MONITORING AND CONTROL OF ELECTRICITY CONSUMPTION USING RASPBERRY Pi THROUGH IoT

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ABSTRACT

In this research, the researchers gathered the functionalities of Internet of Things (IoT), android smartphones and Raspberry Pi for monitoring and controlling. An android smartphone was used to monitor the electrical energy usage of the user's devices. The Android smartphone had an application installed for monitoring and controlling of the user's energy usage. Moreover, a database has been developed for storing the data from both the android application and from sensors. The system was tested with different electric devices, and the results were shown in details. Based on the results, the system had high accuracy (99.5%) with regards to particular devices, while very low accuracy (18.5%) for some other devices.

Keywords: *electricity consumption; monitoring, control, IoT, Android, Raspberry Pi*

INTRODUCTION

Technology is improving day by day. Right now, owning a smartphone has become more of a necessity. There are various things that a smartphone can do that make it convenient for smartphone owners to have one than none. Smartphones can also access the Internet, which is also very important for smartphone owners. The current technology is now heavily influenced by the use of the Internet, the biggest worldwide communication of computers. The Internet can be used everywhere from business, academics, and private communication to government networks. As of now, the Internet is being applied to a variety of appliances or devices to control the said objects to be wirelessly and automatically operated which is called the Internet of Things (IoT).

Many automations with IoT applications that are present today use microcontrollers like Arduino and Raspberry Pi.[1][2][3][4] The said microcontrollers are used alongside with programming languages like

python and C++.[1][3][5] The proponents have decided to use Raspberry Pi and Arduino in making this project. The Raspberry Pi served as the main controller of the system and Arduino for sensor inputs.[6] Raspberry Pi is capable of connecting to a w-fi connection which will be used to connect to the android smartphone. A current sensor AC/DC 50 ampere and ACS758 based module were used to get the current readings and were connected to Arduino Uno. Arduino Uno was used to receive analog input that raspberry pi cannot do. The Arduino Uno read the data gathered by the current sensor, so that it can be understood and read by the raspberry pi through python that was sent to the cloud server. The Android application was able to retrieve the data from the cloud server and used that data to display a line graph on the android application. The line graph was daily updated and there was a refresh trigger button to check the current readings of the usage of the energy. The android application had the capability to turn on or off several relays that were connected to the raspberry pi. The android application also used an energy usage plan in which the user can enter a certain amount of energy that was considered the limit for the month. The application notified the user when the limit of the usage has been reached.

This study aimed to develop a prototype of energy consumption monitor and control through android application using Raspberry Pi and Android Application. Specifically, the study aimed to create a system, which allows user to monitor electricity consumption, develop a database to store past readings of electricity consumption, and develop an android application for user to monitor and control the system.

The use of the android application on a home energy consumption monitoring can be considered as a way to adapt with the current trend in technology. Through the use of android application and with the help of Internet, the energy consumed by the user can be monitored and controlled wirelessly. One of the many additional features was to control the electrical lines by turning off or on with use of android phones. Moreover, the user can retrieve and view the data of the energy consumed in the cloud sever. The energy consumed was monitored and viewed in a line graph form through the android application design.

The proponents will greatly benefit from this research, as they have to study several things to complete this research. This research needs to have the necessary knowledge and skills related to electrical engineering that are helpful to the proponents' future. The monitoring of the other home energy consumption meter uses GSM in bill notifying and monitoring. Those do not include the use of android application in monitoring and controlling the energy consumed by the user.

REVIEW OF RELATED LITERATURE

As innovation advances, cell phones have turned out to be about more than just making calls. Little, smart, and adaptable, present day mobile phones have turned out to be intense devices that join cameras, media players, GPS frameworks, and touch screens.[7] Android users increase, hence there are lots of android applications being developed not only for entertainment, but also for industry purposes.[8] Controlling of home appliances is a part of home automation, and through the increasing numbers of internet users and smartphone users, it was developed. Android smart phones can serve as a web server that is able to store data and control the appliances.[9] In this related research, the proponents used smart phones to remotely access the a data logger. The monitoring system is capable of viewing PC or smart phones.[10] Java programming is used to create android application and Android Studio Platform that can be utilized to make applications.[11] There are many ways to monitor gathered data and one of them is the use of web and Laravel through database.[12][13] A related study also used android application. GSM and another studies used Zigbee in transferring data wirelessly. [14][15] Many of Automated ElectricMeter Reading and Monitoring System utilize a relay for controlling the load.[16] There are still many different studies that used different design and hardware implementation like using Integrated Circuit, ADE7757, commonly used for electrical purposes. Others use MQTT Protocol. [17][18] Being low-cost is also very important in every study and should be tried to do to lessen the cost. [15][19] Utilizing Raspberry Pi in IoT based studies can be of great importance since there are many sensors in an industry with diverse use which can be used alongside Raspberry Pi.[20]

