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Development of a new temperature data acquisition system for solar energy applications

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ABSTRACT

The experimental work in solar energy researches generates large amounts of data; take a lot of time, effort and high cost. Solar energy researches in many places still depend on thermocouples and the traditional methods of measuring and recording temperature data. The great advance in temperature sensors and the fast development in microcontrollers encourage many researchers to design many data acquisition systems. In this work a new sensor-based temperature data acquisition system for solar energy applications has been proposed, designed, constructed and tested. The main advantage of this system method is its flexibility and ease of changing the type of sensors and way of recording data. It is especially suitable for large and remote installations where cost is a deciding factor in the choice of measuring system.

1. Introduction

Due to the vast expansion of complexity of the solar energy applications, the needs to add dozens or more of sensors to any solar experimental setup to measure its performance became mandatory. However, in order to use at least ten sensors, a highly cost data acquisition system must be used. Additionally most of these expensive data acquisition systems don't have any internal storage units such as secure digital (SD) card to store the sensors data. Therefore, they require an external computer attached via universal serial bus (USB) or any interface to store the sensors data, which may be considered an additional cost to the overall system. Moreover, these systems require a sort of user supervision to operate correctly.

The rapid evolution of solar energy researches during the last decades resulted in the installation of many solar energy systems over the world. But the installation cost is still high, so the data measurements. However, such effort requires detailed knowledge of system temperature and the site where the system will be installed. Thus, the development of automate database management systems is indispensable. Such systems typically consist of microcontroller-based unit for recording the signals of interest, while the collected data are usually transmitted to personal computers (PC) for storage and further processing. Automatic sensor-based data acquisition systems are currently used for both monitoring system performance and storing data. Data collected can be used to evaluate and measure the system performance during long periods [1–4]. Several data acquisition systems have been developed for use in a specific purpose such as monitoring the performance of photovoltaic (PV) systems, which include measuring, acquisition and processing environmental variables [5,6]. These systems depend manly on personal computers and highly expensive temperature sensors and microcontrollers.

Sine experiments in solar energy systems require long times and may be carried out in remote places; data recording and storage are required. Data acquisition systems are employed for photovoltaic water pumps, greenhouses and PV solar plants [7–10]. Data acquisition systems are also developed for large experimental installations [11–13]. These systems are also used in monitoring meteorological data in whether station. Measurement of meteorological data based on wireless data acquisition system monitoring is also developed by Ref. [14].

Around the year 2000, the sensors price has been sharply dropped and so the microcontrollers. Therefore, many sensor-based microcontroller data acquisition systems have been developed to monitor and store the meteorological and systems data [15–21]. Most of these systems are developed for specific solar systems. Some systems use computers to display the data (LabVIEW in data acquisition system). A new trend has begun using FPGA [22], which

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is a sort of reconfigurable digital system on a single chip. Thanks to a new generation of digital systems called microcontrollers, the low cost smart embedded systems can be now designed and assembled easily with a little knowledge of microprocessors engineering. These low cost chips are now considering a pivotal axis of the modern control systems, since it is mainly consisting of a small computer embedded on a single chip. Therefore, this work discusses a new approach of designing and making a low cost recording data acquisition system by using the microcontroller technology.

Most microcontroller chips consist of five main parts;

1 Central processing unit (CPU), to execute the user program.
2 Memory unit for user program and the data memory.
3 Input/output units, to provide the chip with ability to communicate with outside.
4 Some additional peripherals such as timers and Analog-to-Digital converters (ADC), to ease the controlling of complex systems such as robots and smart systems.
5 Bus system, to connect all the previous components together.

In this work a simple low cost sensor-based microcontroller data acquisition system for monitoring the temperature data in solar installations is developed. The system can easily change the date, time of experiment start and end, sampling rate and deals correctly with corruption such as power failure. The features of the proposed data acquisition system are;

1 The system can handle up to 16 sensors, with the capability to increase the number of sensors by using additional ADC ICs.
2 The user can easily adjust the starting up time, the ending time, the number of sensors and the sampling interval by using user interface system (4 buttons + LCD screen).
3 The system has its own storage system such as flash memory or SD card; therefore it doesn't require any external computer to store the sensors data.
4 The system automatically creates a new file on the SD card every day and records data on it.
5 The data are stored in a Comma-Separated Values CSV file; therefore the data can be handled and analyzed easily by any mathematical software such as Excel or MATLAB.
6 The components of the systems are available in any electronic store with cheap prices and it can be assembled easily by using simple tools.
7 The system can be adjusted to measure any sensor (temperature, humidity, … etc.) as long as the output of the sensor lies between 0 and 5 V DC.
8 The system can be easily modified to monitor the sensors remotely by using the internet.

