

New Approach on Solar Water Heater Energy Smart Metering System Using Adafruit Feather 32u4FONA

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Abstract—These days consuming and saving Energy efficiently it is becoming a major issue because the need for energy is increasing day by day. In this paper, one of the solution was to replace water electric heater by solar water heater, and hence elaborate an option where instead of paying the installation of the system, the domestic energy consumer pays the solar energy consumed while boiling the water from cold state to hot state. The goal of providing such data is to optimize and reduce their power consumption. The Energy Meter proposed here deals with the measurement of cold and hot water temperatures, the quantity of water used and hence calculate the energy being consumed by a consumer thereafter sends data to the provider's message box who finally prepares the bill.

Keywords—Smartmeter; Energy; Solar water heater; Messages; Adafruit Feather 32u4FONA

I. INTRODUCTION

Solar water Smart Energy Management solution increases self-consumption, reduces electricity bills and provides greater user convenience. The solution integrates solar energy, storage management and home energy management under the use of this energy in the form of heat to boil water [1]. In this study, Solar energy usage and storage is maximized by letting the water being heated during the day and be used at night and in morning as it is obviously need. This can be one of the most advantageous system, as it lets the stored energy to be used when needed [2]. Around five solar water heaters were installed and each of them was equipped with a smart metering system. The project is still under development where an auto generated bill system and online payment are being developed. As seen, there was a successful achievement where around 40 customers are now requesting for this new system because for them it is cheaper and efficient if compared to the existing one which requires to pay the total amount for the installation [3].

II. RESEARCH ELABORATION

A layout depicting the flow of the process in the Solar Water Heater Energy Smart meter system is as shown in Fig.4 for easy selection of system main components [4].

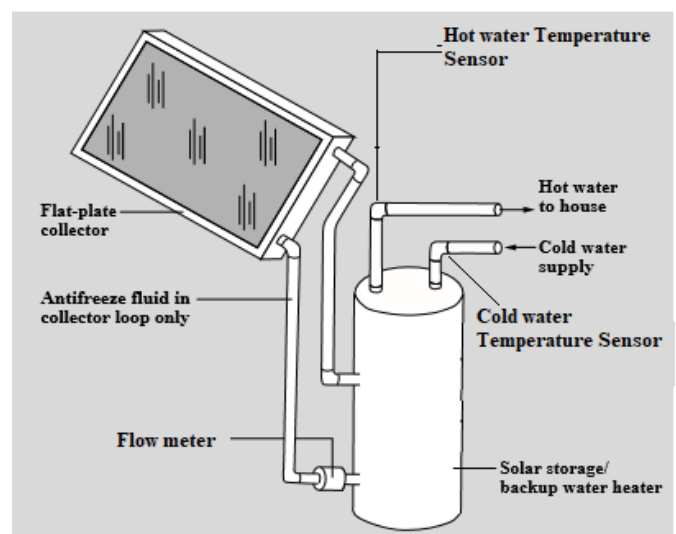


Fig. 1. Process mechanical part

Figure 2 also, shows the process block diagram for clear illustration of input and output of the system, where all electronic devices that were used are shown.

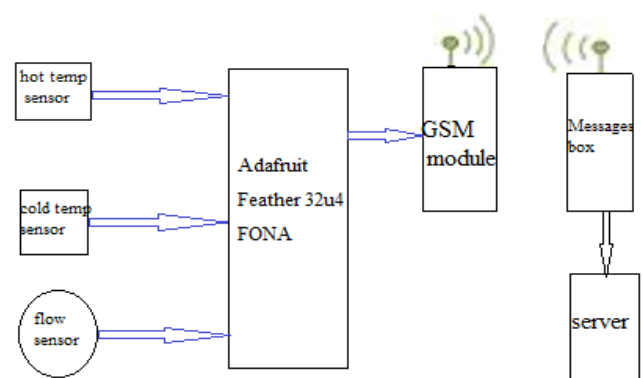


Fig. 2. Process block diagram for clear illustration of input and output of the system

The system consists of a single Flat plate collector with a storage tank [5] and an energy smart meter system as shown in figure 3 below.

