Embedded Data Acquisition Systems for the logging and monitoring of PV parameters

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Abstract

Data Acquisition Systems (DAS) have already been used to acquire signals that range from medical, renewable energy, audio, etc. Photovoltaic PV) produced energy signals regularly vary with the amount of received solar irradiance and environmental factors such as the solar panel temperatures. Users with the interest of knowing the degree of PV output energy variations often use online solar maps and climatic records to build and evaluate solar profiles. This research proposes to take advantage of the dropping prices and high performance of microcontrollers to build aa DAS that will be used to monitor and logs PV produced power together with surrounding temperature values. The microcontroller circuit is interfaced to a voltage /current detector, temperature sensor and an optional battery detection circuit. The logging aspect will also enable solar profiling of received solar irradiance and PV panel temperatures, which will then reduce the reliance upon solar maps and climatic data that are not always free. By using a DAS, users will be able to monitor and build their custom solar profiles based on received solar irradiance together with temperature information. The stored records or live information will be useful in the maintenance or upgrades of Photovoltaic energy systems.

Keywords:
Photovoltaic, logging, solar profile

1. Introduction

The ever changing climatic condition is a reality [1]. Since performances of all forms of photovoltaic system is influenced by weather conditions, it is now becoming necessary to closely monitor and record their performance in order to take informed short term or long term corrective measures. In some instances, where hybrid systems are used; good knowledge about solar resources will enable proper management of available power sources. e.g. the system may be switched to diesel whenever the cloudy weather persists. The use of photovoltaic energy has gained momentum over the past 10 years [2]. This rise is caused by increased electricity cost and a need to save the ozone layer [3]. South Africans are experiencing several scheduled blackouts since 2014; thanks to ageing power stations, electricity theft and equipment vandalism. As a solutions to these blackouts called Load shedding; stand-alone photovoltaic (PV) systems may be used to provide backup electricity supply as explained in [4]. In order for standalone systems design to succeed, solar profile of various regions will have to be created using techniques that may be similar to those discussed by [5]. Battery bank operational time has serious impact onto the performance of Stand-alone PV systems. Poorly designed systems will result to small or oversized battery-bank. In a case of small battery-banks that are not monitored, the system will over-discharge the batteries to cause a costly damage.

2. Literature review

2.1 Solar energy profiling

Solar site survey refers to the process of evaluating the site that will be hosting PV system for its ability to produce adequate solar insolation required for the production of desired output power within the available financial budget [6]. The output of this survey is a solar energy profile. In [7] and [8] solar energy profile has been built by using small PV panels together with a Data Acquisition System (DAS). Solar irradiance records that were obtained over a certain time period are stored and thereafter compared to the prevailing load requirement. With this strategy, the solar energy is expected to be equal or more than what the load demands.

2.2 Data Acquisition Systems

Data Acquisition refers to the digital process of collecting analog signals to a processor. DAS equipment comes in many forms that vary in speeds, cost, number of channels, etc. Energy from the sun often varies within a fraction of a second, which is convenient for sampling by DAS as stipulated by Nyquist rate [9].

2.3 Thermal sensors and light detectors.

At the component level, devices such Light Dependent Resistors (LDR), photodiode and phototransistors are used to detect light, whilst thermistors are used for temperatures. In [5], it was found convenient to use a small solar panel for the detection of solar as it will incorporate anticipated losses from temperatures, humidity, conversion, etc. [10] used Dallas temperature sensor for the detection of temperatures.

In this research: Microcontroller based DAS has been interfaced with a voltage / current detector [11] (solar sensing), and a Dallas temperature sensor (rooftop temperatures). The produced outputs performance data that enable corrective actions such as cooling of roof mounted panels or adjustment of rooftop panels. A battery detection circuit is also included for the convenience of tracking the level of battery energy.

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3. Methodology

3.1 Hardware components

The core components used for this study are: Microcontroller that is used to implement a DAS, a Dallas temperature sensor [12], LM7809 voltage regulator and current / voltage sensor used to sense solar panel derived output power.