Synthesis of Related Litarature

According to the review of related literature, there are different methods and techniques in designing and implementing the system. Most of the study conducted and implemented cited the used of sensors, GSM, and smartphones in monitoring different parameters.The data sensed by the sensors were analyzed and sent via different methods like SMS text messages and internet. Additionally, most of the studies use Web-based in viewing and accessing the information in through the use of internet. The use of .net platforms was also seen by the proponents to produce a graphical user interface. Thus, the use of different methods and technologies can be beneficial to provide efficient and functional systems. Similarly, smartphone and database were used by the proponents in developing the system. Finally, the proponents' have decided to research on a prototype that can measure energy consumption of homes that can be easily monitored and controlled through the use of android application that has a databased which can be accessed through the Internet.

CONCEPTUAL AND THEORETICAL FRAMEWORK

Conceptual Framework

The study aimed to design and develop a prototype that can monitor and control the electricity usage. The proponents were able to make a diagram that shows the comprehensive procedure of the research (see Fig. 1). With the use of the diagram, the proponents were able to decide which hardware and software were needed. Moreover, the diagram also helped the proponents in accomplishing the prototype.

As Figure 1 shows, the start of the diagram is the sensors. The data that were gathered by the current sensor through the use of Arduino which were sent to raspberry pi. The raspberry pi processed the data and produced an output depending on the data gathered. Raspberry Pi was connected to the internet to send the information to the database. The Android application fetched the information in the database through the internet. It was also used to monitor the energy usage and to control when to turn on or off the relays.

Figure 2 shows the Input, Process, and Output of the system. The input was the data gathered through the use of the sensor which

was the ACS758 based module connected to the Arduino. Another input is from the relays which is also connected to the Arduino. The Process of the system is the set of actions to be done by the system once that input data has been received. The process done is mostly from the side of raspberry pi which converts the data gathered into information that can be sent to the database. The output of the system is what the system do after the depending on whether the input can be viewed on the android application.

As figure 3 shows at the start point, the system read the current of electricity through sensors attached to the Arduino. Raspberry Pi was used to gather the current readings into electric power which was sent to the database through the internet. Once the android application has accessed the internet connection, the android application will retrieve the information on the database so that the android application will be able to make a graph showing the current usage of energy. When the total readings of energy usage have reached the set amount of readings entered by the user, the application will notify the user.

The control of the system is also on the application on android (see Fig. 4). There was virtual buttons on android application in which the user can use to turn on or off electrical connections through the relays. When the user pressed button 1 to on, the android application sent to the database button 1 is on. The raspberry pin turned her on or off relay 1 once it has received the data from the database. The same is for button 2. Button 3 is for all other buttons. If button 3 is on, then all other buttons means on as well and vice versa.

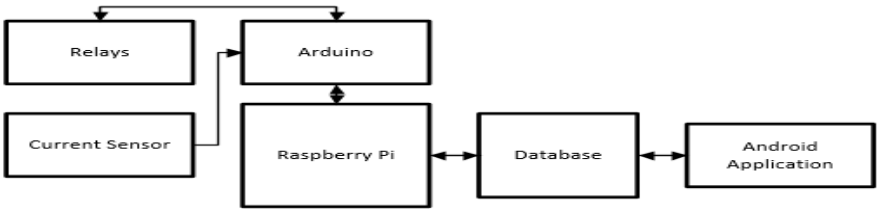

Figure 1. System Block Diagram

INPUT	PROCESS	OUTPUT
• Current Sensor • Relays	• Send information from Raspberry Pi to database	• Usage History • Relays on/off

Figure 2. IPO Chart

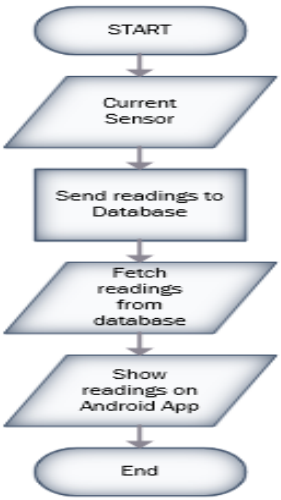

Figure 3. Flow Chart of the Monitoring System

Theoretical Framework

1. Arduino Uno

ATmega328P based microcontroller board. This microcontroller has 6 analog inputs, 14 digital input and output pins in which 6 can be used as PWM outputs. This also has a 16 MHz quartz crystal, USB connection, power jack, an ICSP header, and reset button.