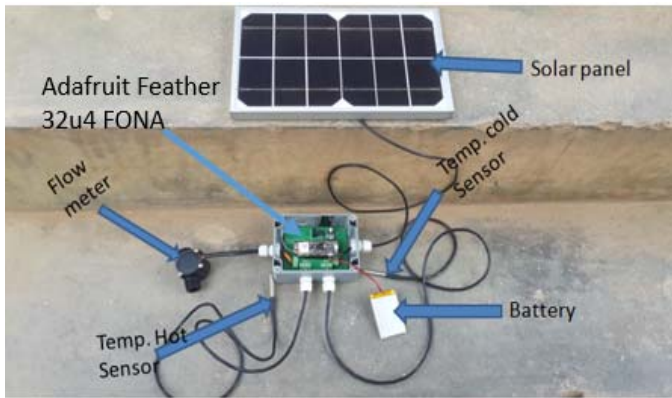


Fig.3.Smart meter system devices identification

The supplied cold water is circulated through the Flat collector and is boiled by the collected solar radiation and hence is transferred to the solar storage tank to be used for household purposes. The addition of a smart meter system, which is the main purpose of this study, is to increase to be able to charge only for the energy consumed not for the installation of the system [7]. To be able to calculate the energy, the below devices were considered in this work.

1) *Cold and hot water temperature sensors*: They are used to capture the temperature of input cold water and output hot water so that the system can be able to calculate the energy consumed by taking the difference in temperature change using the below equation (1), like it is done in calorimetry[8].

$$T_2 - T_1 = \Delta T \quad (1)$$

Where T_2 is the temperature of hot water and T_1 the temperature of cold water

2) *Flow meter water*: It is used to measure the consumed amount of water in liters and hence helps the system to get the mass of water used where the system takes the volume the liters consumed multiply by the specific gravity of water to get the mass [9][10]. Finally the energy is calculated by converting the amount of calories gained by the water into Joules, where the Calories (Q) is calculated using Calorimetry formula in

$$Q = Cm\Delta T \quad (2)$$

With, Q=Quantity of gained heat in Calories

C= Mass Specific heat capacity of water in

[$J \times Kg^{-1} \times K^{-1}$]

J=Joules

Kg=Kilogram

K=Kelvin.

3) *Adafruit Feather 32u4FONA* : Adafruit Feather 32u4 FONA is the new development board, which is an 'all-in-one' Arduino-compatible + audio/sms/data capable cellular with built in USB and battery charging [6]. Adafruit Feather 32u4FONA with GSM module is shown in figure 4 below



Fig.4. Adafruit Feather 32u4FONA with GSM module

This helped to send data to the message box so that the Energy consumed can be metered remotely.

4) *Message box*: As the purpose of this work was to measure the solar energy used to boil water from temperature T_1 to T_2 the message from metering system, are sent to this box which is connected to the Server and messages are accessed by using a computer with PuTTY software installed as shown below in figure 5 [11]

```
mysql> show databases;
+-----+
| Database |
+-----+
| information_schema |
| PowerRwanda |
| mysql |
| performance_schema |
+-----+
4 rows in set (0.00 sec)

mysql> use PowerRwanda;
Reading table information for completion of table and column names
You can turn off this feature to get a quicker startup with -A

Database changed
mysql> show tables;
+-----+
| Tables in PowerRwanda |
+-----+
| SMSRecords |
| customersIMEI |
+-----+
2 rows in set (0.01 sec)

mysql>
```

Fig.5. Accessing SMS Records

The message box and the server are also shown in the figure 6.

DHCP. Address was 172.16.0.3
 Center connector: the server address is 10.10.10.10.
 It was only connected for debug
 Right connector: the address was 192.168.2.10.
 It was connected to the SMS Box.

The Message box receiver has no programming. It has to be considered as a "Black Box".

The IP address programmed was: 192.168.2.1, it was connected directly to the main server.