2. Description of the proposed system

Fig. 1 shows a photograph of the proposed data acquisition system. The system consists of four main parts; the master control board, the Arduino board, the power supply unit and the sensors terminals unit. The Master control board is responsible for controlling and monitoring the data acquisition system by using 4 press buttons and an LCD screen. The Arduino board is responsible of measuring the sensors voltages and storing their values in the SD card. The power supply circuit is designated to provide the appropriate voltages to the whole system. Finally, the sensors terminal unit is designed to ease the connection between the sensors and the Arduino board as shown in the same figure.

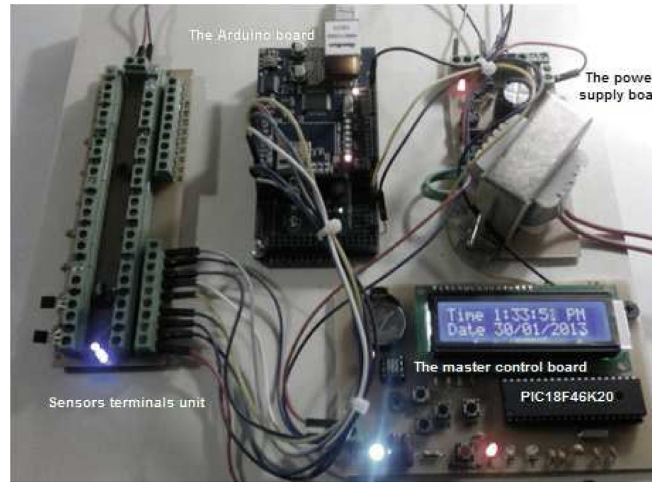

Fig. 1. Photograph of the proposed data acquisition system.

A block diagram of the proposed system is shown in Fig. 2. The main component of the master control board is PIC18F46K20, which is a low cost microcontroller from Microchip Company with a memory size of (64 KB program and 3 KB data memory), makings it the most suitable microcontroller for the data acquisition systems [23]. Also, it has a reasonable number of Inputs/Outputs pins (32 pins), to ease connection to many external peripheral such as LCD screen, 4 buttons and the real time clock (RTC) as shown in this figure. Additionally, the most distinctive feature of this microcontroller is that, it has 8×8 hardware multipliers, to increase the speed of floating point calculations [23], which it is an important feature in solar applications. The program of this microcontroller is written by CCS-PICC software version 4.084 from CCS Company, which is a powerful C compiler especially designed for this PIC microcontrollers.

In order to keep tracking the current time and the date, a dedicated RTC chip called DS1302 has been used. This chip is connected to the PIC18F46K20 microcontroller chip via Serial Peripheral Interface (SPI) protocol system [24] as shown in the figure. The SPI is a standard protocol invented by Motorola Company, which it is mainly used for connecting multiple digital devices with minimum number of wires together [25]. The most important feature of the DS1302 is that, it has the ability to keep tracking of the current time and date even when the power supply is unavailable by using a 3.3 V backup battery as shown also in Fig. 2. In order to communicate with the DS1302, the CCS-PICC software provides the necessary commands and libraries to ease the utilization of the SPI and the DS13020 chip.

The second board of the data acquisition system is the Arduino board, which is a low cost microcontroller development board from Arduino Company. This board has been utilized to measure and to store the sensors data on the SD card in CSV file formats. The main component of the board is ATMega2560, which it is a powerful low cost microcontroller from ATMEL Company [26]. This microcontroller has a large memory size (256 KB program and 8 KB data memory) making it the most suitable microcontroller for the filing system and the SD cards applications. The microcontroller ATMega2560 is connected to the SD card via the SPI protocol as shown in Fig. 2.

Moreover, the ATMega2560 microcontroller can measure up to 16 analog sensors and up to 53 digital sensors because it has a huge number of Input/Outputs (86 pins) [26]. The ATMega2560 program code was written by using the Arduino software version 1.0.1 from the Arduino Company. After writing the program, it can be