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Design and Fabrication of A Low-Cost Data Logger for Solar Energy Parameters

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Abstract
In this research, the design and fabrication of a single board data logger system is presented. An LM35 linear temperature transducer IC served as the temperature sensor device while a solar panel of dimension 6'x18' coupled to a constant load driver circuit served as the solar irradiation variation sensor unit. At the heart of the low cost logger is a Single Board Computer based on an 8 bit MCU embedded platform. Temperature readings and solar voltage variations data were logged successfully. Results indicate consistency with normal weather conditions. Logged data is then transferred to the personal computer for further analysis.
Keywords: Data logger, temperature, solar voltage, microcontroller, single board computer.

Introduction

A data logger is an electronic instrument (or specialized computing device in some cases) that records digital, analogue, frequency or smart protocol based measurements over time (Nashtara, et al, 2006). It is an all-purpose piece of measuring equipment that finds use in an extremely wide range of applications (Jakkree, 2009).

Data loggers have been successfully deployed in many scientific and industrial applications. Some of the important areas in which data loggers are widely used include biomedical instrumentation (Cifrek et al, 2004), power quality measurement (Yeary et al, 2001), automotive engineering (Illic et al, 2004), etc. The data logger has to be portable, hand-held, battery-operated data collection device for collecting "real-world" data which can be used as an interface connected to a computer or as a stand-alone instrument (Jakkree, 2009).

In this work, a digital data logger is designed for logging solar energy parameters. A single printed circuit board (PCB) was used to fabricate the digital data logger. The output power from a solar panel and the ambient temperature are logged. The accuracy of measurements and data are very important, hence, this research applies the single-board computer designed in implementing the logger capable of storing data every 3 seconds.

1. Materials and Method

2.1 PCB Fabrication

The following steps were employed in this research to design, build and transfer the circuit to a printed circuit board (PCB).

- Selection of a CAD tool that is compatible to speak with PCB related file formats.
- Preparation of detailed schematics using the CAD tool.
- Preparation of footprints of the components.
- Layout of the design in a board file.
- Build on copper clad fibre board via toner transfer.

The schematic completes the interconnections between different components. That is more in depth details of the design than the functional diagram. The board file (.brd) gives details about the footprints of the component packages.

This file contains sufficient information to process the fabrication. The .brd file is then printed for use in toner transfer. Fig. 1a shows the PCB data logger fabricated in this work.

2.2 Module Design and Implementation

The data logger circuit is built around the Microchip PIC18F4550 Microcontroller. (Microchip Technology Inc, 2011) The solar energy sensor circuit is made up of voltage dividers R2 and R3. R2 and R3 take the 12V - 15V solar panel voltage and scale it down so that the input to the analog to digital converter is below 5V as required by the microchip.

The operational amplifier is used to measure the current draw. Using a 0.1Ω resistor between the negative wire of the solar panel and ground, the current going though the panel can be measured by measuring across the resistor. To get useful current value, a non-inverting amplifier that amplifies that voltage to a bigger and easier to manage voltage is used. This amplifier multiplies the voltage by 1 + R5/R4 = 48. This multiplies the measured voltage by a factor of 48, thereby bringing it to a more suitable level. Component P5, the 20pin connector provides the connection point of the sensor circuit unit to the single board microcomputer unit. This circuitry is shown in Fig.1b.

The temperature sensing device used is the LM35 which is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in ^oC). It has an output voltage that is proportional to the Celsius temperature with a scale factor of $0.1V/^oC$. The LM35 does not require any external calibration or trimming and maintains an accuracy of +/-0.4^{o}C at room temperature and +/- 0.8^{o}C over a range of 0^{o}C to +100^{o}C.

The general equation used to convert output voltage to temperature is:
Temperature (^{o}C) = Vout * (100^{o}C/V). . . . (1)
The voltage variations sensed from the solar panel is divided down within the range of 0V – 5V suitable for the ADC input of the single board computer. (National Instruments LM35 Datasheet, 2000).

3. Results and Discussion

The developed single board computer was used after the design to implement a data logging system. The energy parameters samples were measured in Eburumede in Effurun, Delta State Nigeria, the coordinates 5034'17.12''N and 5048'37.58'' E were collected using a GPS device. The data logging system keeps track of temperature and voltage variation across a constant load attached to a solar panel. The development of these systems with the single board computer proved to be successful.