The message box receiver had number: +250 78 468 91 78

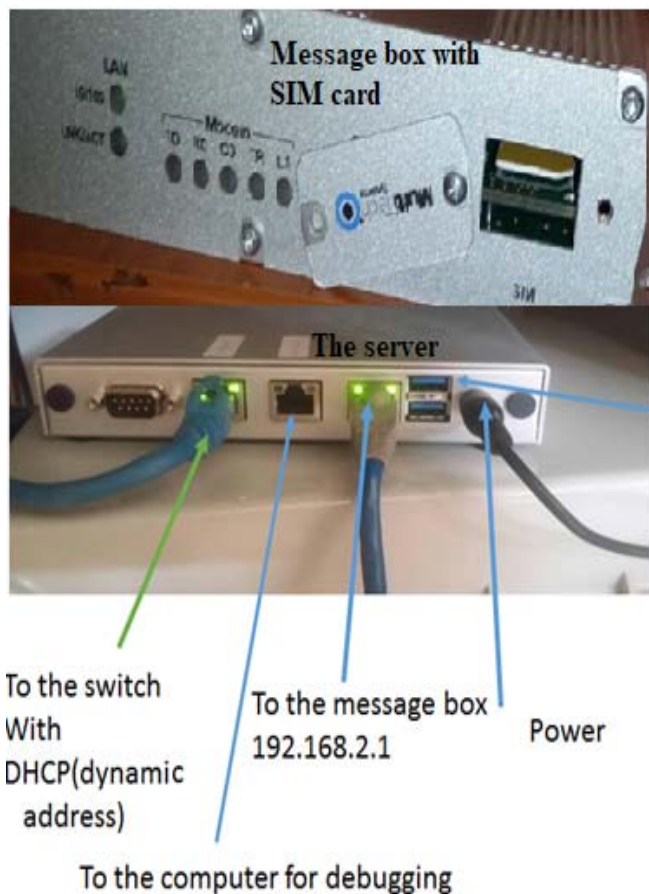


Fig.6.Message box and the server

III. SMART METER SYSTEM LAYOUT

As explained, the customers are not required to pay for the solar water heater installation. This is the result of the development of a smart metering system which calculates the energy consumed by basing on the cold and hot water temperature then sends the message to the provider in order for him to prepare the bill [12] [13]. Some components were required and using MULTSIM software, the smart meter system circuit was developed and printed as a PCB.

The shown figure 7 below, represents the designed smart meter layout with the allocation of all the components.

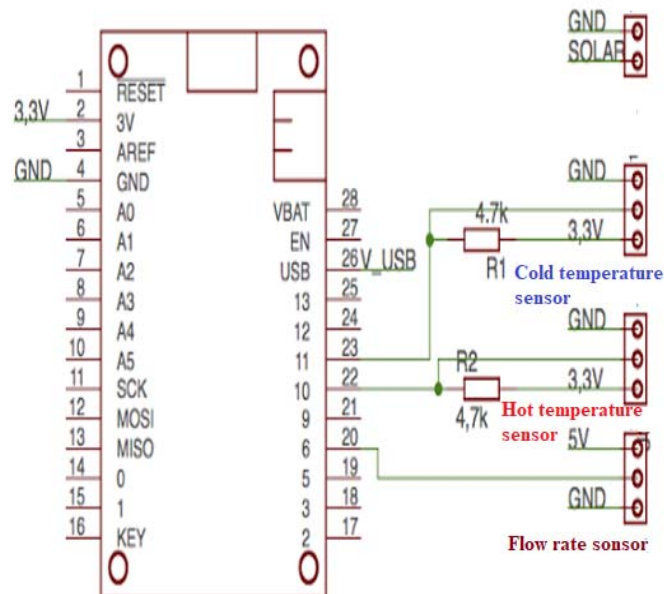


Fig.7.Schematic of the smart meter system before its printout

Also, the printed circuit is shown in figure 8. As it is shown the Printed Circuit Board was designed and printed for IPRC which the institution that is proving this service.

