Paper No: SC-12 **Smart Computing**

Smart electricity monitoring and analysing an IoT system with a mobile application

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Abstract: **Now, the demand for electricity has increased in the World. This demand was increased concern to the raises of many developed and developing nations in the world. In Sri Lanka, the energy was provided by only less electricity power stations. So, the scarcity of electricity has occurred eventually. Thus, reducing and controlling power consumption will be responsible for all consumers. Furthermore, consuming data should be tracked by the consumer is essential now. But recently, consumers are using traditional meters in each home. It has failed to provide these facilities to the user. Moreover, Digital meter is trying to reduce these limitations. This research study focuses on a Smart Electricity Monitoring System using a mobile application. This is an IoT based project. The electricity consumption can be observed by the user through a user-friendly mobile app. And also, the monthly electricity bill has automated. This smart electricity meter system can be separated into three divisions, and the first system is the hardware setup using Arduino to measure electricity consumption at home. The real-time Alternate current and Alternate voltage through the hardware setup were measured through this system. By considering these values, the Alternate power will be generated. Then the real-time values were converted to units(kW/h) and sent to the database through Wi-Fi. The real-time database in Firebase was the other system. Storing real-time data and permitting them to retrieve them through the mobile application was the main function here. The final system is the user-friendly android application. This system aims to get more involvement of the consumer to their electricity consumption and reduce global electricity consumption. As the results can be observed through the mobile application, the user can get some idea of saving and reducing electricity than earlier.**

Keywords: *Android, Arduino, Firebase, IoT, Smart electricity monitoring*

I. INTRODUCTION

Sri Lanka is facing a massive problem with the electricity crisis. In Sri Lanka, we have few electricity power stations [1]. Mainly the electricity power generation is doing by heat power stations. It s common knowledge that there are many technical issues in those stations and also that their power generation cost is high. In general, it is forecaseted that their will be shortfall in electricity generation with the current trend in use of it. Most people don't have any idea about electricity consumption. Educated people also don't care about it. If we have a good idea about electricity consumption, then we could reduce this problem. There are about 6.5 million power consumers in Sri Lanka [2]. From them, about 85% are domestic users. Let's assume that each domestic consumer reduces their monthly units by a single unit the total savings of the whole country per month will be about 5.5 million units. That's means about 1MW (1000 kW) could be able to save. The reality is 1MW generating cost is very high. So, we could be engaged directly to solve our national problem.

The smart electricity monitoring system is an IoT based project which links the internet, software, and hardware together. This concept is not a new terminology to the IT world, but still, no any system using this concept. Rather than existing hardware systems in Sri Lanka like digital electricity meter, this system is using both software and hardware technologies to more involvements of the user. This is highly advanced and useful to electricity consumers. Here we can measure daily and monthly electricity units(kW/h) through this IoT system. So, it is easy to generate our monthly bill automatically on a particular day of the month for all consumers.

Here we can observe real-time measures of amperage(A), voltage(V), power(W), units(kW/h) through the android application. Using the measure of units, the monthly bill has automated. Moreover, here users have a creative option to get tips by considering the up to now power usage of the consumer. Either tips for the consumer or there has an alert service to the user when it reaches to particular unit levels such as 30, 60, 90, 120, etc. It will help them to reduce their consumption. Furthermore, here we have an analysis section on the mobile application. So, any user can get a detailed idea of the electricity consumption. This android application is highly user-friendly and useful to all users.

Here the system is using a real-time updating database in firebase. Furthermore, we can retrieve data at the same time when they were updated, and it is the most advanced feature in this system. The entire system is connected with a Wi-Fi connection, but the mobile application is separated from them. We can observe data from anywhere using the android application.

IoT technology is supporting the world to get connected with systems. In this case, also really users are connecting easily with this smart electricity monitoring system. In present instances, electricity consumer never tries to involve in reducing their consumption. Nobody wants to waste their time at the meter always. So, until they got the bill, they don't know the units that they have used. Most people are amusing with their bills some times. And they can't get any idea how the bill generated in detail. All the problems are trying to reduce by using this system.

