WIRELESS TRANSMISSION OF METERING DATA FROM A PHOTOVOLTAIC SOLAR HOME SYSTEM VIA GLOBAL SYSTEMS FOR MOBILE COMMUNICATION (GSM) SHORT MESSAGE SERVICE (SMS)

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Abstract
This paper focuses on the area of remote solar home system metering in an effort to bridge solar energy management in the industry with information technology (IT). A wireless platform was designed using ordinary mobile phone handsets to relay real time digital metering data from a remote PV solar home system via a GSM short message services to a central server (private computer). Here, we experimentally demonstrate the concept of a wireless data transmission of digital direct current (DC) metering data, based on simple and cost-effective telecommunication technologies through programmed microcontroller circuits that connects to two mobile phones (client and server sets).

A set of data was obtained through direct cable connection (meter-adaptor-PC) and also through wireless connection (meter-GSM-adaptor-PC). The microcontroller at the server end extracted and decoded data from the received SMS (for wireless connection) and relayed the data to the data adaptor. The applications software in the PC downloaded the data from data adaptor and grouped it into clusters. Statistical graphs were plotted from the clustered data and real time virtual metering data was displayed at the PC.

From the results, data received from the wireless transmission mode matched the real time data on the meter display but with short time lapses due to SMS delivery delays. The data from direct cable connection was highly reliable because data streamed live from the meter to the data adaptor. It was also observed that the GSM-SMS was practical to the extent that programming errors were eliminated and the network is reliable enough to reduce data transmission inefficiencies. Further work on a dedicated, efficient, and an all-in-one meter with wireless transmission capabilities is required for wide scale adoption of the technology.
This technology can find applications in off-grid electrification where investors can sell power through aggregated solar home systems instead of establishing grid connected solar farms. Solar energy can also be quantified to qualify for clean development mechanisms so as to benefit from carbon finances.

Key words: PV solar home system, DC power meter, GSM, data adaptor software

1.0 Introduction

The Kenyan solar home systems' market is one of the leading off-grid solar markets in the world and the biggest on the African continent (Lay, 2012). Solar electricity in Kenya is widely used for households' applications such as television, radio and cellular telephone charging that helps improve communication (Buragohain, August 2012). An estimated 382,631 SHSs had been installed in the country by June 2012 with an annual growth rate of 15,000 units (Lay, 2012). Since this energy is not metered, this paper aims to design a GSM based wireless platform to facilitate data transfer from DC power meters in remote areas to a central server.

In order to keep track of the amount of energy consumed from solar systems for meter reading and data collection, good metering practice is a powerful tool which forms the basis of an effective energy management campaign (Carbon Trust, 2012). Energy data from solar home systems is very important for performance monitoring and also various applications such as solar power sale agreements and carbon finance programs (Carbon Trust, 2012).

Energy meter is a device that measures the amount of electrical energy consumed by a residence, business, or an electrically powered device (Omijeh, 2013). The rationale for installing energy meters is twofold: to control energy consumption/costs and to improve equipment energy use/reliability (Plourde, 2011). Modern energy meters provide effective means of data collection that allow substantial saving through the reduction of meter re-read, greater data accuracy, frequent reading, improved billing and customer service, more energy profiles and consumption trends updates and better deployment of human resource (Ismail, 2013).

Electric energy meters have undergone several advancements in the last decade (Jain, 2011). The conventional electromechanical meters are being replaced by new electronic meters to improve accuracy in meter reading (Karimi, 2012). Several researchers have come up with new technologies such as advanced metering infrastructure (AMI) which uses technology to capture and transmit energy use to a collection point on an hourly or sub-hourly basis in contrast to standard meters that provide a daily energy usage total and a cumulative monthly bill for smart grid (Karimi, 2012).

The relatively sparse research on direct current (DC) electricity metering has left room for further research in this area. Direct current (DC) electricity metering market is one of the most sophisticated and underdeveloped as compared to alternating current (AC) electricity. As a consequence, perhaps, the range of meters and data collection techniques available to consumers are fewer, making it difficult to not only have accurate energy readings, but also to readily access their consumption information to identify power input and output patterns (Carbon Trust, 2012).