Temperature readings and solar voltage variations were sampled and logged at an interval of three (3) seconds for a period of 3days within a time frame of 7hrs, 10hrs and 12hrs depending on the day.The temperature and solar voltage readings obtained for three different days are displayed in figures 2-4 respectively.

The data logger was used to log temperature readings between 17.30hrs and 24.00hrs. From the graph, we observe a decrease in temperature from about 31.2^{o}C at 17.00hrs to about 28.9^{o}C at a record time of about 19.05hrs. However, there was a slight increase in temperature to about 29.5^{o}C at a record time of 19.58hrs and thereafter decreases from 29.4^{o}C at 20.00hrs to 27^{o}C at 24.00hrs. Thus we observe clearly from the temperature readings that the temperature was higher in the evening (17.30hrs) than in the early morning (24.00hrs) which is consistent with normal weather condition. (Ojieabu et al, 2010). The solar voltage variations obtained for the same date are presented in figure 2b

The solar voltage variation was logged. From fig. 2b, we observe a drop in voltage from 2.1V between 17.00hrs and 18.00hrs to about 0.1V at about 18.58hrs. A 0V was recorded at 19.00hrs while between 19.30hrs to 24.00hrs show fluctuations in voltage value between 0.05V and 0.1V respectively.

The temperature readings for the second day were recorded for 12hrs starting from 24.00hrs to 12.00hrs as displayed in fig. 3a.

A careful observation of figure 3a indicates a temperature drop from 29^{o}C at 24.00hrs to 25^{o}C at about 06.30hrs. Thereafter, there was an increment in temperature to about 35^{o}C at a record time of 09.30hrs which decreased slightly to 30^{o}C at 10.05hrs. A high temperature of about 42^{o}C was recorded at about 14.00hrs and thereafter decreases steadily to 25^{o}C at 19.00hrs which was maintained till 24.00hrs. From our analysis, we observe that temperature recorded in the morning was lower than that recorded in the afternoon which again is consistent with normal weather conditions. (Ojieabu et al, 2010)

The solar voltage variations corresponding to the temperature readings obtained for this particular day are displayed in figure 3b. Here the solar voltage variation is seen to increase from 0V to about 2.4V between 06:00hrs to 07:00hrs. It remained between 2V to 2.6V from about 08:00hrs to about 18:30hrs. Thereafter it decreases to 0V.

The temperature reading for the third day was recorded between 24.00hrs and 10.00hrs as shown in figure 4a.

A temperature of about 25^{o}C was obtained at 24.00hrs, which increased slightly and then falls steadily to about 23.9^{o}C at about 05.57hrs. A temperature of 24.2^{o}C was recorded at 07.05hrs, attains a maximum of 28.2^{o}C and decreased to exactly 28^{o}C at 09.10hrs. From figure 4a, we observe that the temperature recorded is lower in the early hours of the day than at other times.

The corresponding solar voltage variations recorded for this particular day are displayed in figure 4b.

From fig. 4b, we observe a very low voltage between 24.00hrs to 06.30hrs, thereafter, the voltage increases gradually to about 26V at 09.05hrs. The curves presented in this research indicate that all values obtained in this work are consistent with normal weather conditions.

4. Conclusion

A data logger for solar energy parameters was successfully designed and fabricated. The data logger was employed in logging temperature and solar voltage readings for 3 consecutive days. Values obtained in this research for the days specified was consistent with normal weather condition. From the view of this study, solar irradiation energy as a source of power supply is available between 06.30hrs to 05.30hrs, (Ojieabu et al, 2010) while solar thermal energy is available at above 250C between 07.00hrs and 05.00hrs. These data collected during the month on March, 2012, supports the development of solar energy systems as a lower cost option for satisfying the many electric energy needs of this region. (Nwokocha et al, 2009)

