serial interface.

In this paper, a computer-based data-acquisition system for monitoring both meteorological data and RES system operational parameters is proposed.

A set of sensors are used to measure atmospheric, as well as quantities regarding the energy produced by the hybrid photovoltaic/wind generator power system, such as the photo-voltaic array voltage and current, the wind generator speed etc. The sensor signals are first filtered and amplified using precision electronic circuits and then are interfaced to a PC, through the MOD bus.

VIII. LEVELS OF PROTOCOL COMPLEXITY

- The sensor initiates the communication and sends data to the Data logger.

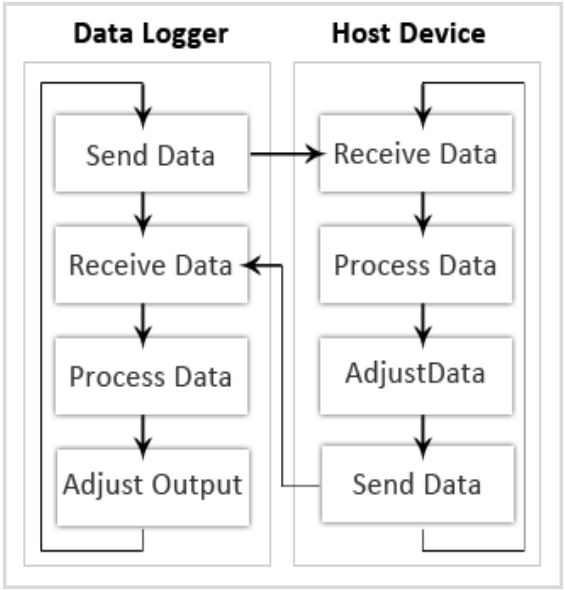

Fig.4.High level complexity

- The Data logger has to be programmed only to receive the data and process it
- The next level of complexity is that of a polled sensor. The Data logger must send a command to the sensor, and then receive the answer from the sensor.
- An even higher level of complexity is when the Data logger must change the commands it sends to the other device based on received messages.

IX. WEB BASED MONITORING

In order to make a web based monitoring system, we have to use the following technology; HTML, Java and web server. In order to observe and control the system while working one computer has been used and already present and LAN line is connected to the internet.

HTML (Hypertext Markup Language) elements are the basic building-blocks of web pages. Java -is a programming language originally developed by ELMEASURE. The language derives much of its syntax from C and C++ but has a simpler object model and fewer low-level facilities. Java applications are typically compiled to byte code (class file) that can run on any Java Virtual Machine (JVM) regardless of computer architecture.

Java Server Pages (JSP) -JSP technology enables web developers and designers to rapidly develop and easily maintain, information-rich, dynamic web pages that leverage existing business systems. Web Server -can refer to either the hardware (the computer) or the software (the computer application) that helps to deliver content that can be accessed through the Internet. The most common use of web servers is to host web sites but there are other uses like data storage or for running enterprise applications. The primary function of a web server is to deliver web pages on the request to clients. This means delivery of HTML documents and any additional content that may be included by a document, such as images, style sheets and scripts. Data Logger is an electronic device that records data over time or in relation to location either with a built in instrument or sensor or via external instruments and sensors. Increasingly, but not entirely, they are based on a digital processor (or computer). They generally are small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and sensors. Some data loggers interface with a personal computer and utilize software to activate the data logger and view and analyze the collected data.

Database is an organized collection of data for one or more purposes, usually in digital form. The data are typically organized to model relevant aspects of reality (for example, the availability of rooms in hotels), in a way that supports processes requiring this information (for example, finding a hotel with vacancies). The term "database" refers both to the way its users view it, and to the logical and physical Materialization of its data, content, in files, computer memory, and computer data storage. Fig.5. gives the basic structure of web based monitoring systems. The data logger reads data from solar panels and stores information in storage device. The web server reads the data from the storage device the clients can access the information on solar panels using internet.

X. MAINTAINING THE INTEGRITY OF THE SPECIFICATIONS

The benefits of web based monitoring systems include;

- Maintenance and reparation will become much easier by means of utilization of internet sub structure.
- Java program is accepted on many platforms thus there is no need to select a platform for installation.
- The long range connections can be operated with the present structure without any extra hardware and software needed.
- Its maintenance and reparation will be easy due to its limited number of connections.

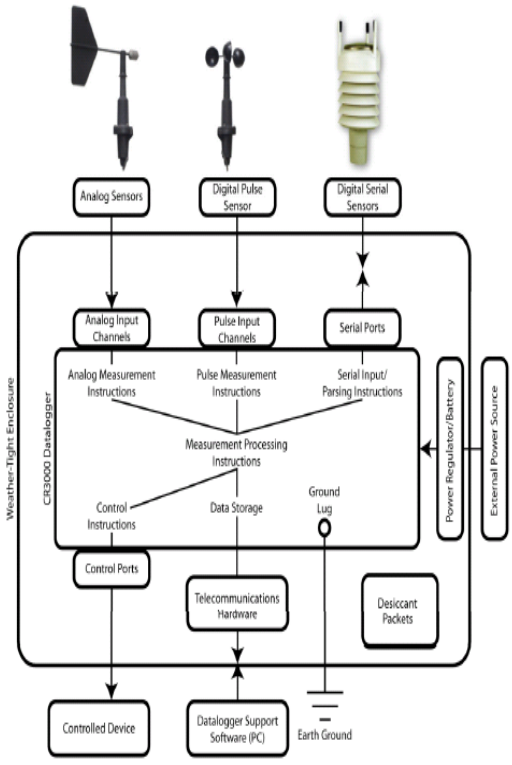

Fig.5. Data Acquisition System overview

XI.CONCLUSION

The rapid evolution of renewable energy sources (RESs) during the last two decades resulted in the installation of many RES power systems all over the world. A disadvantage of RES systems is that the installation cost is still high, so their design optimization is desirable. However, such an effort requires detailed knowledge of meteorological data of the site where the system will be installed and operational results from similar systems, if available. Many data-acquisition systems have been developed in order to collect and process such data, as well as monitor the performance of RES systems under operation, in order to evaluate their performance, display and store the collected data in the PC disk & it can be easily extended for controlling the RES system operation. Data-acquisition systems are widely used in renewable energy source (RES) applications in order to collect data regarding the installed system performance, for evaluation purposes.

XII. REFERENCES

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