It is well worth accessing the data, as they can be invaluable in identifying potential energy savings. The technology available for the transfer of consumption data from metering ranges from GPRS or GSM modems sending data bundles to a receiver, through low power radio technology to ethernet/internet interfaces (Younis, 2011). A robust telecommunication infrastructure combined with continued lowering cost of GSM-SMS transmission makes the system more cost effective in future. SMS can be sent between users or to and from an application, which gives service development an extra flexibility that encourages innovation (Younis, 2011). The GSM network is designed to be compatible with future technology upgrades such as GPRS, third generation (3G) and Long Term Evolution (LTE) cellular telephony (Younis, 2011). Thus, investments in this area are relatively safe in the medium to long term. GSM network is inherently digital which makes it secure, relatively error-free, and jamming-proof. There are a variety of applications wherein the GSM network can be useful for industrial use, and most of these are in the realm of Data (Younis, 2011) and can find applications in solar energy monitoring, energy management, and carbon finance platforms.

Abundance of sun energy around the world coupled with advancing technology of PV technology, falling prices of solar PV systems, the need for emissions reduction and a fledging carbon market and finance heralds a bright future for solar power. Therefore, there is a growing demand to develop a technology that will aid in advancing solar industry towards current trends such as taping carbon finance for small solar users.

2.0 Materials and Methods

2.1 Project Setup

The idea in this project is not to replace the existing energy meters, but to incorporate a GSM data transmission platform to existing digital meters. Thus, our design primarily has a digital DC power meter with data logging capability to measure and record metering data with an LCD display to display power output, DC energy loads (phone chargers, AC/DC television, and energy saving bulbs), charge controller, 75Ah battery, GSM mobile phones, Programmable Logic Controller (PLC) circuits (client and server), Personal Computer (PC) data adaptor, and applications software to store and generate statistical graphs and virtual metering data display at the PC. A solar PV home system consists of a 50Wp solar PV panel, and a balance of system to mount the panels.

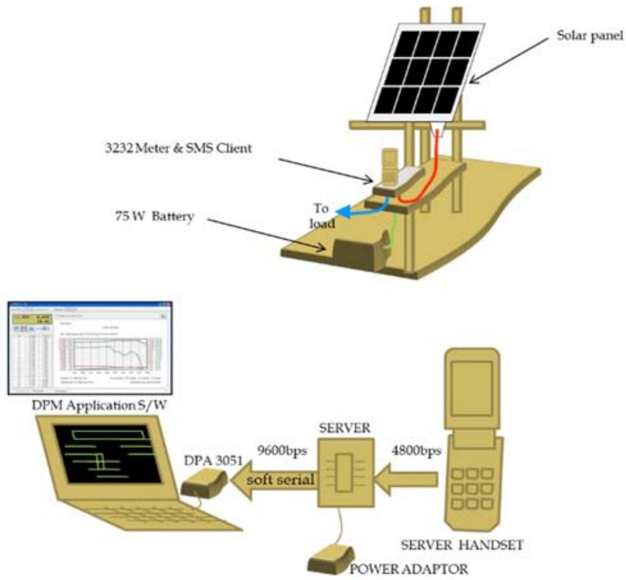


Figure 22. Demonstration setup

2.1.1 Digital DC Power Meter

A digital DC power meter measured the real time DC Voltage, DC Current, Watts, and it also displayed the Amp-hour, Watt-hour and Time. The power meter was powered by the input voltage with a minimum 5V DC. The Power Meter Memory stored up to 1,500 sets of data even when the Power Meter was switched off.