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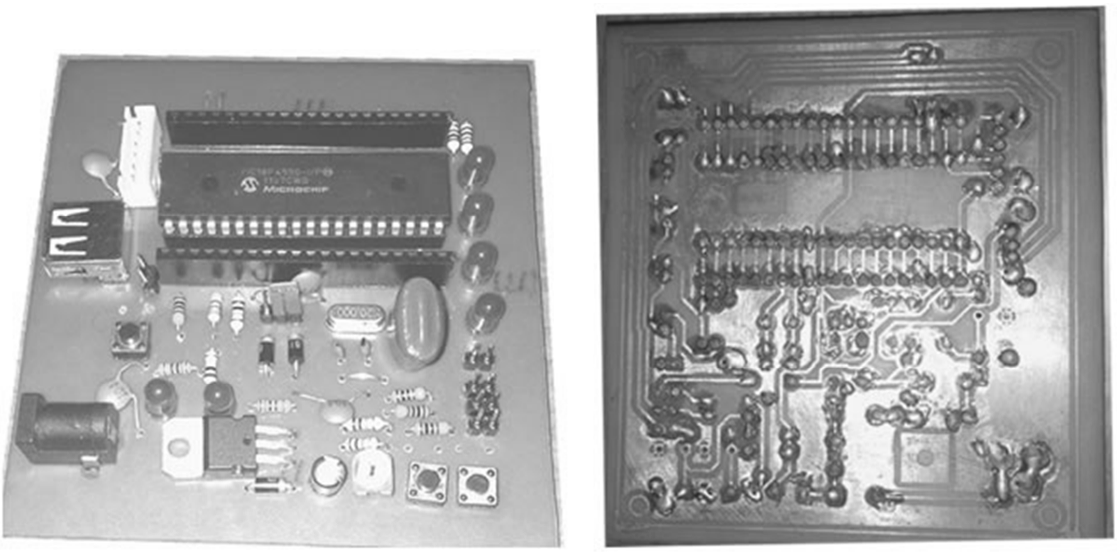

Fig. 1a: Fabricated Data Logger

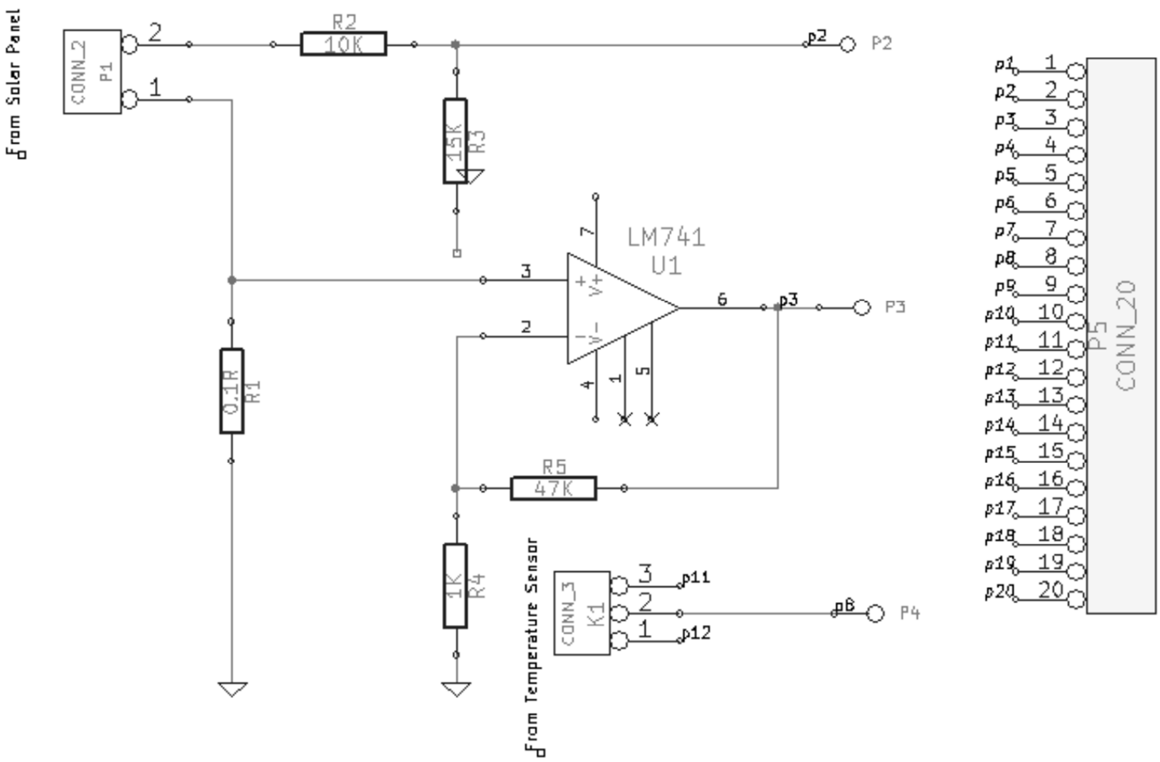

Fig.1b: Parameters sensing unit.