The main target is to design and develop a user-friendly and helpful mobile application to observe electricity consumption and generate bills automatically. Besides, here we have some useful facilities to get some tips such as an assumed bill, assumed units per month, etc. So, the user will try to reduce their bill with additional charges, also, with the alert system. The user will recognize how future consumption should be done. And users can analyze their daily usages, monthly usages through this app. This mobile application can be used to observe the user's earlier bills also. So, this system is useful for both electricity consumers and electricity distributors (the Electricity Board).

Fig. 1. Traditional Electricity Meter

II. RELATED STUDIES

A. Traditional electricity meter

Electricity meters are the type of electrical devices used to detect and display the consumed energy in the form of readings. Traditional electricity meters were being used since the late 19th century [3]. The traditional meter is consisting of an aluminum disc to find the usage of power using a magnetic field. The total power consumption always can be displayed on the panel. So, the monthly usage should be calculated manually, considering the previous value. So, the user has submitted a problem with this situation. Normally, the user never observes his/her monthly consumption until receiving the bill. Eventually, monthly usage will be increased, hence the less observation of the user for consumption. A traditional electricity meter has shown in Fig. 1 [1].

There are some limitations that can be faced by the traditional electricity meter. Such as,

- Users have to anticipate for the monthly electricity bill because these traditional meters are unreliable.
- There cannot be introduced any new type of tariffs based on hours with these traditional meters.
- It was difficult to develop any software applications and a supportive database system.
- There should be employed a lot of inspectors to perform the meter readings.
- The bill calculating method will be changed with the date of meter reading, so this is so difficult for the consumer to assume the bill.
- Most of the cases, the bill will get a massive increment of a few unit changes.

According to the above limitations and so other things were created an enormous gap between the electricity consumer and the distributor.

B. Digital electricity meter

Today the traditional electricity meter has digitally operated and reduced the limitations for the consumer [4]. But still, there have some fewer restrictions to be reduced.

Fig. 2. Digital Electricity Meter

The digital electricity meter is an environmentally friendly device that also used to measure the consumed power at the home or any other place. This digital electricity meter is mainly to provide a direct benefit to consumers to save money and reduce the electricity bill. In this electricity meter, it was used as an advanced infrastructure for sending meter readings automatically to the electricity distributor. A digital meter which using in Sri Lanka has shown in Fig. 2 [5]. An accurate meter reading will be given by the Digital Electricity Meter as a benefit to the consumer. In this meter, the consumption will be recorded based on hourly or less than hourly intervals. There are so many extra features in this digital meter such as having a non-volatile data storage, remotely connect or disconnect capability, tamper detection and also having a two-way communication facility. Here can be remotely collected data reporting to the central meter. Then the functionalities of the digital meter were monitored by the central meter. A broader understanding will be given by these meter readings to the consumer than a traditional meter so that the consumer can be altered with the habitants of energy-consuming. All the information that was measured from the digital meter can be used to generate many advanced analyses for the new generation. But still no more software application support with this digital meter. The followings are some benefits of the Digital Meter.

- The operational cost is low than the traditional meter.
- Time will be saved because there will no time consuming for reporting the meter readings to the energy providers.
- The electricity bill can be paid online.
- The consumer could be reduced power consumption in high peaks and save money.
- These features will be automatically terminated when they are not in use.

Every electricity consumer in Sri Lanka comes with a traditional electricity meter. Both Digital meter and the proposed solution must connect additionally to the home electricity system. The differentiation between the Digital meter and the proposed solution in this paper has shown in TABLE I. Digital meter is mainly using to get the peak/ off-peak electricity consumption of the consumer. This proposed solution always measures the electricity units according to the time-based function. So, it is very simple to functionalize this peak/ off-peak concept in the presented system in future studies. As well as this system supposed to make more concepts in different requirements of the power producer. So rather than the digital meter concept, this proposed solution is the most helpful and important to both the consumer and the producer.

