Energy Meter (E-MON) With IoT Monitoring (Web & Apps)

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ABSTRAK

This paper explains the design and implementation of smart socket energy monitor using the widely used microcontroller Arduino, LCD Display with capability of monitoring via web and application. Nowadays as electric utilities used electric meters installed at customer premises to measure energy consumption for billing purpose; demand for accurate meter reading is sought after. One of the ways in which today's energy problems can be overcome through the reduction of energy consumption in electrical household items. This has increased the emphasis on the need for accurate and economical measurement of energy methods. Energy Meter (E-MON) is used to monitor the usage of energy continuously while the load is connected to the socket. Major components used in this project are Arduino (UNO R3) board, SCT-013-00 current sensor,voltage sensor unit, LCD Display and Module Wi-Fi. In this project SCT-013-00 is used to detect the current and voltage sensor unit is used to detect voltage that goes through the load and socket. Arduino (UNO R3) will detect the input from current and voltage sensor while LCD will display the consumption of load in Voltage (V), Ampere (A) and Volt-Amps (W). This paper explains the process of design implementation and scale prototype and the challenges it faces in monitoring the value via IoT platform.

Keywords-component: *smart energy monitor, Arduino, current sensor, IoT*

1. INTRODUCTION

With the advent of more mechanical development and urbanization, energy has become a fundamental element in our everyday life. An electricity meter, electric meter, or energy meter is a device that measure the amount of electrical energy consumed by residence, business or an electrical powered device. A home energy monitor provides feedback on electrical energy use. Devices may also display cost of energy used, and estimates of greenhouse gas emissions. Various studies have shown a reduction in home energy use of 4-15% through use of home energy display [1].

A means to reduce household energy consumption is to provide real-time feedback to homeowners so they can change their energy use. In 2010, UK based Current Cost announced a partnership with Google PowerMeter, a former online tool that connected to Current Cost devices, enabling users to receive real-time energy information on their customized Google homepage, wherever they were [2]. Real-time data on how much energy is being consumed in the home was sent directly to the Google Power Meter. The free software tool then visualized the information for users to view on their own iGoogle homepage, a personal web portal which enabled individuals to create and access a wide range of customize information, web feeds and Google Gadgets.

The purpose of creating a monitoring meter is to create awareness about the energy consumption and thus the energy usage by the user can be optimized and reduce. Doing so reduce consumer energy costs, as well as converse energy. However, not all household items used the same amount of power. Incandescent light bulbs, kettles, irons, electric cookers are resistive loads while fridges, washing machines are partially reactive loads. By recognizing item and the power that they draw, preventive action can be taken such as:

i. When you boil a kettle, only use much water as you need
ii. Turn appliances off, don't leave them on standby
iii. Use energy-saving light bulbs

Energy Meter (E-MON) With IoT Monitoring a basic device which used a plug in socket so that it can measures one appliance energy used at a time. By simply plug in the appliance electrical plug to Energy Meter (E-MON), it can tell you how much the energy that individual item is using continuous while plug in. If you want to find out how much energy a group of appliances is using, such as a laptop, router and printer, you can plug a multi-socket adaptor or extension lead into the monitor.

The aim of this project is to implement a low cost energy meter with IoT capability to monitor the data from measuring system and transfer over Wi-Fi module and to web based cloud and display in smartphone apps. The paper organization is as follow: Section 2 presents the relation of electrical consumption and electricity cost, Section 3 presents the design of E-MON both hardware and IoT extensively, Section 4 is will address the finding of both hardware and IoT results, and lastly, Section 5, discuss conclusion and further work that can be suggested [3].