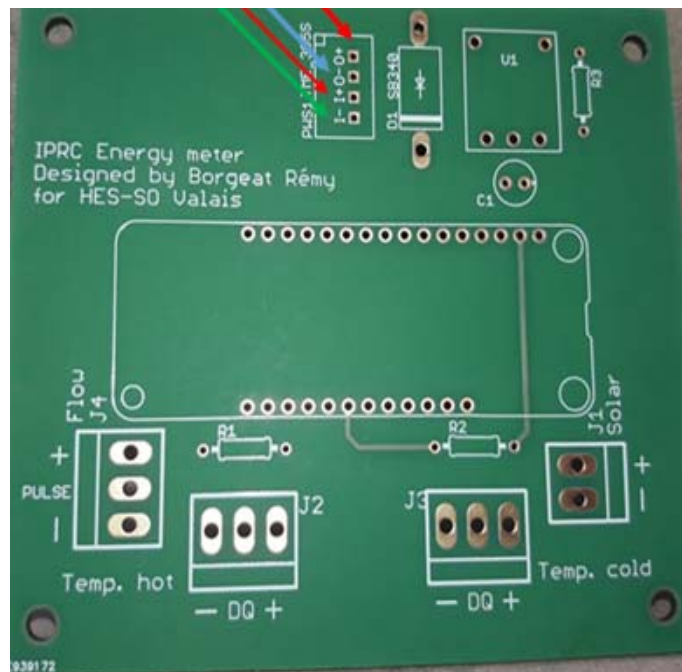


Figure 8: PCB Layout after printout

In addition, figure 9 shows the printed circuit board after soldering the auxiliary components which are for example the connector for solar PV supply, cold and hot temperature sensors connectors, the voltage regulator and the flow meter [14].

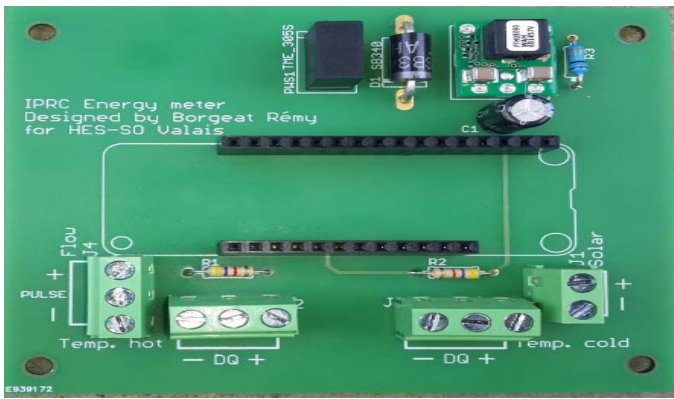


Figure 9: PCB view with all the components soldered in the correct position

IV. FLOW CHART OF THE ALGORITHM USED TO REGULATE THE SYSTEM

The proposed control mechanism gives a solution to energy transfer control and visualization of energy units consumed. Water heater solar energy measuring system implemented, requires an adapter of communication for transmitting and receiving their data so that they can be analyzed and interpret by the service provider during bill preparation period.

The data collected from each meter located to different customers, must reach reliably and securely to the service provider (in this project the seller of energy is the Integrated Polytechnic Regional center), for billing and analyzing. In another way any command from provider office that addresses each location of the customer and each meter box must arrive reliably and securely to its target and vice-versa.

Micro-controller (which is Adafruit Feather 32u4FONA in the developed project for this paper) based hardware unit was developed with additional message box communication in receiving transmitted data where messages are sent to the specific number of the SIM card of the message box [15]. Data is sent to the message box located in IPRC using GSM communication module and then it is transferred to central computer (server) through Ethernet cable then after collected through with the ZigBee or other communication cable or wirelessly by using putty software as shown in figure 10. The software was developed in Arduino to proceed the proposed billing procedure.

The shown figure 10 below is the flow chart of the algorithm used to regulate the system.

Also, database can be generated to store the details of the consumers and then whole system can be operated as fully automatic system.

As the further work, Pages can be created in VB for billing information and smart communication with the consumer and then the detailed information can be sent on E-Mail and also via SMS to give reminder of cut-off date of billing when the customer has delayed in paying the required amount.