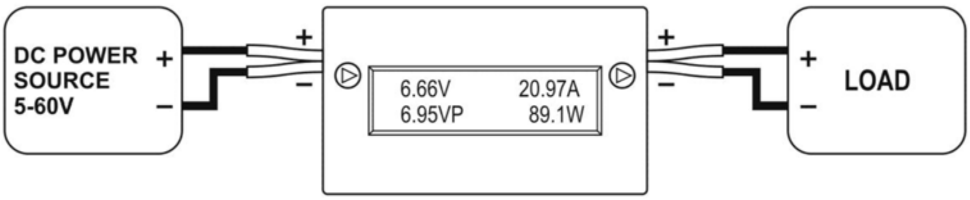


Figure 23. Digital power meter

2.1.2 Programmable Logic Controller (PLC)

Client and Server side ATmega PLCs were programmed via Arduino IDE to query for data from the meter and to convey the data to the adaptor. The PLC sent/received and decoded instructions to/from the phone in form of attention (AT) commands. Figure 3 below shows the ATmega PLC architecture.

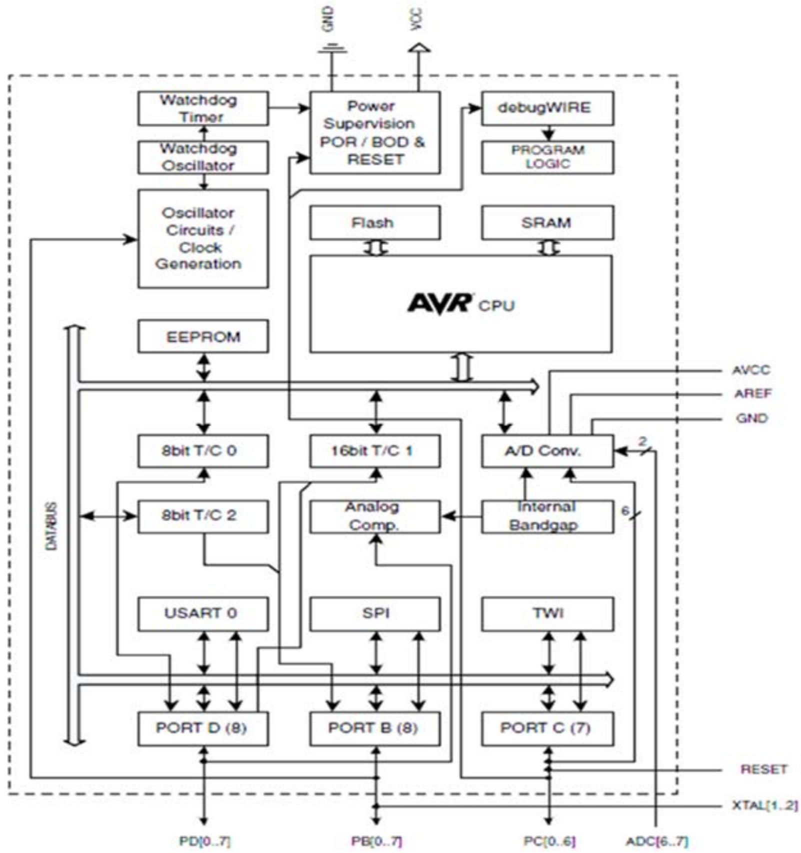


Figure 3 Programmable Logic Controller

The meter and the data adaptor communicate with the PLC using a 9600 bps Universal Asynchronous Receiver/Transmitter (UART) serial signal. Two Motorola W220 sets were used as the SMS modem at the client (TX) and server (RX) ends. Data was sent across the mobile phone's UART port at 4800bps.