2. HIPOTESIS

2.1 Electricity Tariff

In discussing about power meter, which is to measure the energy consumption used, the usage of electricity is related closely to electrical tariff which is the system used in Malaysia to measure the cost of electrical consumption in every household. The current tariff for domestic consumer is shown as below [4]:

Table 1: TNB's Electrical Takriff for Domestic Household

	TARIFF CATEGORY	UNIT	CURRENT RATE (1 JAN 2014)
1.	**Tariff A - Domestic Tariff**		
	For the first 200 kWh (1 - 200 kWh) per month	sen/kWh	21.80
	For the next 100 kWh (201 - 300 kWh) per month	sen/kWh	33.40
	For the next 300 kWh (301 - 600 kWh) per month	sen/kWh	51.60
	For the next 300 kWh (601 - 900 kWh) per month	sen/kWh	54.60
	For the next kWh (901 kWh onwards) per month	sen/kWh	57.10
	The minimum monthly charge is RM3.00		

The cost of electricity is calculate monthly using a power meter readings at every households. The kilowatt per hour (kWh) used for that month will be applicable to the tariff and the rate will be multiply according to kWh used. The downside of using energy without caution will resulting in higher cost and rate as the table indicate. With E-MON, user can actually measure their energy usage, monitor them via android application and thus create more awareness and better practice in energy saving [5].

3. METHODOLOGY

Energy Meter (E-MON) With IoT Monitoring is divided into two categorize. The control system (hardware) and IoT development.

3.1 Control System (Hardware Design)

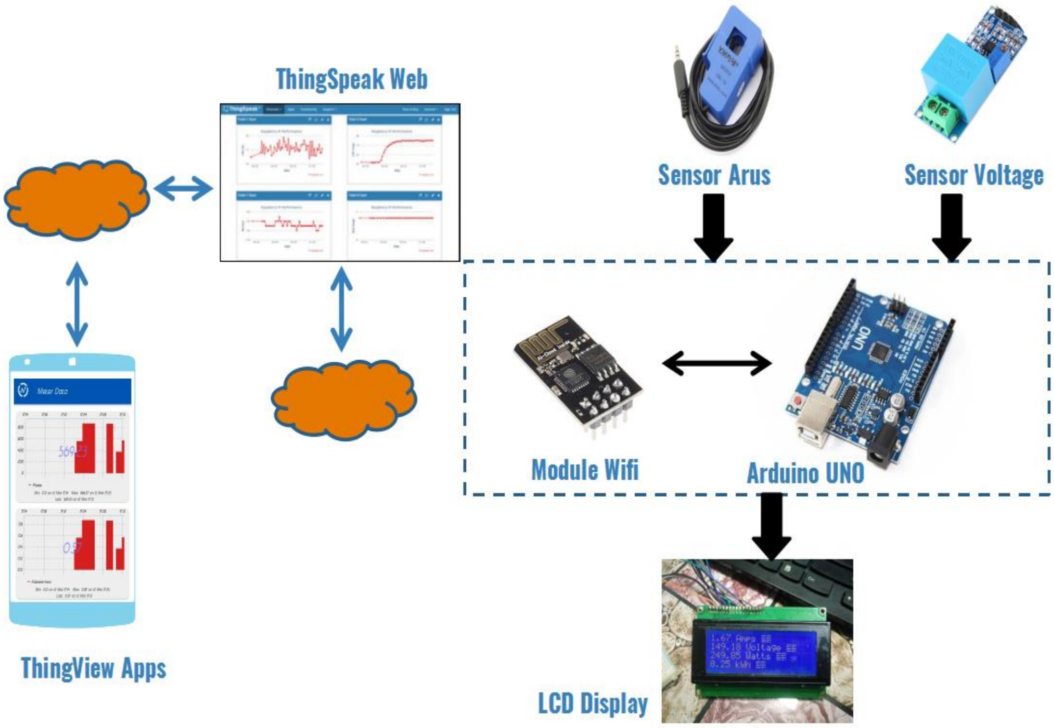

Figure 1: Energy Meter (E-MON) With IoT Monitoring Model

The control system has been designed to measure the voltage and current used by the load socket. The micro-controller than will calculated the RMS values and send to web or smarthone application via Wi-Fi Module. LCD display will also show the current usage for user convenient. The IoT development consist of sending the data from the control circuit into the cloud web which in this case *ThingSpeak* web was used. *ThingSpeak* is an open IoT platform with capabilities of MATLAB analytic to collect, analyze and act upon data transfer. For this project *ThingSpeak* was used to collect and analyze the data streams from control system in the cloud so user can monitor them using smartphone application.

3.1.1 Voltage Sensor

The voltage sensor ZMPT101B in Figure 1 used to measure the maximum AC voltage that used single-phase AC active output voltage mutual inductance module equipped series of high-precision voltage transformer and high-precision op amp current, easy to 250v within the AC power signal acquisition.