2. Current Sensor AC or DC 50A based on ACS758

The current sensor used was based on Allegro ACS758. It can take up to 50 Amperes and can be used as for either AC or DC. It has input and output that was in series with one of the connection lines of the AC connection. This current sensor was powered by 5V dc.

3. Raspberry Pi

Raspberry Pi is a tiny computer, which uses Raspbian operating system, based on Debian optimized for the Raspberry Pi hardware. Raspberry Pi can be used to learn programming languages and apply practical projects.

4. Relay Module

Relay module consist of VCC, Gnd, and 8 inputs. The relay module was powered by 5V DC. This module was used and attached to the Arduino Uno so that the electrical connections can be turned on or off by the user.

System Architecture

Both the relays and current sensor were connected to the Arduino Uno. The analog input from the current sensor was received by the Arduino Uno and controlled by the raspberry pi (see Fig. 5). The gathered data were processed and were sent to the database via raspberry pi. The inputs came from the android application. The choices of whether to turn on or off the relays were decided by the users who hold the Android phone. The readings were sent to the android application and displayed for the users to see.

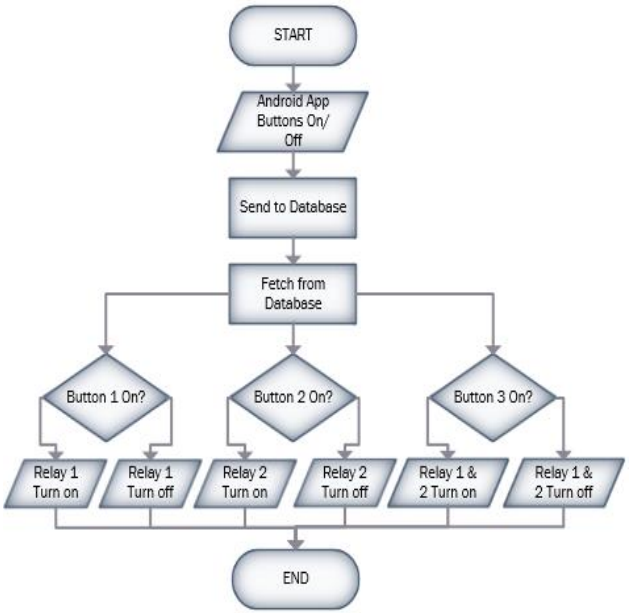

Figure 4. Flowchart of the Control System

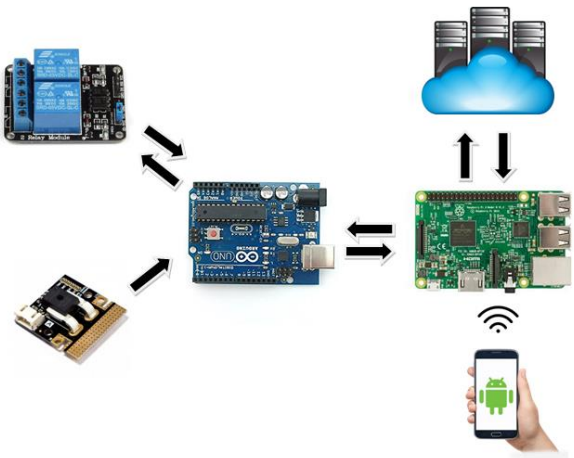

Figure 5. System Architecture

RESULTS AND ANALYSIS

Building the System

The current sensor had In and Out and in series with one of the connection lines of the AC connection. The blue, red, and black were connected to the Arduino Uno. The red wire was connected to the 5V of the Arduino Uno that represent as VCC of the current sensor. The black wire was for the GND, while blue wire is V_{out} that was connected to the analog input that gives readings to the Arduino Uno (see Fig. 6).