TABLE I. COMPARISON BETWEEN DIGITAL METER AND PROPOSED SYSTEM

Function	Digital Meter	Proposed Solution
Cost	About Rs.10000	About Rs.3000 (Cost estimation is given below in TABLE II)
Analyzing data by the user	No function to analyze data	Through the mobile application, the user can analyze all past consumed data
Monitoring data by the user	The user has come near to the meter and monitor monthly usage	The user could monitor real-time consumption through the smart meters. The user could monitor Daily usage of the current month graphically. The user could monitor electricity consumption and their relevant bill values of earlier months.
Time-based bill generation	Have the Peak/ Off-Peak facility to generate the bill	This system could be able to functionalize for peak/ off-peak bill generation for future requirements
Monthly electricity bill sending	The bill reader comes to give the bill	User is able to get the bill as a notification through the mobile app

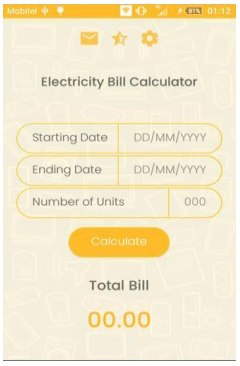

Fig. 3. Main screen view of the Electricity Bill calculating application

C. *Electricity bill calculators*

1) *Bill Calculating Mobile Application*

The main activity of the existing electricity bill calculating mobile application has shown in Fig. 3. This mobile app is already available in the Google Play Store. But more manual data should be filled to get the monthly bill. It is not necessary for the consumer. Notably, the number of units has to calculate by considering the previous bill data and then the computed value should be entered into the field to get the bill. Consumers aren't trying to involve their power consumption as these more manual things. Here only the main function to generate the bill has been developed in the mobile application.

2) *Bill calculating web applications*

Fig. 4 denoted the existing web page to calculate the Electricity Bill. Here also same manual data for the mobile application should be inserted into the fields to generate the monthly bill. So, this concept also was unable to make more involvement of the user to their consumption. The same manner in the mobile version has declared in this concept to generate the bill.

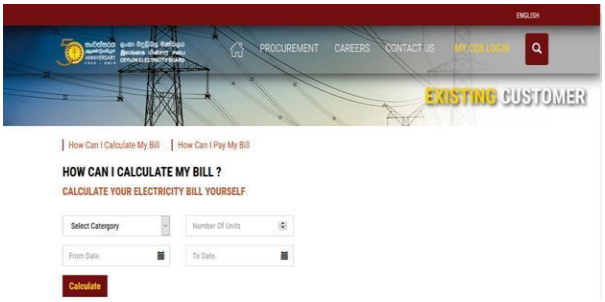

Fig. 4. CEB Web page for Electricity Bill calculating

D. *Related research studies*

The study [6], has been proposed a necessary process that makes reductions in energy use and Carbon Dioxide emissions immediately. Here the design and prototyping of a Home Electricity Monitoring System were described that provide real-time information on electricity usage. The data was displayed on an LCD screen and the computer which related to this system, also wireless communication was used.

A Low-cost IoT energy monitoring system was designed and implemented in the study of [7], that could be used for many applications, such as billing system, energy management, and home automation. A low-cost PZEM-004T, a non-invasive CT sensor, an SD3004 electric energy measurement chip, and a Node MCU was used to design this hardware system. Here also the voltage, current, active power and accumulative power were recorded as the results.

A ZNETH's (Zero Net Energy Test Home) Power Monitor (ZPM) was proposed and implemented in the study [8], which provides detailed energy consumption data for each node in the building. Here all the data will be shown on a display panel and will be stored as an Excel file to facilitate further processing. Also, this data will be displayed on the computer screen via a novel virtual environment building system. Here immediate access will be given by the virtual environment to the building power consumption information in a user-friendly format.