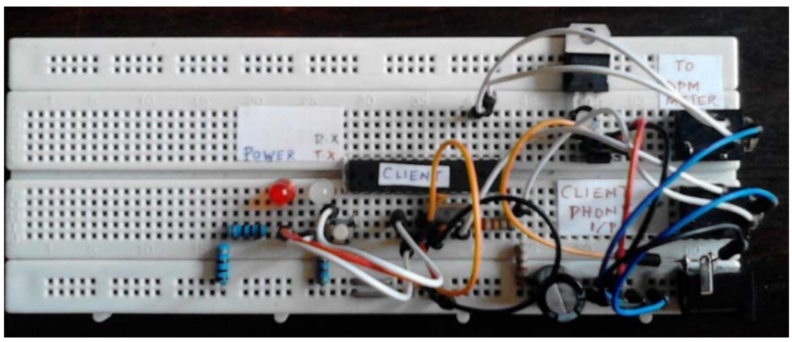


Photo 1. Client Programmable Logic Controller

The PLC hardware was setup as shown in photo 1 above. The AC power adaptor to server was connected and the voltage set at 7.5 to 12V with correct polarity

observed. The SIM cards were inserted to the server and client handsets respectively and the handsets switched on. Next, as a cost saving measure, 200 SMS bundles were purchased.
Before powering on the server and client, messages from both the client and the server were cleaned up. The data adaptor connected to PC through USB 2.0 standard. The application software retrieved data from DPM-3232 and DPM-3221.

Photo 2. Hardware Demonstration Setup

2.2 Data extraction from SMS

A String handling C++ PLC program at the server end extracted data from the received SMS for every separator character encountered. For instance, V13.5, A3.3, W44.55K where variable 13.5 is the panel voltage, variable 3.3 is the panel current level, 44.55 is the power output and Character 'K' marks the end of the command.
The three variables were stored in the PLC memory for extraction while an AT+CMGD command was sent to clear the SMS memory once it had been correctly decoded so as to accept more data. A query signal was then sent back to the client for the next update. Once the three values (V, I and P) were extracted, they were arranged into a format acceptable to the data adaptor and hence the DPM software.

3.0 Results

The client hardware was switched ON while connected to the solar meter in full sunlight. The client circuit received power for the solar panel. The meter displayed the voltage, current, power, time, peak Watt and Watt hour. The client power LED lamp gave a bright RED glow while the TX/RX Lamp blinked yellow 3 times and remained yellow for a few seconds and then started to blink GREEN indefinitely. A confirmation SMS indicating that the remote meter logging system had been initialized was sent to an auxiliary phone (personal phone) as programmed**.**

The server circuit was switched on. The circuit was powered by an AC power adaptor. The RED lamp switched on while the rest of the lamps blinked immediately after which the virtual meter displayed zeros for one second then went blank and indicated connection OK in green on the top left. The YELLOW (transmit) lamp remained on for a few seconds and later went off. The GREEN (receive) lamp started to blink.

After a few seconds the server received data and since the data was valid, the BLUE lamp turned on and the data was displayed on the PC for about five minutes (as the ORANGE clock lamp ticked by). After five minutes the cycle was repeated with fresh data being sent for every update. An SMS was also sent to the user containing the data received.

A set of data was obtained through direct connection (meter-adaptor-PC) and also through indirect connection (meter-GSM-adaptor-PC). The primary variables transmitted to the application software from the meter were: voltage, current and time. The other variables (secondary) derived by the software from the primary variables were: Power in Watt and Ampere hour. The applications software downloaded the data and grouped it into clusters titled group1, group2, group3 etc. as illustrated in Tables 1 and 2 in the appendices.

Data was recorded in GSM-SMS transmission connection mode after every five minutes (averaged for the five minutes). This was done to account for SMS delay in delivery. On the other hand, direct data transmission was programmed to transfer data averaged on a three minute interval. Therefore, data from a direct connection gave a more detailed metering information.