It's on board micro-precision voltage transformer is far better for measures, the the other method which used the regular converter [6], (transformer+rectifier+voltage divider) which can be dangerous if used without proper method. This voltage sensor also give a better reading even if the input signal is in square of triangular, however it will affect the RMS value. For this project purpose the same shape signal is assume when applying to Arduino. The output of the analog 0 to 5 V can be connect directly to Arduino pin.

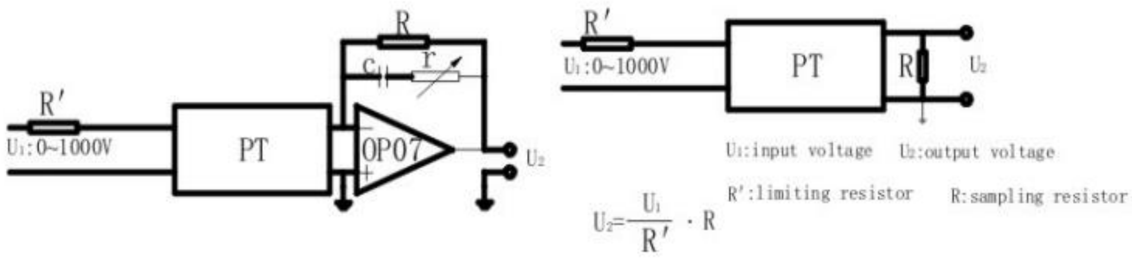

Figure 2: Wiring diagram of ZMPT101B

The main properties is shown in Table 2, and the output characteristic is shown in Figure 3. The relationship between RMS input and output voltage depend on the current-limiting resistor R used.

Table 2: ZMPT101B Main properties

Parameter	Value
Turns Ratio	1000:1000
Primary and Secondary Current	2 mA and 2 mA
Dielectric Level	3000 VAC/min
Frequency Range	50~60 Hz
Phase Angle Error	≤20°, (50 Ω)

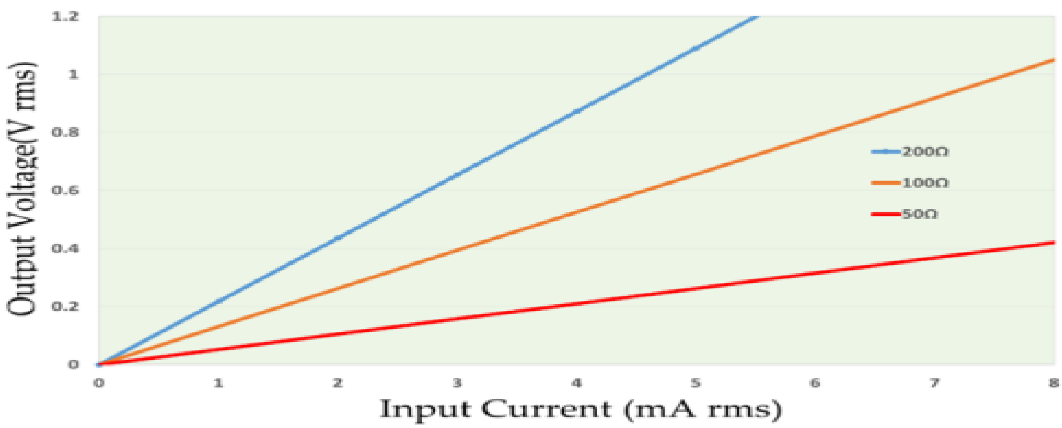

Figure 3: Output voltage and input voltage

3.1.2 Current Sensor

In this project a non-invasive current sensor SCT-013-00 such as in Figure 1 was used to measure alternating current (AC). The split core type, can be clipped onto either live or neutral wire that want to be measure, which in our case load socket of E-MON prototype without the need to do any high electrical work. It has a primary winding, a magnetic core and secondary winding.