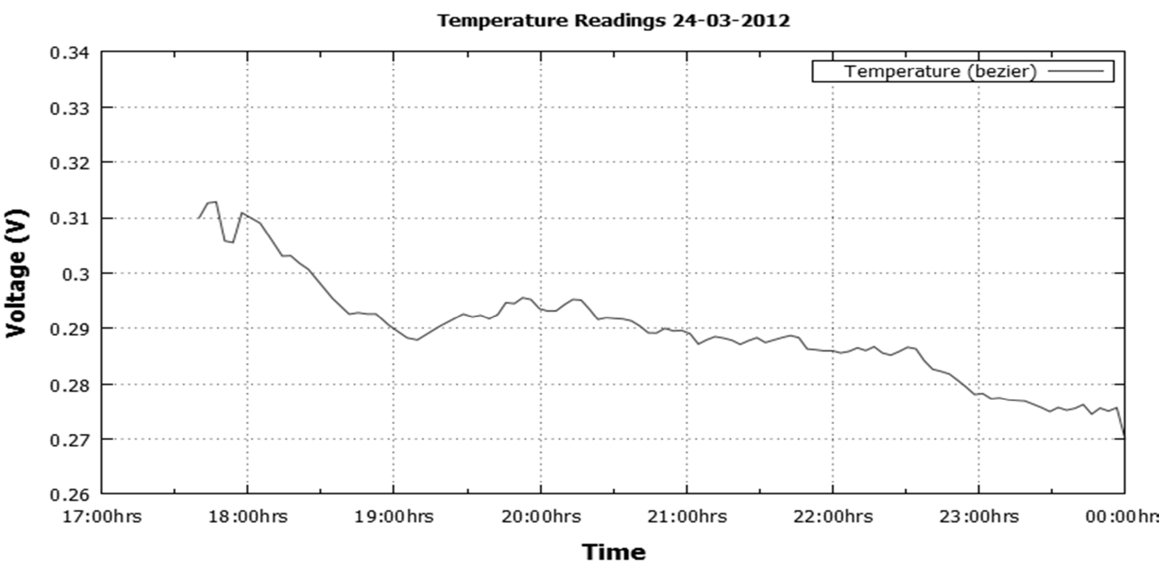

Fig. 2a: Temperature Readings on 24-03-2012

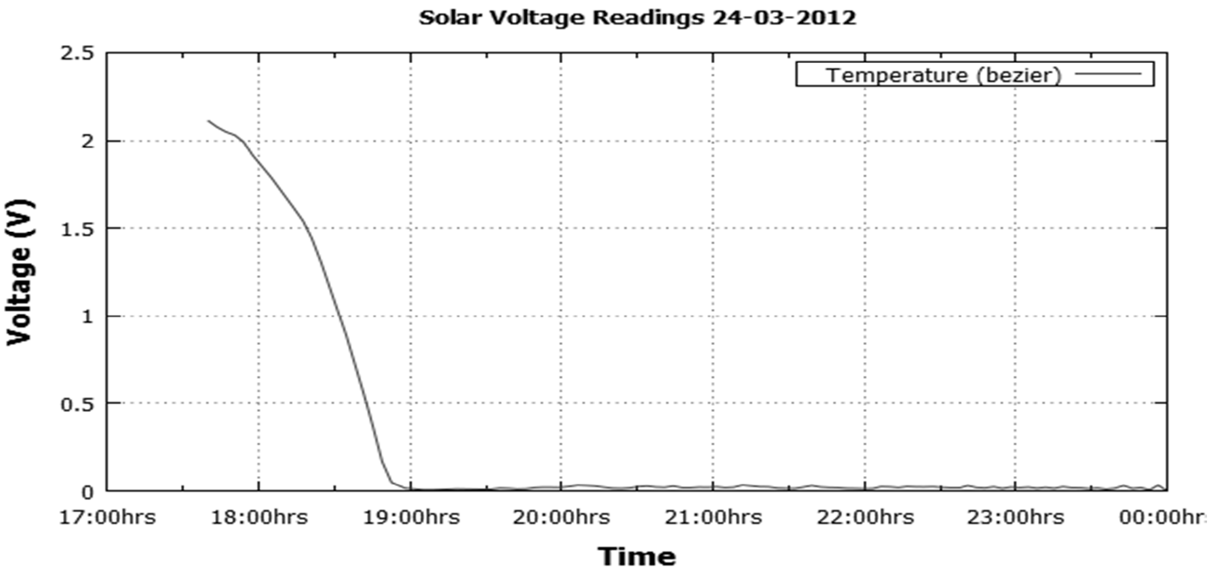

Fig. 2b: Solar voltage variations on 24-03-2012

