A LOW COST I–V CURVE TRACER FOR PV CELL CHARACTERIZATION

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ABSTRACT

Solar energy harvesting is considered as one of the most promising solutions to the upcoming energy crisis. Energy conversion devices based on the principle of photovoltaic (PV) effect which are known as PV cells are mostly employed for this purpose. There are a number of research work going on for the development of advance PV cells with enhanced features. Current-Voltage (I-V) characterization is one of the immensely used methodologies to investigate their performance. Commercial I-V tracers are relatively expensive due to their sophisticated design and lesser production. This study has been conducted to develop an economical I-V curve tracer using advance electronic approaches and components, specially suitable for research laboratories. The system has been fabricated and performance was tested. A dye-sensitized solar cell was used as a testing unit. The device is fully operational.

Keywords: PV cell characterization, curve tracers, I-V characteristics

1. INTRODUCTION

1.1 PV Cells

PV cells can be modelled as a current source in parallel with a diode. When the cell is not illuminated, it behaves as a diode. When illuminated, a current is generated in the cell which is proportional to the incident light intensity [1,2].

1.2 I-V Curve Tracing

In I-V curve tracing, the output current (I) is plotted against the cell voltage (V) while sweeping the load resistance from infinity to zero. A common behaviour of an I-V curve is given in the Fig. 1. This curve can be used to obtain several performance parameters such as short-circuit current density (J_{SC}), open-circuit potential (V_{OC}), maximum power (P_{max}), fill factor (FF) and efficiency (η) [1].

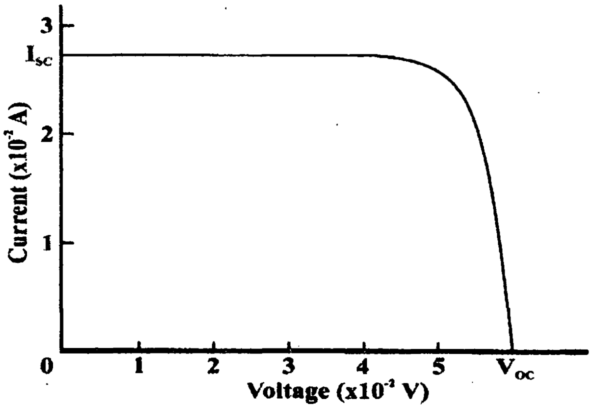

Figure 1: An I-V characteristic curve

Numerous methods are used for data acquisition in PV cell characterization. In automated curve tracers, several technologies are used to obtain data. One method is employing an electronic-load (e-load) as a variable load resistance. A metal-oxide-semiconductor field-effect transistor (MOSFET) can be used as an e-load due to its electrical characteristics [3,4].

In a MOSFET, the drain-source current (I_D) has a linear relationship to the gate-source potential (V_{GS}) in the triode or the linear region. V_{GS} can be varied electrically. Therefore, MOSFET is suitable to use as an e-load. When V_{GS} is minimum, transistor is in the cut-off region where it operate as a resistor of infinite resistance or an open switch. In the saturation, transistor is in fully-opened state (closed switch) where resistance is zero. This behaviour is similar to an electronic-load with a broad resistance range.

2. EXPERIMENTAL

In the proposed system, the above mentioned e-load method has been used due to the simplicity and electronic controllability. An enhancement mode n-MOSFET; CEG8205 has been used as the e-load as it has very low drain-source resistance at the saturated mode [5].

A digital potentiometer has been used to bias the e-load. The voltage and the output current were measured using a 12-bit analogue-to-digital converter (ADC) system. Collected data was processed by an 8-bit general purpose micro-controller (Atmega16) and transmitted to the interface software through a Serial-USB bridging circuit. The micro-controller also operates as the central controlling unit of the device.

The interface software was designed using the Laboratory Virtual Instrumentation Engineering Workbench (LABVIEW).