A Smart Meter for Smart Electricity Consumption has introduced in the study [9]. The consumer was helped by this Smart Meter to know the information about the electricity consumption for appliances in their residences. Here the power consumption has measured and analyzed by conducting a case study on various households. So, the behavior of consumers in using devices was illustrated using these Smart Meter data.

Then some consumption patterns were understood using measurements and analysis of consumption over time. This research was exhibited with the help of case analysis, ARIMA model using the XLSTAT tool and flattering techniques. So, the user could be able to change their behavior when they had better control over their habits through this system.

The study of Autonomous Home Energy Monitoring and Management System [10] needs to be considered both energy consumption and generation simultaneously to reduce the energy cost. Here a developed system was presented that uses a photovoltaic module to charge a super-capacitor, which provided energy to a microcontroller-based autonomous sensing platform.

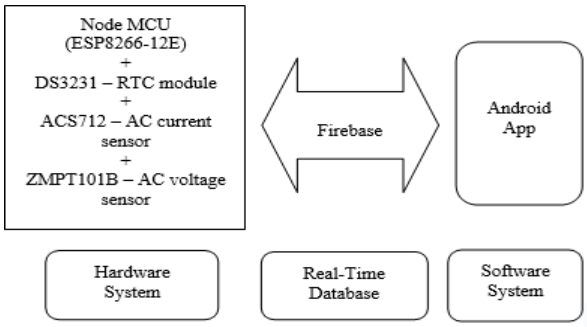

Fig. 5. Structure of the entire system

Embedded software on the node was structured around a framework that gives equal precedence to each aspect of the sensor node, the inclusion of distinct software stacks for the management of energy and the processing of sensors. A structured and modular design was promoted by this study which allows for efficient code reuse and encourages the level of interchangeable protocols.

TABLE II. COST ESTIMATION OF HARDWARE SYSTEM

Item	Quantity	Total Cost ($)
Node MCU	1	5
ACS712 current sensor	1	2.5
ZMPT101B voltage sensor	1	3
DS3231 RTC module	1	2
ADC module	1	3
Connection wires	1 pack	0.5
Total		**16**

III. METHODOLOGY

This project could be divided into three major divisions. Hardware systems for current and voltage measuring, the real-time database for updating, storing, retrieving data and a mobile application for real-time retrieve data and analyze them were them. Fig. 5 has shown the structure of this entire system, which was being tried to do a great job to involve users in their daily electricity consumption. So, reducing the electricity consumption of users was the main purpose of this system.

A. Hardware system

In the hardware system, an ACS712 current sensor to detect Alternate Current using voltage pulses and a ZMPT101B voltage sensor to detect AC voltage were used. Also, a DS3231 RTC module to get the current date and time was used to manage data sending to the correct path. Here an ESP8266 Wi-Fi module (Node MCU) was used to send real-time data to firebase. Node MCU was the most helpful Arduino board to transfer real-time data through wireless connections. Using Arduino language and Arduino IDE, the entire hardware system has programmed.