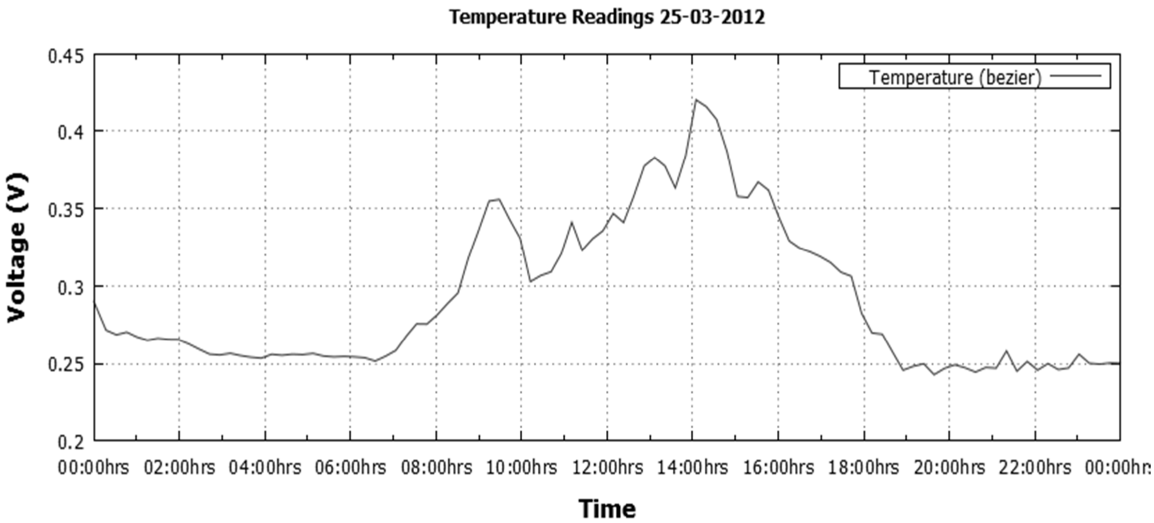

Fig. 3a: Temperature readings obtained on 25-03-2012.

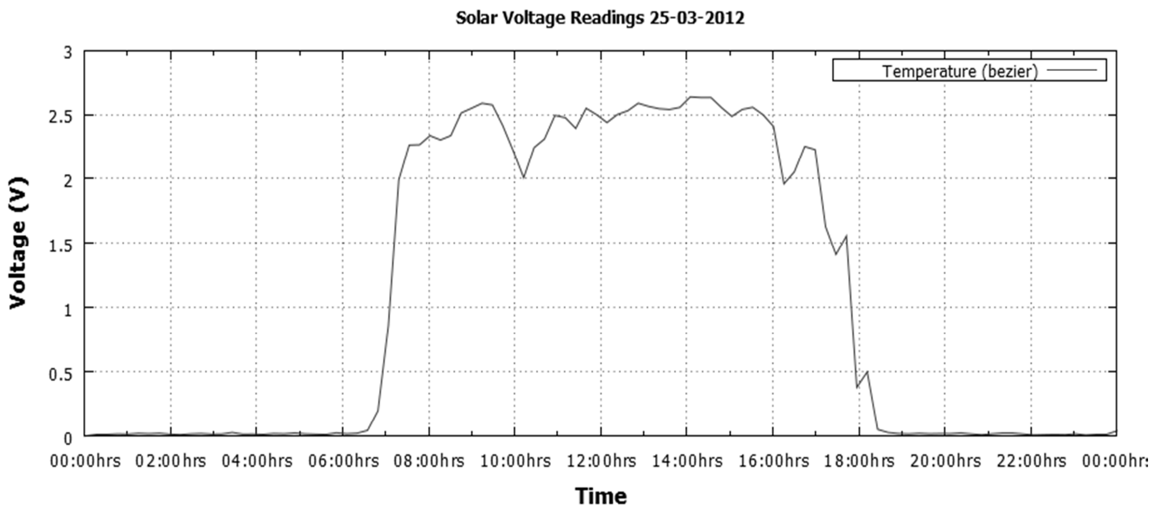

Fig. 3b: Solar voltage variations obtained on 25-03-2012.