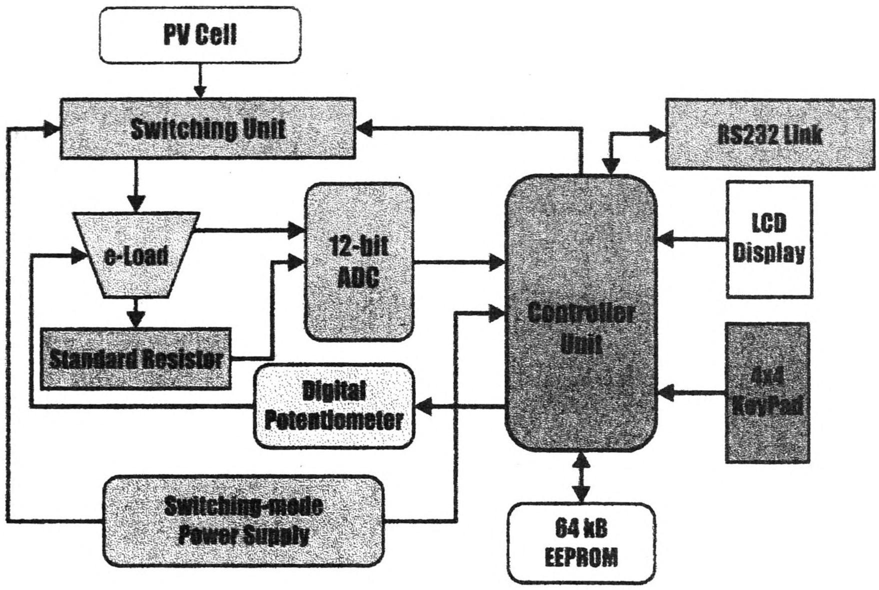

Figure 2: Block diagram of the device

Several techniques have been used to maintain the operation accuracy of the device. Precision voltage references are used in ADC to reduce the effects from power fluctuations in the supply circuit. Circuit was designed to minimize electro-magnetic interference and signal noise.

3. RESULTS AND DISCUSSION

3.1 e-Load Characteristics

The characteristics of the e-load were obtained as follows,

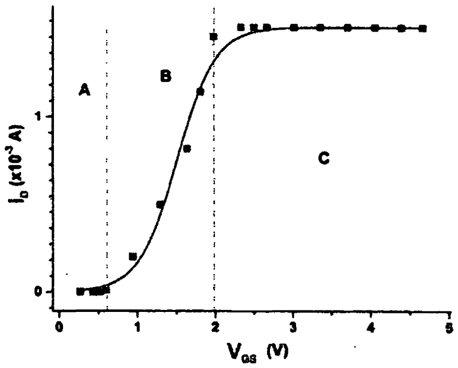

Figure 3: e-Load Characteristics of CEG8205

The triode region (B), cut-off region (A) and the saturated region (C). The variable operation of the e-load is found in region B.

The MOSFET (CEG8205) has performed as per the theoretical prediction. Its linearity in the triode region is sufficient to be used as an e-load. By using two MOSFETs in parallel configuration, it can reduce the saturated junction resistance to a negligible value (15×10^{-3} Ω).

3.2 PV Characterization

A Ruthenium dye-sensitized TiO_2 cell with a gel polymer electrolyte consisting with polymethylmetacrylate, ethylene carbonate, propylene carbonate and tetrapropylammoniumiodide (PMMA: EC: PC: Pr_4NI) was used for investigation. Data were gathered using manual and automated (by proposed system) methods.

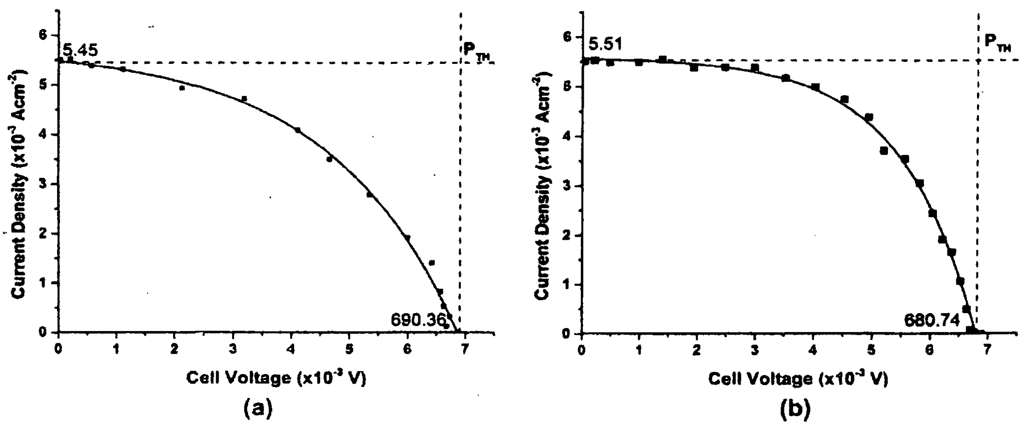

Figure 4: I-V curve of a PMMA:EC:PC:Pr_4NI cell: (a) manual method, (b) from the device

The P-V curve of the cell can be obtained as a secondary result of the I-V characteristics.