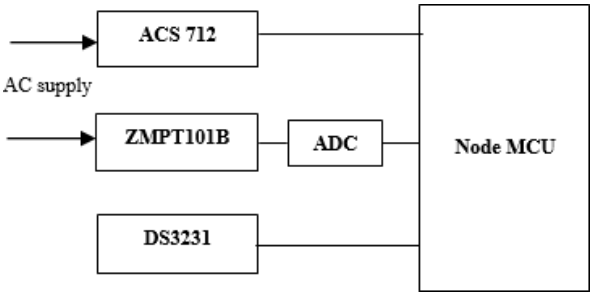

Fig. 6. Structure of the Hardware System

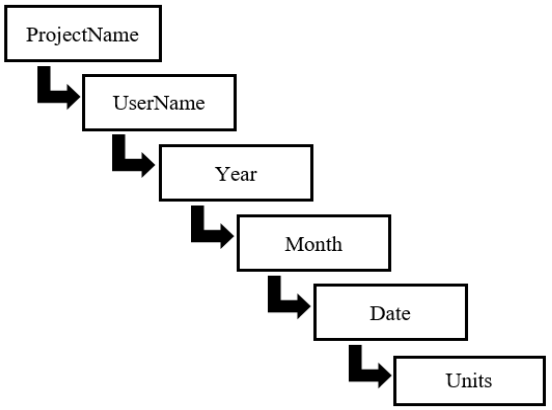

Fig. 7. Hierarchy of the Database

The cost estimation of the hardware system has shown in TABLE II. (Present date price about Rs.3000) More accurate AC power was given by this system, because here both current and voltage values will measure, instead of a constant voltage value such as 220V or 230V. Also, sensor calibration was the most important operation to get fine values. Also, an ADC was used to connect the voltage sensor to the Node MCU because there had only one analog pin on the board. The connecting diagram of the Hardware System has shown in Fig. 6.

The measurements for Average AC current per second will be detected by the current sensor, and the measurements for Average AC voltage per second will be detected by the voltage sensor. Let,

$$P = I * V \quad (1)$$

$$\text{unit (kWh)} = (P*.001) / 3600 \quad (2)$$

Using the above theoretical formulas such as Power Equation (Eq. 1) [11] and unit equation (Eq. 2) [12] can be

calculated the consumed units at home continuously. Using these values, the entire system has programmed.

B. Real-Time database

A real-time database was required by this entire system. Here all the data were sent and retrieved in each second. So it was connected with real-time data transferring. In this system, Firebase was used for this real-time transferring. Also, firebase was the most useful server platform, especially for android mobile applications. And here more other facilities were provided from Firebase for all mobile apps. Such as authentications, cloud messaging, cloud functions, analyzing usages and testing, etc. The hierarchical structure was used in the Firebase database, as shown in the following Fig. 7. Using these hierarchical data, the analysis can be generated to the user.

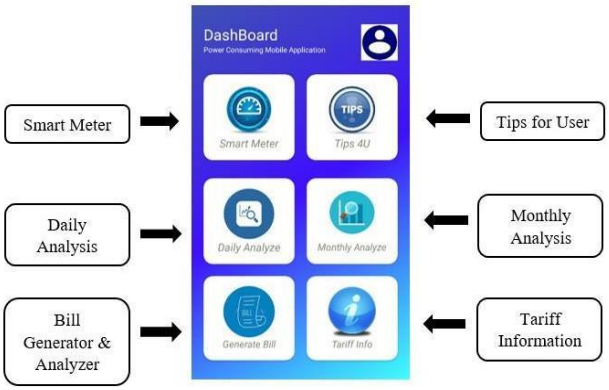

Fig. 8. The dashboard of the Mobile Application

C. Mobile application

This monitoring system was used to get more involvement of the user to his/her electricity consumption. Because of the tied schedules of users, they don't have time to spend extra time with existing systems for electricity consumption monitoring. Those were hardware systems that were only recording the consumption continuously. So more manual calculations should be done by people to get an idea of his/her present usage. Some software systems such as mobile applications and web applications were only providing a facility to generate user's monthly bills with more manual inputs. So, this system will be the most user-friendly and suitable approach with fewer user inputs for monitor user's electricity consumption.

Mostly this mobile application was used to observe monthly units (Kw/h), get the assumed bill, automatically generating the monthly bill, retrieve day by day usage of the current month and retrieve monthly usages and bills of several years. So, by this user-friendly mobile application, the user will be involved in their electricity consumption than earlier. All the latest mobile versions (> android 3.1/ API 12) can be used in this smart mobile application easily. The dashboard of the developed mobile app has shown in Fig. 8 below.

IV. EXPERIMENTAL RESULTS

In this section, all the operational and experimental outcomes were presented. To gather those results, we have implemented a prototype of a hardware module, Fig. 9. Then this system has tested with one electricity consuming home since October. According to the testing data through the prototype, the monitoring and analyzing functions in the mobile application were described in this section. This is only the testing stage of this hardware module. This could be more helpful to identify the sensor errors in the system. Sensors calibration is a very essential action to do in this system.