The relay module consists of VCC, Gnd, and 8 inputs. The relay module was powered by 5V DC. The red wire represents as the VCC and the black wire for the Gnd. The proponents used two inputs 1 and 3. The inputs of relays was controlled by the Arduino Uno (see Fig. 7).

Figure 8 shows the log-in UI (User Interface) of the android application. The user can log-in utilizing the user's account. On the off chance that the user isn't registered then the user has a decision of whether to use a current google account or g-mail or register using other email. There is no need to sign-up if the user has decided to use a g-mail account.

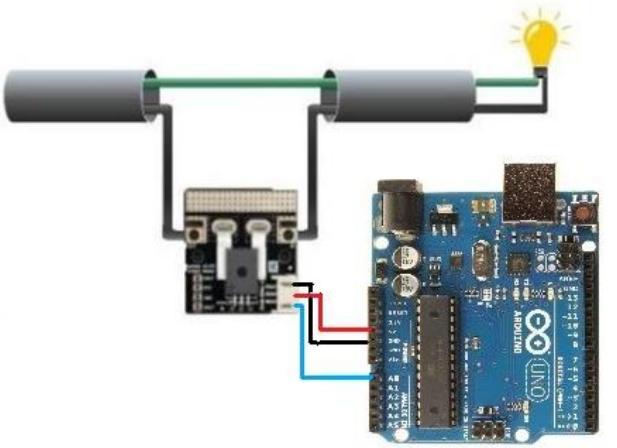

Figure 6. Current Sensor Connection to Arduino and AC Line

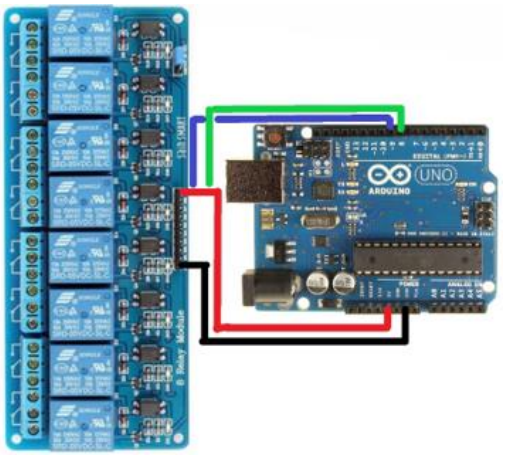

Figure 7. Relay Module

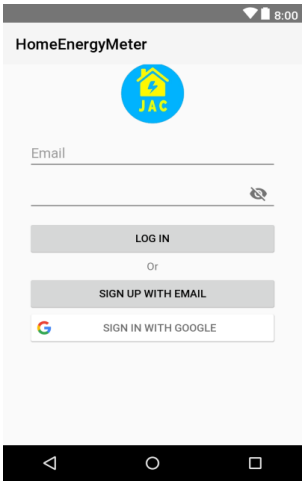

Figure 8. Android Application Log-in User Interface

Figure 9 shows the monitoring and control part of the android application, where the user can switch on or off the relays. The right side

of the switches was where the reading of the respective switch was shown. The power switch's purpose was to control every other switch. If the power switch is turned on, every other switch will also be turned on and vice versa. Logout means going back to the previous page.

Figure 10 shows the signup page where the users who decided to use a non-google mail account can register, while figure 11 showed the data reading from raspberry pi were sent and stored. This was also where the android app asked the readings and send signal for the relay modules.

Data and Results

The appliances used by the proponents for testing of measurement of energy are the light bulb, laptop charger, motor and amplifier (see Fig. 12).

