Low Cost Data-Logger and Monitoring System for Small Solar PV Energy System

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Outline:

- Introduction
- Literature Review
- Load estimation and system sizing
- Design of data logger
- Design of a cell phone App
- Conclusion
Introduction:

- Energy is significant for development
- Urbanization & Technological advancement
- World consumption will rise 28% (2015-2040) (IEO, 2017)
- Over 20% of world population, do not have access to electricity
Contd...

- **Bangladesh:**
  - Low energy consuming country per capita (Islam et al., 2014)
  - Power shortage

- Alternate Energy Source: SHS
- Up to May 2017, about 4.12 million SHSs

GDP: doubled in between 2010-2016 (World Bank, 2016)

Consumption increases to 81.29% (2000-2016) (Power cell, 2017)

40% people lack access to electricity (Hossain et al., 2017)
Solar Home System:

Data-Logger & Monitoring System for Small Solar PV Energy System

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Motivation and Objective:

- Thesis Motivation:
  - Battery failure
  - Irregular use of panel
  - No regular maintenance or monitoring
  - Lack of awareness

- Thesis Goal:
  - Develop a low cost, low power datalogger
  - User friendly, easy access able monitoring system
Literature Review:

- Literature Survey:
  - Data Transfer Mechanism
  - Controller
  - Monitored Parameters
  - Sampling Intervals
  - Program Development Software
  - Monitoring Method

- 3 main category:
  - Hardware
  - Communication
  - Monitoring Software
Hardware: Atmega, PIC, DAQ, PLC, Arduino

Communication: RS232, PCI bus, Satellite, RF, GSM, GPRS, TX5002, Ethernet, Zigbee, Wi-Fi

Monitoring Software: Turbo C, Assembly, LabView, Java, VB-SQL, Matlab, Mplab, Autobase, Blynk, Thinkspeak, EmonCMS, Adafruit
Lab-VIEW based real-time interface system:

“software tool that integrates several types of instruments into a single system which can offer online measurements of all data sources and compare simulation results with monitored data in real-time” (Aissa Chouder et. al.[6])

Arduino based data logger:

“open-source electronic platform was developed to solve the current problem of monitoring photovoltaic (PV) systems especially for remote areas or regions in developing countries” (M. Vivar et. al.[7])

Remote intelligent monitoring system:

“based on TinyOS for monitoring and management for PV power generation. This system had implemented remote monitoring and reverse control by the host computer, ARM gateways, wireless sensor networks and other components” (Jihua et al. [8]).
Contd…

- **Smart Remote monitoring system using IOT:**
  Shri hari prasath et al., presented their research in [10] to design and implement a Smart Remote monitoring system using IOT that can monitor the Solar PV PCU and stores data in the cloud database through an easily manageable web interface.

- **Satellite based System:**
  An android based design of an electronic system for the measurement and control of the physical parameters like water temperature, solar collector’s fluid temperature, solar radiation level, etc. to monitor and consequently optimize thermal-solar plant functioning is presented by J. M. Bright[12].

- **IoT and MQTT based System:**
  S. Begum et al. [13] have implemented an Operation & Maintenance (O&M) system using predictive analytics and supervisory control and data acquisition (SCADA) with the help of internet cloud along with IoT devices.
Example of Datalogger and Monitoring Software:

Data Logger

Monitoring Software

Data Logger & Monitoring System for Small Solar PV Energy System

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## Price Comparison:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Manufacturer</th>
<th>Price (CAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Geo Solo II PV</td>
<td>GEO</td>
<td>$126.97</td>
</tr>
<tr>
<td>2.</td>
<td>Eco Eye Smart PV</td>
<td>Eco Eye</td>
<td>$130.36</td>
</tr>
<tr>
<td>3.</td>
<td>Owl Intuition PV</td>
<td>OWL</td>
<td>$135.45</td>
</tr>
<tr>
<td>4.</td>
<td>Solar Cache Wi-Link Kit</td>
<td>DSM Energy Control Ltd.</td>
<td>$659.02</td>
</tr>
<tr>
<td></td>
<td>Comprehensive Energy Monitor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>SMA Data Manager M powered by ennexOS</td>
<td>SMA Solar Technology AG</td>
<td>Not found</td>
</tr>
<tr>
<td>6.</td>
<td>Solarfox® Solar Display Systems</td>
<td>SOLEDOS GmbH</td>
<td>$575.78</td>
</tr>
</tbody>
</table>
Available Commercial Systems:

<table>
<thead>
<tr>
<th>Data logger</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>PICOLOG 1012</td>
<td>• Relatively cheap (€200)</td>
<td>• Time stamp per sample missing</td>
</tr>
<tr>
<td></td>
<td>• Very user friendly interface</td>
<td>• Must be permanently connected to a PC</td>
</tr>
<tr>
<td></td>
<td>• Repetitive unlimited samples with unique file names</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Real time mathematical calculations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 12 input analogue / digital channels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 2 output digital channels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Remote download</td>
<td></td>
</tr>
<tr>
<td>DAQPro 5300</td>
<td>• User friendly interface</td>
<td>• Modestly prices (€300)</td>
</tr>
<tr>
<td></td>
<td>• Onboard memory for medium data storage</td>
<td>• 8 input analogue channels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited number of samples</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mathematical calculations after data collection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• One alarm output reduces input channels by 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• No remote download</td>
</tr>
<tr>
<td>CAMPBELL Scientific CR800</td>
<td>• User friendly interface</td>
<td>• Very expensive (€1000)</td>
</tr>
<tr>
<td></td>
<td>• Onboard memory for extensive data storage</td>
<td>• 6 single-ended analogue input channels</td>
</tr>
<tr>
<td></td>
<td>• Remote download</td>
<td>• Mathematical calculations after data collection</td>
</tr>
<tr>
<td></td>
<td>• 4 output digital channels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Resistance measurements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pulse counter</td>
<td></td>
</tr>
</tbody>
</table>
SHS in a Rural Area

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## Load Estimation and System Sizing:

- **Load estimation:**

<table>
<thead>
<tr>
<th>Load</th>
<th>Qty.</th>
<th>Watts</th>
<th>Total Watts</th>
<th>Hours/Day</th>
<th>Wh</th>
<th>Total Wh</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED Light</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>4</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Mobile Charger</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>15</td>
<td>51</td>
</tr>
</tbody>
</table>
System Sizing:

Panel size \( (m^2) = \frac{\text{Total kWh use by appliances per day}}{(\text{solar hours per day}) \times \text{efficiency factor}} \)

\[ = 0.1905 \, m^2 \sim = 20\text{Wp (is 0.2056 m}^2) \]

Battery capacity in Amp-hours (Ah)

\[ = \frac{\text{energy requirement in Wh per day} \times \text{days of autonomy}}{\text{battery DoD} \times \text{system voltage (V)}} \]

\[ = 18.75 \text{ Ah} \]
Contd...

System Block Diagram
Homer Simulation and Optimization:

System Modeling of 20 Wp SHS in HOMER

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System Modeling of 75 Wp SHS in HOMER

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System Modeling of 130 Wp SHS in HOMER
Data Logger Design:

Block Diagram of Designed Data Logger
Micro-controller & Sensors:

- ESP 32
- Voltage Sensor
- Current Sensor
- LDR
- LM35

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Schematic Diagram:

PV

MPPT

LDR

LED

Switch

HTTP

SD CARD

Laptop

WiFi

SparkFun ESP 32 Thing

VCC

GND

SCK

MISO

MOSI

CS

SCLK

GND

3V3

VCC

battery

Load

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Hardware Prototype:

- Voltage Sensor
- Current Sensor
- LM35
- LDR
- SD Card
- Switch
- LED

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Experimental Setup:
Data Logger Design Flowchart:

START

ADC READY

CHECK_SWITCH

SAFE TO REMOVE SD CARD, LED ON

SW_OFF SD CARD READY

WRITE_SD CARD

DELAY_10S

DELAY > 10

DISPLAY PARAMETERS ON WEBPAGE

TAKE INPUTS

SAFE TO REMOVE SD CARD, LED ON

SD CARD READY

WRITE_SD CARD

DELAY_10S

DELAY > 10

Refresh WEBPAGE

START

ADC READY

TAKE INPUTS

DISPLAY PARAMETERS ON WEBPAGE

CHECK_SWITCH

SAFE TO REMOVE SD CARD, LED ON

SW_OFF SD CARD READY

WRITE_SD CARD

DELAY_10S

DELAY > 10

Refresh WEBPAGE
Coding:

Data logging

Web server

Arduino IDE
Web Server:

192.168.4.1

Local Server IP

Solar Home System

Direct Data Download

Downloaded text file

Local Server

Weather is SUNNY
- Temperature, Deg C = 7
- Charging Current, Ic = 1.97 A
- Battery Voltage, Vb = 13.15 V
- Output Power, W = 25.85 W

Click HERE to Download Data
Plot on Excel:

Plot of PV Parameters

Time:
- 13:15:10
- 13:19:25
- 13:23:40
- 13:27:55
- 13:32:10
- 13:36:25

Value:
- 0
- 50
- 100
- 150
- 200
- 250
Android App Design:

Android App Development Architecture

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App Design Flowchart:

1. App initialization
2. Connect webpage (192.168.4.1)
3. Get PV parameters
4. Display PV parameters
5. Clear plot, reset all counters
6. Xaxis < Plot Width
7. Delay > 10 sec
8. Start delay_10s
9. Plot Vb, Ic, P
10. Compare Vb with threshold value
11. Send text SMS
12. Counter = 5 min
13. Start counter
14. Vb < Vb Th.
15. 0
16. 1

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Scratch Code:

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Hardware Setup:
Plot on Cellphone App:

<table>
<thead>
<tr>
<th>Monitoring Parameters:</th>
<th>Monitoring Parameters:</th>
<th>Monitoring Parameters:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather is SUNNY</td>
<td>Weather is SUNNY</td>
<td>Weather is SUNNY</td>
</tr>
<tr>
<td>Temperature, Deg C = 5</td>
<td>Temperature, Deg C = 5</td>
<td>Temperature, Deg C = 5</td>
</tr>
<tr>
<td>Battery Voltage, Vb = 13.02</td>
<td>Battery Voltage, Vb = 13.22</td>
<td>Battery Voltage, Vb = 13.24</td>
</tr>
<tr>
<td>Charging Current, Ic = 7.64</td>
<td>Charging Current, Ic = 12.1</td>
<td>Charging Current, Ic = 3.48</td>
</tr>
</tbody>
</table>

Data-Logger & Monitoring System for Small Solar PV Energy System

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Text Message Alert Feature:

- sent text message
- received text message
## Cost Calculation:

<table>
<thead>
<tr>
<th>NO</th>
<th>Item</th>
<th>Quantity</th>
<th>Price</th>
<th>Per Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Voltage Sensor</td>
<td>1</td>
<td>11.64</td>
<td>11.64</td>
</tr>
<tr>
<td>2</td>
<td>Current Sensor</td>
<td>1</td>
<td>2.76</td>
<td>2.76</td>
</tr>
<tr>
<td>3</td>
<td>Resistors</td>
<td>300</td>
<td>4.56</td>
<td>0.106</td>
</tr>
<tr>
<td>4</td>
<td>ESP32</td>
<td>1</td>
<td>19.95</td>
<td>19.95</td>
</tr>
<tr>
<td>5</td>
<td>Software Arduino IDE</td>
<td>---</td>
<td>Free</td>
<td>----</td>
</tr>
<tr>
<td>6</td>
<td>Software AI2 For Android App (IDE)</td>
<td>---</td>
<td>Free</td>
<td>----</td>
</tr>
<tr>
<td>7</td>
<td>LM35</td>
<td>1</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>LDR</td>
<td>50</td>
<td>1.49</td>
<td>0.029</td>
</tr>
<tr>
<td>9</td>
<td>LED</td>
<td>500</td>
<td>4.68</td>
<td>0.009</td>
</tr>
<tr>
<td>10</td>
<td>Micro Switch</td>
<td>10</td>
<td>0.94</td>
<td>0.094</td>
</tr>
<tr>
<td>11</td>
<td>SD Card Socket</td>
<td>1</td>
<td>3.95</td>
<td>3.95</td>
</tr>
<tr>
<td>12</td>
<td>SD Card with Adapter (16GB)</td>
<td>1</td>
<td>9.98</td>
<td>9.98</td>
</tr>
<tr>
<td>13</td>
<td>Micro USB</td>
<td>1</td>
<td>1.93</td>
<td>1.93</td>
</tr>
</tbody>
</table>

**Total Cost C$ 62.78**  
(Initial Cost)  

**Per Unit Cost 50.45**  

### Power Consumption of Developed System

**Overall System Cost Calculation**
### Power Consumption & % Error:

<table>
<thead>
<tr>
<th>Device</th>
<th>Voltage Source</th>
<th>Current Drawn</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32</td>
<td>3.3V</td>
<td>150mA</td>
<td>500 mW</td>
</tr>
<tr>
<td>Current Sensor</td>
<td>5V</td>
<td>12.5mA</td>
<td>62.5 mW</td>
</tr>
<tr>
<td>LM35</td>
<td>3.3</td>
<td>40mA</td>
<td>130.6</td>
</tr>
<tr>
<td>Voltage Sensor</td>
<td>5V</td>
<td>13mA</td>
<td>65 mW</td>
</tr>
<tr>
<td>SD-Card</td>
<td>3.3V</td>
<td>0.15mA</td>
<td>0.5 mW</td>
</tr>
<tr>
<td><strong>Total Power Consumption</strong></td>
<td></td>
<td></td>
<td><strong>758.6 mW</strong></td>
</tr>
</tbody>
</table>

#### Power Consumption of Developed System

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameter Name</th>
<th>Measured Value</th>
<th>Actual Value</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Battery Voltage</td>
<td>13.22 V</td>
<td>13.06 V</td>
<td>+1.07%</td>
</tr>
<tr>
<td>2.</td>
<td>Charging Current</td>
<td>2.06 A</td>
<td>2.16 A</td>
<td>-4.6%</td>
</tr>
</tbody>
</table>
Future Work:

- Larger PV and Community Based System
- Graphics on the Web Page
- File Removal Process for SD Card
- Database Option in the Monitoring App
- Customization for other Location
Publications:

- Abstract Accepted:

- Journal Submission (Ongoing):
Reference: (partial)


Thank You

The future is green energy, sustainability, renewable energy.
-Arnold Schwarzenegger