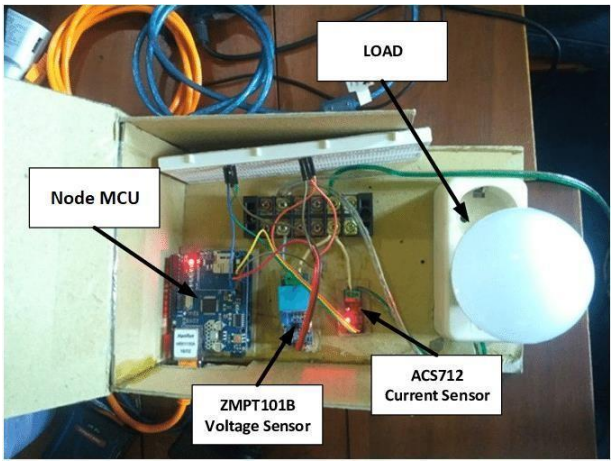

Fig. 9. The designed prototype of hardware system

Fig. 10. Smart Meter view in the mobile Application

Here the real-time data which were stored on the database could be analyzed with the user-friendly mobile application. Smart meter UI is the main panel that all the real-time data were displayed to the user. Here the consumer could be able to observe the units, current, voltage and the power on different four smart meters. The cumulative units of the related month will be represented on the unit meter. Also, real-time changes in amperage, voltage, and power could be observed in other meters. The view of the Smart meter UI has shown in Fig. 10

In any specific day of the month, the consumer could be able to get a simple idea on the assumed bill for the month by considering some analysis as a tip. Below Fig. 11 denoted the view of Tips UI, which provides this facility and some other suggestions.

The consumer will be involved in electricity consumption when there can analyze data quickly. Still in existing systems, there had nothing to investigate the electricity consumption of the user. Here some daily analyzing views of the current month will be provided to the user. In Fig. 12 has shown the UI of the Daily analysis in November month. By considering this, the user will be able to analyze whether any day had used power more than the average level.

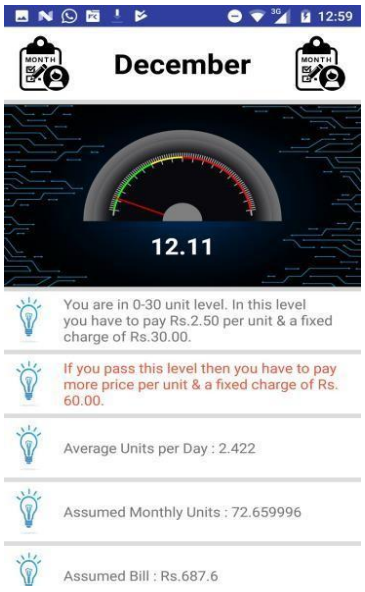

Fig. 11. Tips UI in the mobile application

A unique UI was designed and developed to analyze all the consumed electricity and their bill each month in the mobile application. This concept also could be able to get more user involvement in electricity consumption. The user could compare the previous electricity consumption graphically. So, some essential data were provided through this application and stored them to analyze any time. The monthly Analysis UI has shown in Fig. 13. Here the data of October, November were presented. Also, the consumed electricity up to that moment in December was presented.