The current in the secondary winding is proportional to the current flowing in the primary winding:

$$Isecondary = CTturnsRatio \times Iprimary$$

$$CTturnsRatio = Turnsprimary \,/\, Turnssecondary$$

Normally, this ratio is written in terms of currents in Amps e.g. 100:5 (for a 5A meter, scaled 0 - 100A) [7]. The ratio for the CT above would normally be written as 100:0.05. To connect a CT sensor to an Arduino, the output signal from the CT sensor needs to be conditioned so it meets the input requirements of the Arduino analog inputs, a positive voltage between 0V and the ADC reference voltage. Calculating the burden resistor is important in getting the accurate reading of AC current. 33 Ω was used for R1 and R2 in this project.

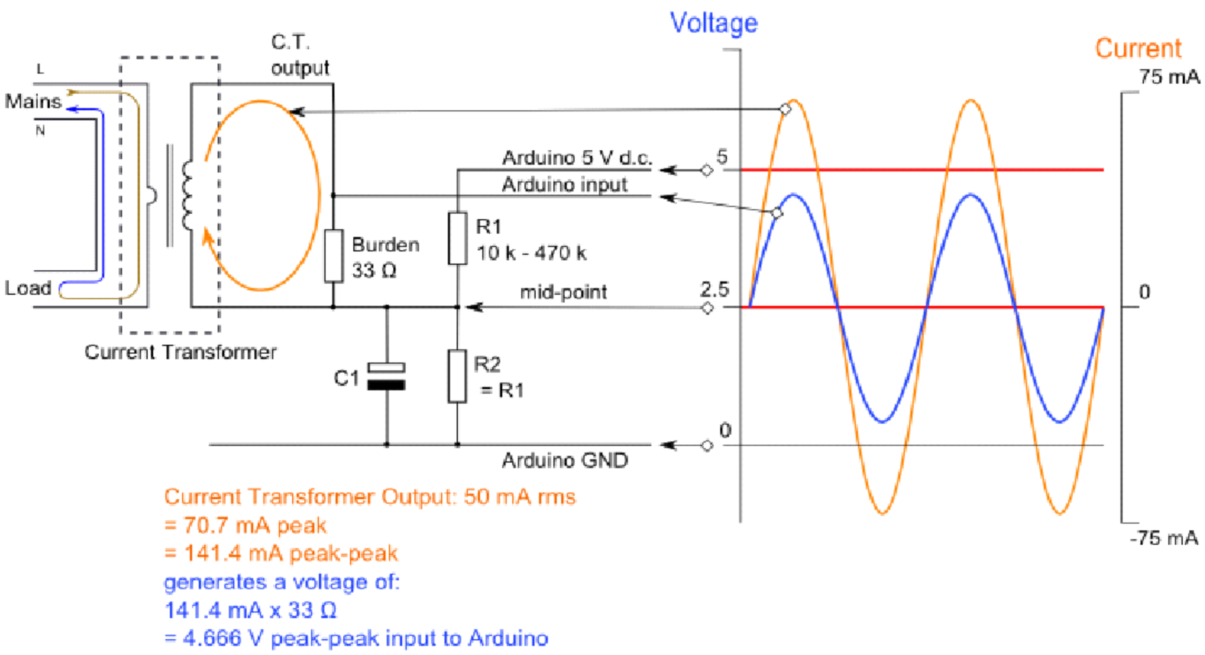

Figure 4: Calculating a suitable burden resistor for 5V input Arduino

3.1.3 Arduino UNO

The main component and the controller used in this project is Arduino UNO board that come with microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller, simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