3.1.1. Temperature sensing

Externally, a Dallas temperature probe is made of a mental of about 50 mm in length and 6 mm diameter. It has a built in DS18S20 circuit, which performs temperature detection activities. Figure 1 shows the physical components of a Dallas temperature sensor.

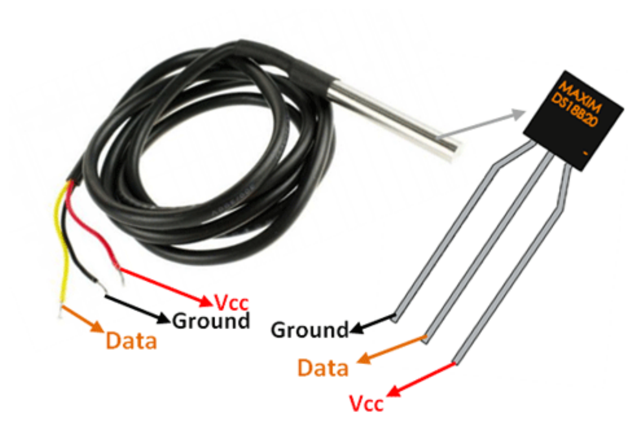

Figure 1: Dallas temperature sensor [12]

3.1.2. Solar power sensing

Produced solar power is calculated by taking the product of measured solar produced current and the corresponding voltage, see equation 3.1. V_{dc} is the voltage measured across the PV array output terminals and I_{dc} is the total current flowing out of the PV array. Compact 50V / 90 A sensor that is described in [11] was used for the purpose of power sensing.

Total solar power = $V_{dc} \times I_{dc}$ …………………… (3.1)

3.1.3. Battery level sensing

If there is a need to continuously monitor batteries, simple battery detection may be implemented as shown by Figure 2. A fully charged 12 V battery gives an open circuit voltage of about 12.7 V, this voltage may rise up to 14 V during charging [13]. When the 12 V battery open circuit voltage drops below 12 V, lower charge level is being signaled. In this research, the microcontroller that collects supplied parameters only allow a maximum of five volts to its analog input /output pins. By using a 9 V fixed voltage regulator as shown in Figure 2, a voltage range of 12 V to 14 V was successfully translated to values ranging from 3 to 5 V. After reading the voltage between the input and output pins of the voltage regulator, the software uses equation 3.1.3 to determine the available battery charge, where a battery voltage below 12 V will indicate low charge.

Battery Sensor = Battery voltage - 9V……… (3.1.3)

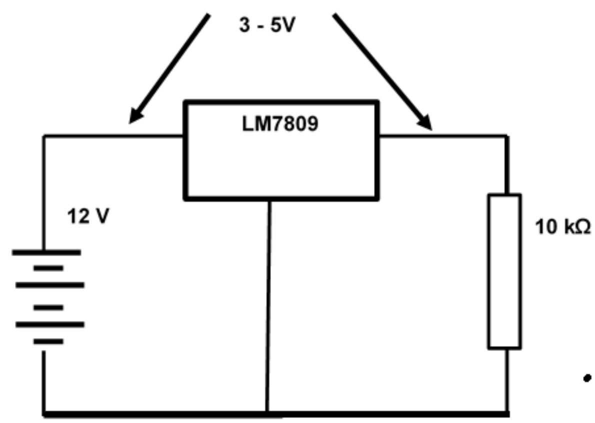

Figure 2: LM7809 based battery level detection

3.2 System software

Arduino sketch has been developed to read all sensors and then use appropriate formulas to calculate the desired output values. The Dallas temperature probe.is accompanied by a suitable library to mediate its functions. An LCD display has been included to provide live readings, and the output values are transmitted to the host computer for recording as comma separated values. There is no need to develop a computer application to login the serial transmitted data from the Arduino as programs such as cool terminal, hyper terminal, etc. may be used. This software algorithm is illustrated by Figure 3.