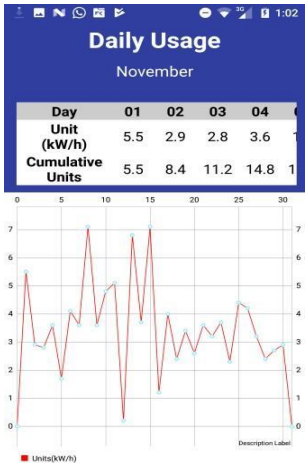

Fig. 12. Daily Usage UI in the mobile application

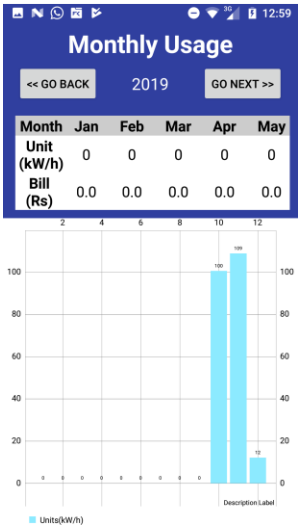

Fig. 13. Monthly Analyze UI in the mobile application

V. CONCLUSION AND FUTURE WORK

The design of a low-cost and useful IoT electricity monitoring system was presented in this study. Real-time electricity monitoring should be essential for electricity conservation and sustainability. According to experimental results, the real-time voltage, amperage, power, and accumulative units could be monitored. Also, the monthly and daily analysis could be observed by this system. So, the user could be able to get more involvement in electricity consumption through this system. The usability and the importance of the designed system were proved by the experimental results. Besides the original goal of developing an electricity monitoring system, this system can also be used in electricity auditing and electricity data saving processes. So, this monitoring system will be more useful to the consumer than existing systems in Sri Lanka. But a variety of electricity monitoring sensor systems were used commercially in other developed countries. So, this will be a similar electricity monitoring system to the consumer as available in other countries.

A. Future work

- An LCD monitoring display was supposed to fix into the hardware system for more compatibility.
- And also, an inbuilt memory card was supposed to include the Node MCU for saving data when the Wi-Fi connection is not available.
- For long-time experimental results, it was supposed to train a data model as a CNN (Convolutional Neural Networks) model and analyze them in a better way. Those works were planned to execute as future work.
- This entire system was supposed to use instead of the Digital Electricity Meter which has special functionality to get the peak and off-peak electricity usage of the user and generate the bill according to those values.

REFERENCES

[1] Ministry of Power and Energy, [Online]. Available: https://www.powermin.gov.lk. [Accessed: 25-11-2019].

[2] "CEB- Electricity Generated", [Online]. Available: https://www.ceb.lk/electricity-generated/en. [Accessed: 25-11-2019]

[3] Ceylon Electricity Board, [Online]. Available: https://www.ceb.lk/ceb-history/en. [Accessed:28-11-2019].

[4] Lanka Business Online, [Online]. Available: https://www.lankabusinessonline.com/sri-lanka-introduces-smart- metering-to-reduce-electricity-generation-costs/. [Accessed: 28-11-2019].

[5] H. Ranmuthu, "How to read Sprint 350 energy meter",2016. [Online]. Available: https://www.diyweb.lk/?p=149. [Accessed: 30-11-2019].

[6] J. G. Josué, J. M. Pina and M. V. Neves, "Home Electricity Monitoring System: Design and Prototyping", in *Second IFIP Doctoral Conference on Computing Electrical and Industrial Systems*, Costa de Caparica Portugal, 2011, pp. 437-444.

[7] K. Chooruang and K. Meekul, "Design of an IoT Energy Monitoring System," in *2018 Sixteenth International Conference on ICT and Knowledge Engineering*, Thailand, 2018.

[8] W. Nader, "REAL-TIME POWER MONITORING, HOME AUTOMATION AND REAL-TIME POWER MONITORING, HOME AUTOMATION AND SUSTAINABILITY", *Architectural Engineering - Dissertations and Student Research*, 2011.

[9] P. V. S. M. Seelam, "Smart Metering for Smart Electricity Consumption", *Master Thesis Electrical Engineering May 2013*.

[10] V. Chandran, A. V. Rajesh, R. A. Kumar, R. N. Jishnu and P. Prashanth, "Autonomus Home Energy and Management System" *IJESRT-INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, 2015.

[11] Hyperphysics, [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elepow.html. [Accessed: 13-02-2020].

[12] Jain, "What are watt, kilowatt and a unit of electricity", 2020. [Online]. Available: https://www.bijlibachao.com/electricity-bill/what-are-watt-kilowatt- and-a-unit-of-electricity.html. [Accessed: 13-02-2020.