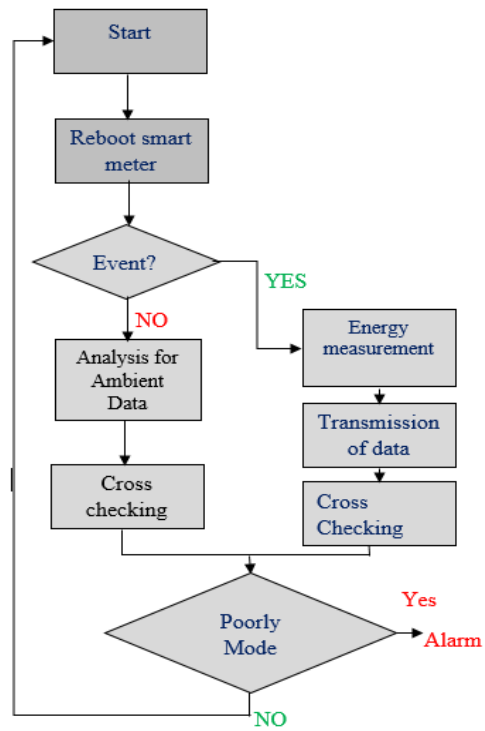


Fig. 10. the flow chart of the algorithm used to regulate the system

PuTTY as a free and open source SSH client for Windows and UNIX systems, provided easy connectivity to our server running an SSH daemon so we could work as if we were logged into a console session on the remote system. SSH tunnels allowed the user to access network services running on a remote server though a secure channel. The user could use tunneling to securely access a MySQL server running on a remote server.

The figure 11 below shows the first step to access the server where the IP address of the server was set to be 168.16.03.0

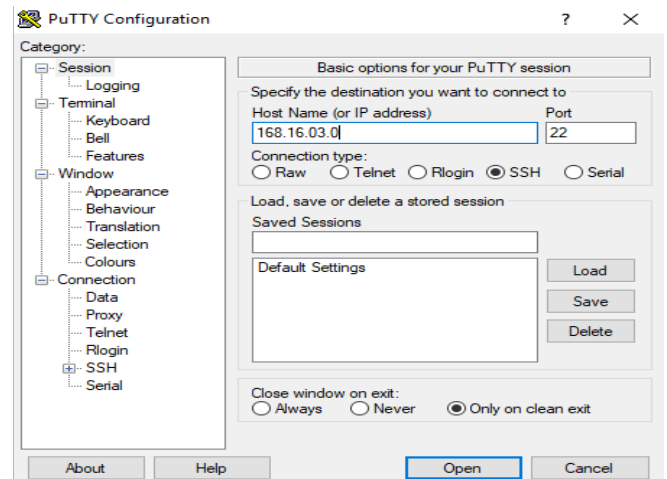


Fig. 11. Entering the system to collect sent messages

V. HARDWARE IMPLEMENTATION

Hardware implementation of the proposed system is as shown in Fig. 12 to Fig. 15. Around five solar water heaters were installed and each of them was equipped with a smart metering system. The project is still under development where an auto generated bill system and online payment are being developed. As seen, there was a successful achievement where around 40 customers are now requesting for this new system because for them it is cheaper and efficient if compared to the existing one which requires to pay the total amount for the installation.



Fig.12.Fixing the solar water heater on the roof of house

As shown in figure 12, technicians are installing the new developed solar water heater. Here, it was at one of Hotels whose name is Home Saint Jean.



Fig.13.Already fixed solar water heater

The picture shown in figure 13, is an already installed system where now the client are enjoying the boiled water for washing their body either in the morning or in the night.



Fig.14.Smart meter system installation

The figure 14 above shows the new developed system when technicians were fixing the smart meter system.



Fig.15.Solar water heater with Smart Meter System

As shown in figure 15 above, the system is under testing. The water here is now boiled and can be used to wash the body.