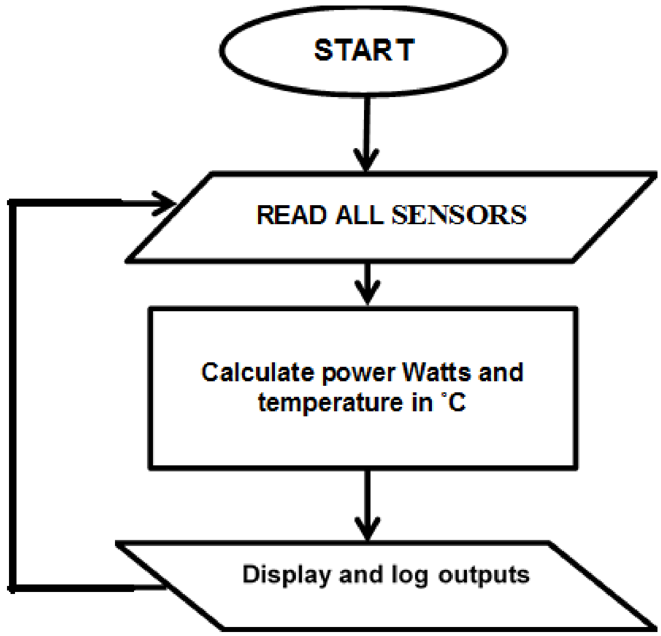

Figure 3: Software program for monitoring and logging system

4. Results and discussions

Figure 4 shows a typical output power that is produced by 200 W array, which is mounted flat to the rooftop that is elevated by 30 degrees and facing north. From the curves, a highest power of 142 W can be calculated by using equation 3.1.

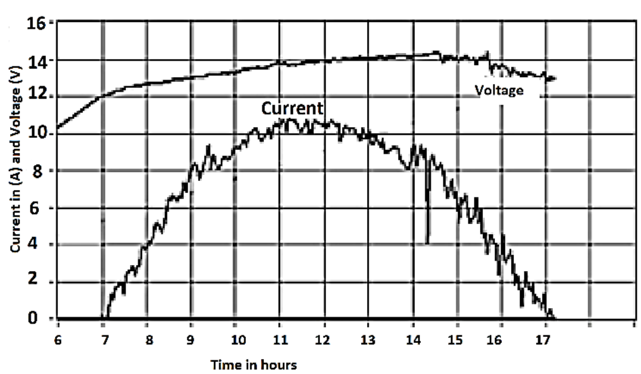

Figure 4: logged solar output from a solar array that is located the latitude of about 28 degrees

In a separate instance, an LCD shown in Figure 5 has been used to display the total power of 188.54W at a roof temperature of 26.7 ˚C. The voltage can be calculated by using equation 3.1.

Figure 5: Real-time PV parameters

5. Conclusions

Real-time solar power and roof temperatures were successfully acquired by microcontroller based DAS, which was interfaced to appropriate sensors as described. By using proper formulas, it will be therefore possible to record accurate values that will be thereafter used to profile the performance of a photovoltaic system. Having profile may remove the necessity of solar maps for the design of future solar system within the same location. A simple 12-volt battery detection may also be implemented by using LM7809 fixed voltage regulator.

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Biography

Nkateko Eshias Mabunda is a senior lecturer at the university of Johannesburg (UJ). He completed his National Diploma and BTech degree in Electronics Engineering at Nelson Mandela Metropolitan University (now called NMU) in 1996 and 1998 respectively. During the year 1998, he also joined Telkom as a Technician for Operations. In 2001, Telkom SA appointed him as a site manager until end of 2002. In his managerial career for Telkom, he looked after the operations, installations and maintenance of equipment within a satellite access node (SAN). He started his lecturing career in December 2002, when he joined NMU. In 2006 he joined UJ as a lecturer in the Department of Electrical and Electronic Engineering Technology (DEEET). During his current career with UJ, he obtained the following degrees with them: MTech Electrical Engineering degree in 2015 and a Doctoral degree in Electronics/ Electrical Engineering in 2018. He is a registered Professional Engineering Technologist with the Engineering Council of South Africa and a member of IEEE. He has published seven international conference papers related to his doctoral work and one journal paper.