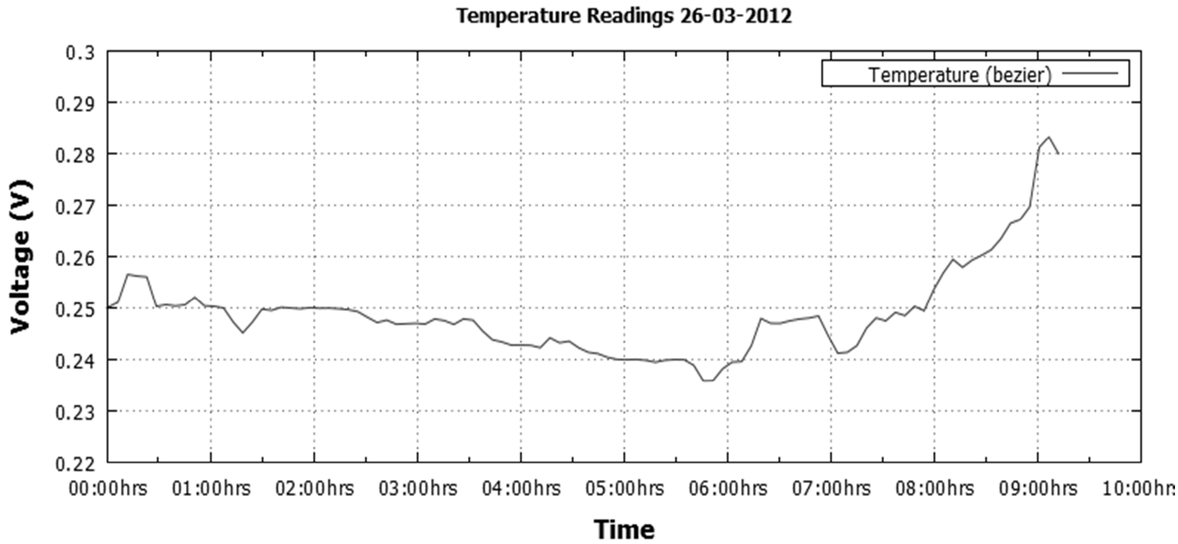

Fig. 4a: Temperature Readings obtained on 26-03-2012.

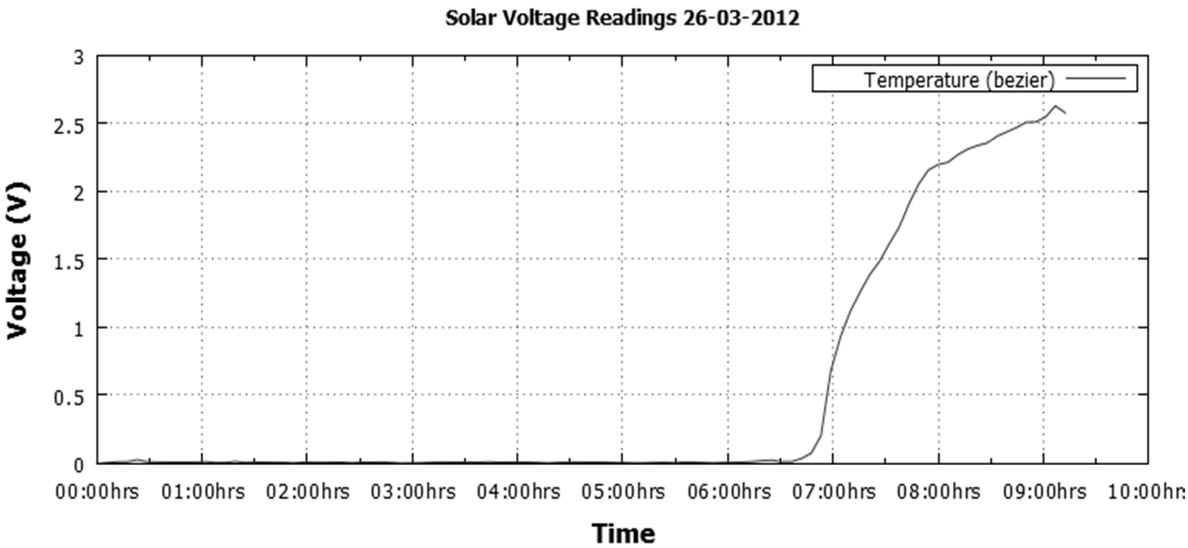

Fig. 4b: Solar voltage variations obtained on 26-03-2012.