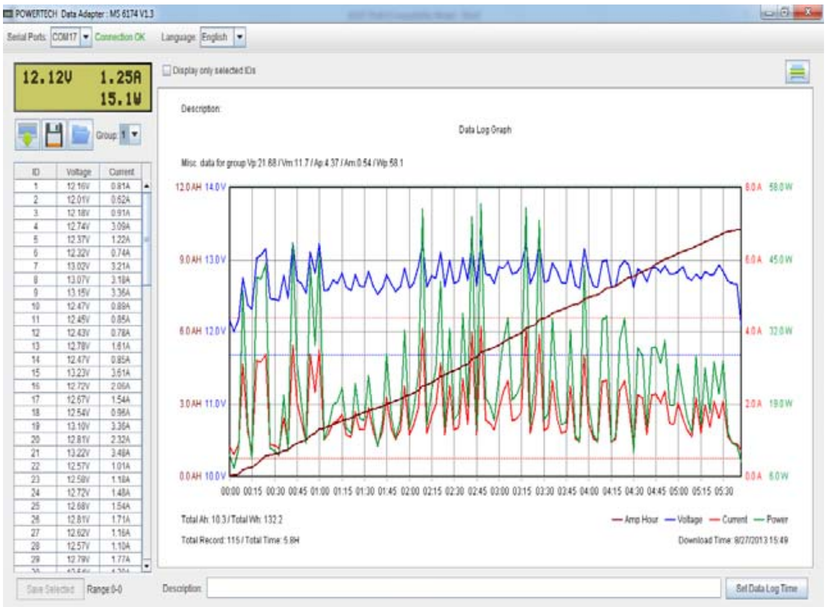
It is worth noting that a graph of the previous data received could only be plotted when the BLUE lamp was ON (meaning that the virtual meter was displaying valid data). After receiving at least 10 data updates, a graph was generated automatically after pressing the download button on the DPM application. The graph appeared immediately. The graph was also generated manually after receiving two data updates. The lamps on server went on high and the voltage/current data uploaded to the application and then the graph appeared. The graph data was saved for future reference by pressing the save button and naming the file location.

The applications software facilitated analysis, recording and saving of this data. The data were used to generate graphs on primary and secondary variables. Its use significantly increases data interpretation and presentation.

Data Log Graph 1 presents a graph generated from data downloaded from the meter by the application software when using GSM-SMS transmission mode. The data table is presented in Data Log Table 1 in the appendices.

Graph 1. Data Log Graph generated by the applications software using data downloaded in GSM-SMS transmission mode

Data Log Graph 2 presents a graph generated from data downloaded from the meter by the application software when using direct cable connection mode. The data table is presented in Data Log Table 2 in the appendices.



Graph 1. Data Log Graph generated by the applications software using data downloaded in direct cable transmission mode

Results obtained using the two different data transmission modes cannot be correlated as they convey data from the same source (meter memory). However, the results do match the data displayed on the LCD screen of the meter for both connection modes.

4.0 Discussion and Conclusions

The goal of this project was to design a GSM-SMS data transmission based mode that sends solar metering data remotely to a server using SMS. The proposed design has been successfully implemented and tested on a mobile telecommunication infrastructure which catered for two way communications between the client and the server. Results obtained indicate some level of unstableness in the transmission system.

The graphs generated from download data plots primary and secondary variables against time. The Data Log Graph 2 generated from data obtained through direct cable transmission mode was more detailed and elaborate because there was more data downloaded than was the case with data downloaded using GSM-SMS transmission mode within the same period. The two modes of transmission are slightly different in that when using the direct data cable connection, the data streams live to the application software display and had a shorter time interval of three minutes between results. On the other hand, when using the GSM-SMS connection, the data is discrete and the application software display has a short time lapse due to SMS transmission delays. Possible explanations for the inefficiency of the transmission system are programming errors and poor network coverage leading to inconsistency in data delivery and slow data download rate from the meter. Overall, the differences are significant in reliability and illustrate the need to work on efficiency of transmission and downloading of meter data.

This project has demonstrated how the solar industry can adopt an appropriate level of GSM-SMS transmission to receive real time data on performance and energy production patterns of solar home systems in remote areas to a server. There is a motivation for research in an all-in-one dedicated metering unit with data logging and GSM/GPRS transmission capabilities.

Efficiency in transmission, recording and analyses of the data can have the added advantages of allowing companies to monitor energy consumption patterns, identify solar panel performances and highlight areas that can be improved. This can find applications in off-grid electrification where investors can sell power through metered home solar systems instead of establishing grid connected solar farms. More benefits such as provision of a platform for aggregating solar home systems to access carbon finance by selling solar carbon credits will arise. The authors hope that this proposed design will be useful for the solar industry to realise more potential benefits from the solar home systems.