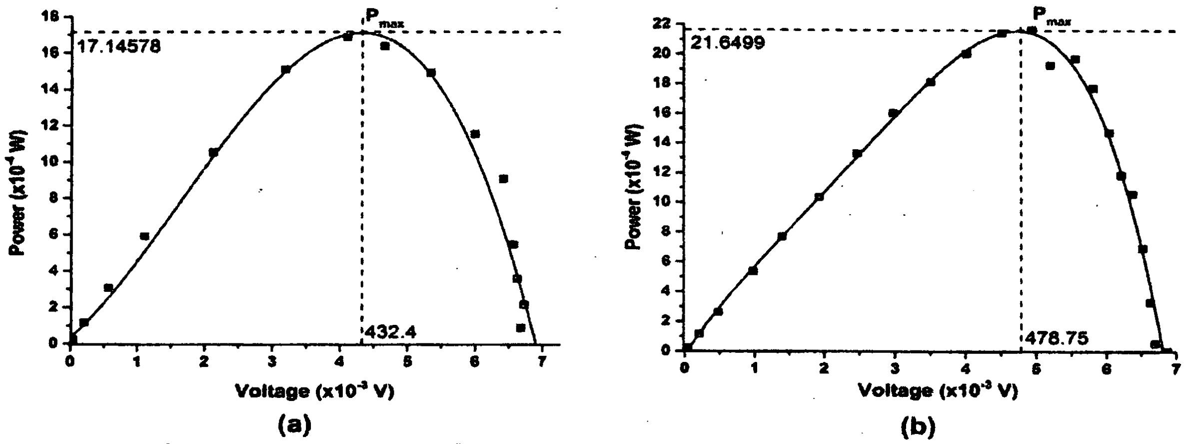

Figure 5: P-V curve of a PMMA:EC:PC:Pr_4NI cell: (a) manual method, (b) from the device

From the obtained data, following results were calculated for the cell. The cell was illuminated using a 100×10^{-3} Wcm^{-2} calibrated light source. The fill factor (FF %) and efficiency was calculated using following equations.

$$FF = \frac{P_{max}}{I_{SC} \times V_{OC}} \times 100\% \tag{1}$$

$$\eta_{max} = \frac{P_{max}}{P_{in}} \tag{2}$$

where, P_{in} is the irradiated power.

Table 1: Calculated results for the sample PV cell

Parameter	Manual method	Proposed device
Short-circuit Current Density (J_{SC}) $/\times10^{-3}Acm^{-2}$	5.45	5.51
Open-circuit Potential (V_{OC}) $/\times10^{-1}$ V	6.903	6.807
Maximum Power (P_{max}) $/\times10^{-3}$ W	1.714	2.165
Current at P_{max} (I_{max}) $/\times10^{-3}$ A	3.96	5.54
Voltage at P_{max} (V_{max}) $/\times10^{-1}$ V	4.324	4.787
Fill Factor (FF) / %	45.5	57.7
Conversion Efficiency (η)	1.714	2.165

According to the results mentioned in the Figs. 4, 5 and table 1, data collected from automated and manual methods show similar distribution pattern. But, the P_{max}, FF and η are slightly different. This is caused by the higher resolution of the data obtained from the device compared to the manually obtained data.

4. CONCLUSION

With the advancement of electronic industry, components have been developed that can perform complex tasks at low-cost and minimum complexity. This enables the development of economical acquisition devices that can mimic the operation of a commercial, high-end instrument up to a satisfactory level.

Total cost for the device is less than 10,000 LKR, which is relatively a lower cost than a commercial device (225,000 - 800,000 LKR) [6]. The system is compatible for low-power PV cells of which V_{OC} is lesser than 4.1 V and I_{SC} is lesser than 100×10^{-3} A. The system has a resolution of 1×10^{-3} V.

Sampling frequency is limited since the fast sweeping of the e-load creates instability in the ADC reading. Therefore, the mean value of several adjacent samples has to be taken as the final data value. The device had to be calibrated using standard calibration tools for precise operation. Repeated results from a cell can be used to set up the system to its optimum performance level. The system can be developed further and customized according to the need of the researcher.

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