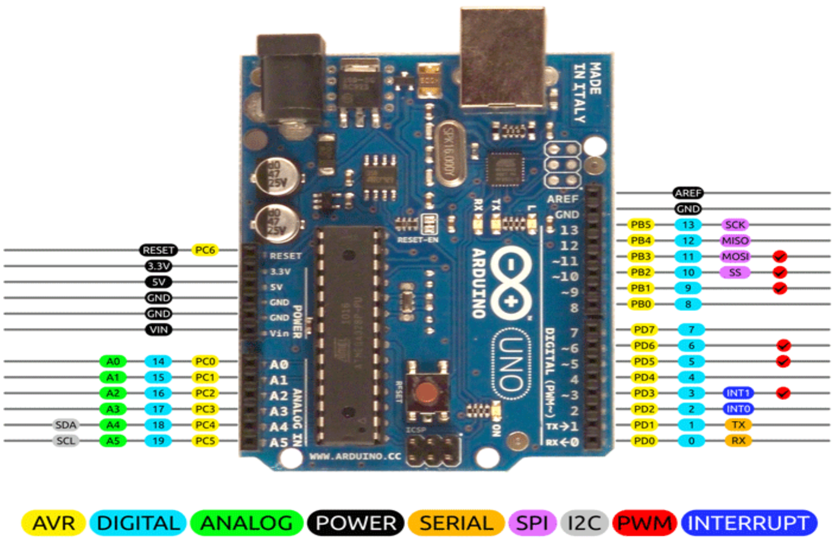

Figure 5: Pin Diagram of Arduino UNO

Table 3: Arduino Uno Properties

Properties	Value
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
Flash Memory	2 KB of which 0.5 KB used by bootloader
Clock Speed	16 MHz

3.1.4 Wi-Fi Module ESP8266

In this project a low cost Wi-Fi Microchip ESP8266 was used to connect to Wi-Fi network. The data stream of current and voltage values from the control system was transfer to cloud using ESP8266. This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime.

AT command set firmware was used to determine the functionality of the Wi-Fi module and connected to Wi-Fi network of our choice.

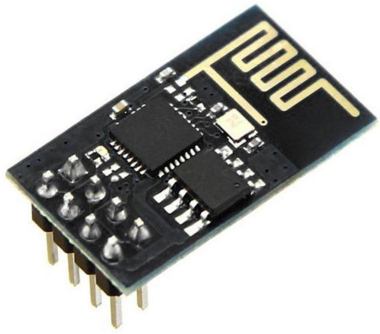

Figure 6: ESP8266 Wifi Module

3.2 Internet of Things IoT

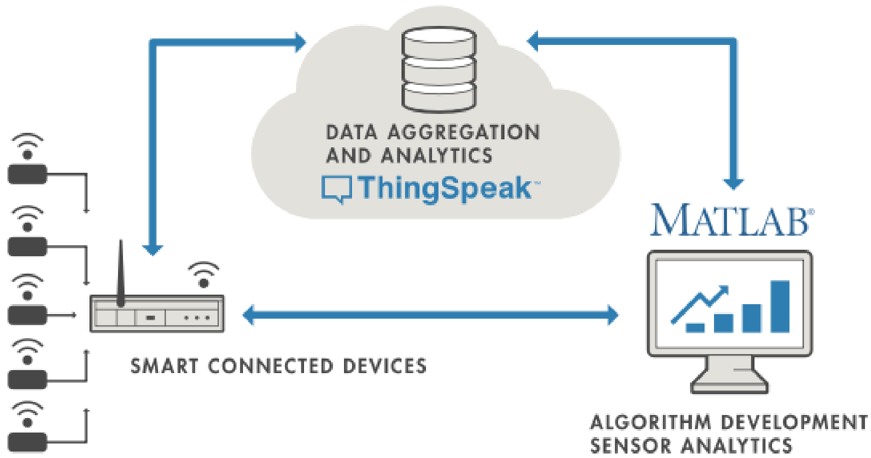

Figure 7: IoT system using block diagram

The IoT capability is used where a large number of devices are now being connected to Internet. With the help of cheap Wi-Fi module and already packed AT-Firmware and cheap cloud competing platform, every hobbyist can used these connected device to communicate with people and data is process and value insight can be gain [8].

The final Energy Meter (E-MON) With IoT Monitoring, used the control system to gain the value of current and voltage, and with the Wi-Fi module, transfer the stream data into ThingSpeak and the data obtain can be view using the application in smartphone or via web. LCD display also indicate the usage of the energy at the device.

Figure 7: Final design of Energy Meter (E-MON) With IoT Monitoring

4. DISCUSSION AND RESULTS

The prototype of Energy Meter (E-MON) With IoT Monitoring, which consist of two part are being tested and calibrate by sensor. Each sensor calibrated and verify using measuring tools such as voltmeter, and clamp to test the accuracy of voltage and current reading. For this purpose two loads water heater and hair dryer are used for the purpose of sensor calibration. These two load also draw large current while being used, so calibration are more easily done than the other.