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7.0 Appendices

Data Log Tables

Data Log Table 10: Data downloaded from the solar meter when using GSM-SMS transmission mode

File Type: DPM Data Log			
Download Time: 8/29/2013 05:20			
Group0001	Description:		
Group0001	Data log Time:		
Group0001	PPP:00.00 Vp00.00Ap00.00Vm00.00Am0.0Wp		
Group0001	ID	Volt	Curr
Group0001	1	13.41V	1.6A
Group0001	2	13.43V	1.6A
Group0001	3	13.46V	1.6A
Group0001	4	13.49V	1.6A
Group0001	5	13.52V	1.6A
Group0001	6	13.57V	1.6A
Group0001	7	13.64V	1.6A
Group0001	8	13.73V	1.6A
Group0001	9	13.88V	1.6A
Group0001	10	14.08V	1.6A
Group0001	11	14.29V	1.18A
Group0001	12	14.25V	1.24A
Group0001	13	14.10V	1.00A
Group0001	14	14.11V	1.04A
Group0001	15	14.18V	1.26A
Group0001	16	14.17V	1.14A
Group0001	15	14.09V	0.88A
Group0001	16	12.88V	0.00A
Group0001	15	12.77V	0.00A

Data Log Table 2: Data downloaded from the solar meter when using GSM-SMS transmission mode

File Type: DPM Data Log			
Download Time:8/29/2013 05:20			
Group0001	Description:		
Group0001	Data log Time:		
Group0001	PPP:00.00Vp000.00Ap00.00Vm000. 00Am00000.0Wp		
Group0001	ID	Volt	Curr
Group0001	1	12.16V	0.81A
Group0001	2	12.01V	0.62A
Group0001	3	12.18V	0.91A
Group0001	4	12.74V	3.09A
Group0001	5	12.37V	1.22A
Group0001	6	12.32V	0.74A
Group0001	7	13.02V	3.21A
Group0001	8	13.07V	3.18A
Group0001	9	13.15V	3.36A
Group0001	10	12.47V	0.89A
Group0001	11	12.45V	0.85A
Group0001	12	12.43V	0.78A
Group0001	13	12.78V	1.61A
Group0001	14	12.47V	0.85A
Group0001	15	13.23V	3.61A
Group0001	16	12.72V	2.06A
Group0001	17	12.67V	1.54A
Group0001	18	12.54V	0.96A
Group0001	19	13.10V	3.36A
Group0001	20	12.81V	2.32A
Group0001	21	13.22V	3.48A
Group0001	22	12.57V	1.01A
Group0001	23	12.58V	1.18A
Group0001	24	12.72V	1.48A
Group0001	25	12.68V	1.54A
Group0001	26	12.88V	1.71A
Group0001	27	12.62V	1.16A
Group0001	28	12.57V	1.10A
Group0001	29	12.79V	1.77A
Group0001	30	12.68V	1.30A
Group0001	31	13.22V	3.48A
Group0001	32	12.57V	1.01A
Group0001	33	12.58V	1.08A

File Type: DPM Data Log Download Time:8/29/2013 05:20			
Group0001	34	12.72V	1.18A
Group0001	35	12.63V	1.24A
Group0001	36	12.81V	1.71A
Group0001	37	12.62V	1.16A
Group0001	38	12.57V	1.00A
Group0001	39	12.77V	1.37A
Group0001	30	12.68V	1.20A
Group0001	41	13.22V	1.48A
Group0001	42	12.57V	1.21A
Group0001	43	12.58V	1.28A
Group0001	44	12.72V	1.08A
Group0001	45	12.18V	1.04A
Group0001	46	12.81V	1.11A
Group0001	47	12.62V	1.16A
Group0001	48	12.57V	1.10A
Group0001	49	12.19V	1.17A
Group0001	50	12.60V	0.90A