VI. RESULTS

Smart Meter communicated with the server through SMS. Each time a message was sent, it was sent to +250 78 468 91 78 and there was 2 different messages:

1) Reboot of the SmartMeter

The message was looking liked this:

FONA "866224026678804" has restarted

Signification: "866224026678804" is the IMEI of the modem of the SmartMeter

2) Transmission of data (Energy measurements)

The message was looking like this:

"16/09/12,22:03:31+08";"866224026678804";"8925010000226140927f";"79%";"96dBm";"38.88degC";"17.19degC";"356.42L";"217096190.00Wh"

a) Signification:

Date and time: 16/09/12, 22:03:31+08

IMEI: 866224026678804

CCID: 8925010000226140927f

Battery: 79.0%

GSM signal strength: -96.0

Hot temperature: 38.88°C

Cold temperature: 17.19°C

Total liters: 356.42L

Total energy: 2.17096192E8

The shown table 1 below shows the output of the smart meter after retrieving the data from SMS box.

TABLE I. RESULTS FROM SMART METER

```

ccid | battery | network signal | T1 | T2 | liters | ener
gy |
-----+-----+-----+-----+-----+-----+-----+
| 5 | 2017-11-02 09:43:04 | N | 04/02/27,01:47:12+08 | +250787053108 |
8925010000256985837f | 100 | -54 | 32.44 | 32.94 | 3248 | 4925
5.5 |
| 5 | 2017-11-02 21:44:03 | N | 04/02/27,13:48:01+08 | +250787053108 |
8925010000256985837f | 79 | -54 | 21.31 | 19.88 | 3359.64 | 5234
8.7 |
| 5 | 2017-11-03 09:45:03 | N | 04/02/28,01:48:52+08 | +250787053108 |
8925010000256985837f | 99 | -54 | 33.44 | 33.19 | 3365.8 | 5234
8.8 |
| 5 | 2017-11-03 21:46:05 | N | 04/02/28,13:49:41+08 | +250787053108 |
8925010000256985837f | 80 | -54 | 21 | 19.81 | 3415.19 | 5325
5.6 |
| 5 | 2017-11-04 09:47:04 | N | 04/02/29,01:50:32+08 | +250787053108 |
8925010000256985837f | 99 | -54 | 29.25 | 35.88 | 3482.68 | 5370
1.1 |
| 5 | 2017-11-04 21:51:03 | N | 04/02/29,13:51:20+08 | +250787053108 |
8925010000256985837f | 78 | -54 | 22.06 | 19.25 | 3551.35 | 5426
    
```

Here, the table retrieved had seven columns.

Column number one is for the CCID which is the chip card identification. For example in these results a smart meter chip card number five was used and its location was at Hotel Saint Jean as it is shown in table 2.

TABLE II. RESULTS FROM SMART METER

Device #	Customer place	IMEI	Phone # Card #	Remark
1	IPRC West Kitchen panels	86287703440 3186	0789815397 1000025838810	PUK 33884747
NA	IPRC West SMS Box	01120100115 8998	0784689178 1000023779718	PUK 19658033
2	Home Saint-Jean	86287703338 6705	0784584795 1000023725700	PUK 52922397
3	Home Saint-Jean	86287703334 9547	0784584809 1000023725710	PUK 02799697
4	Home Saint-Jean	86287703336 1047	0785541979 1000024069087	PUK 63115699

Column number two shows the battery status every time the message is sent. As an illustration here, the battery was full charged (100%) on the 2nd, November 2017 at 09:43:04 and at 21:44:04, the battery was at 79% charging.

If we can have a look at column number 4 and 5, we can have the value of hot and cold water temperatures while column 6 and 7 are there for giving the number of liters consumed and the energy gained to boil water from cold state

to hot state, and this is energy to be used for elaborating the bill as shown below.

Provider Address

Address client

Date

Reference: Solar Boiled Water

Client Number: 005

Bill No: 25

Month: September

Period 01.09.2017:00h00m - 30.09.2017:23h59

Previous Index: 4520kWh

New index: 5043kWh

Consumed Energy: 523 kWh

Reference Price: 180 FRW

Total Amount to be paid: 94,140 FRW

Account Number: Hidden

Signature:

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