While running the E-MON with hair dryer, the value of current that being draw are 1.49 Amps which is within the range of clamp meter shown in Figure 8. Each sensor are calibrate individually to get the range of true value of the current and voltage.

a)

b)

Figure 8: Measuring the current with E-MON with hair dryer a) LCD displaying the value of current & Voltage draw by hairdryer b) Clamp Meter reading on the actual current by hair dryer.

When hardware system already been set up and calibrated, the IoT development will take places. The stream of data from voltage and current sensor are being transmit to the cloud by the Wi-Fi module. ThingSpeak which is an open IoT platform has a free account that offer a fully functional experience with a certain limits on its functionality. The stream of data from the sensor are then being collected privately and MATLAB will analyze and visualize the data according to user preference.

For this project, ThingSpeak platform is configure to show the value of Current, Voltage, Power and Kilowatt-hour of the item that being measure by E-MON. Figure 9 shown the display data of energy consumption used by hair dryer in real time from ThingSpeak web and smartphone application.

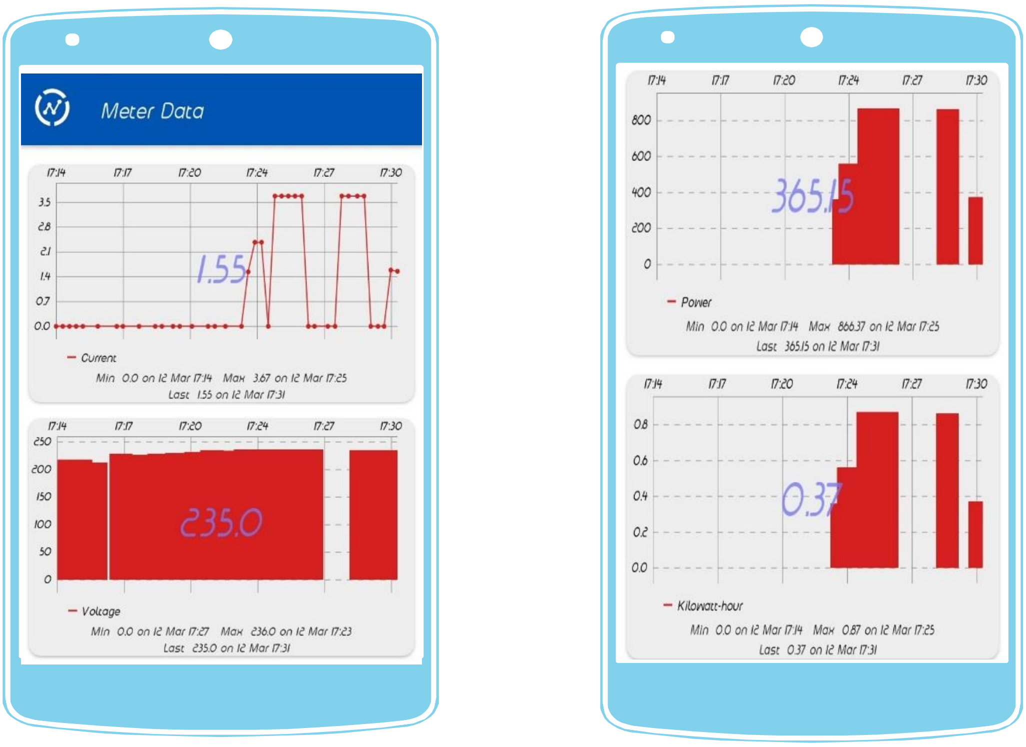

Figure 9: Energy consumption by Hair Dryer monitor via smartphone

5. CONCLUSION

Overall, Energy Meter (E-MON) With IoT Monitoring (Web & Apps) is designed to measure and monitor the energy consumption of household item that is plug to electrical socket and measure using E-MON. This prototype is more cost effective and non-evasive than the other energy meter that is currently out in the market. Its IoT ability which can display the value of energy being used in real time using smartphone are convinient. With various emerging IoT platform which offer various functionality and free cloud service, data stream from E-MON can be saved and view by consumer at any time and place. The Energy Meter (E-MON) has been test successfully.

However, a future works of making a more accurate reading of current and voltage regarding any types of household electrical items are underway. Various calibration technique and data are needed to make a better energy meter. The IoT platform also can upgraded, to show the costing of electricity depending with various hours used

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