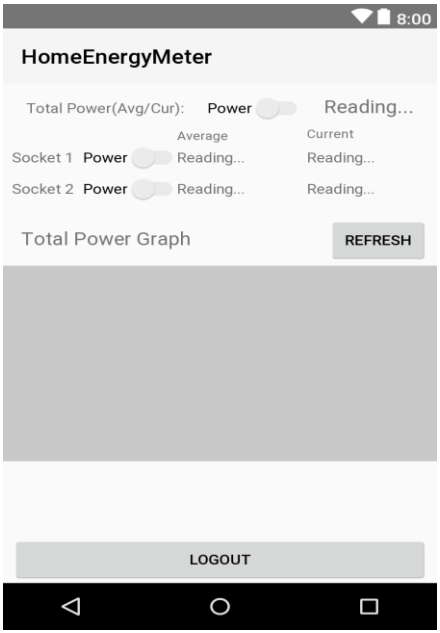

Figure 9. Monitoring and Control Arduino Application UI

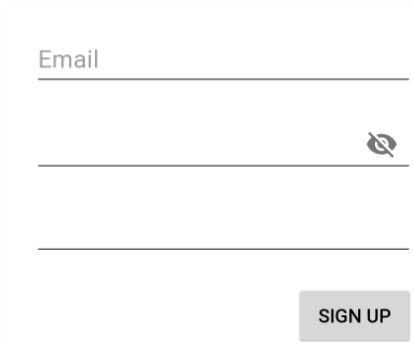

Figure 10. Sign up page

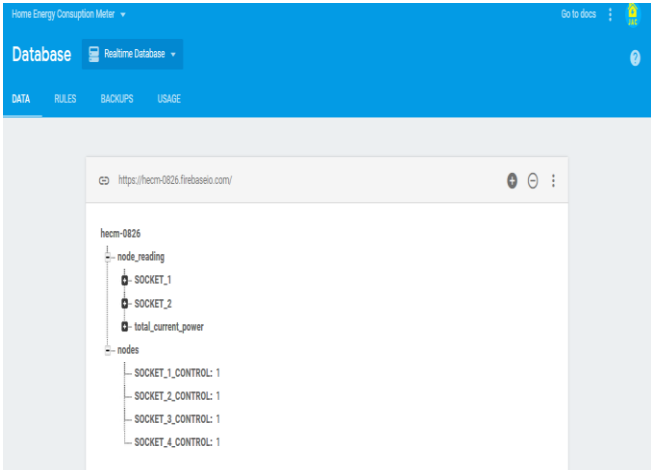

Figure 11. Firebase Database

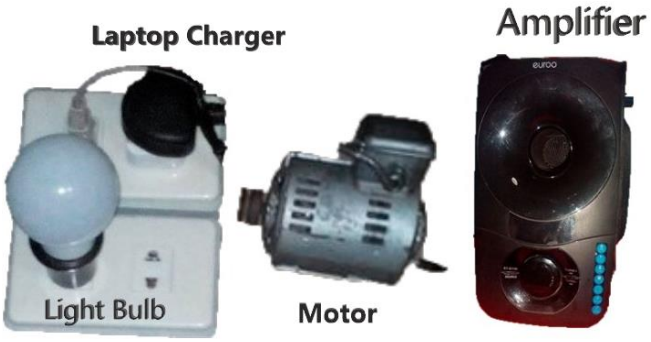

Figure 12. Appliances Used for Testing

Table 1 shows the results of the measuring of the energy used by the appliances. This table shows ten tests made by the proponents the average of those tests.

TABLE I. MEASUREMENT OF SINGLE APPLIANCES (WATTS)

	Measurement of single appliances (Watts)										Average
Light Bulb	15.623	18.203	15.172	15.19	14.826	14.809	14.67	14.41	14.081	13.769	15.075
Laptop Charger	46.296	41.637	51.233	38.849	31.401	47.232	32.336	39.784	25.824	29.548	38.414
Motor	602.6	559.8	609.11	570.04	578.42	575.61	595.15	568.18	588.64	591.43	583.9
Amplifier	3.4986	4.4339	2.5634	5.3692	2.5634	3.4986	9.0757	2.5634	11.882	10.011	5.5459

Table 2 shows the results of the measuring of the energy used by multiple appliances plugged in to one or two sockets which is computed as the total energy used. This table shows ten tests of different appliances used at the same time made by the proponents and the average of those tests.

TABLE 2. MEASUREMENT OF MULTIPLE APPLIANCES (WATTS)

	Measurement of multiple appliances (Watts)										Average
Light Bulb and Laptop Charger	75.688	60.672	44.98	56.948	63.599	54.125	61.728	68.154	42.14	62.594	59.063
Motor and Amplifier	626.78	597.94	571.91	593.3	588.64	575.61	614.27	626.78	556.08	598.87	595.02
Amplifier and Light Bulb	18.55	13.891	14.826	19.468	20.403	15.761	19.468	18.55	17.614	12.955	17.149
Laptop Charger and Amplifier	46.937	76.069	85.942	88.159	50.02	82.703	59.321	62.11	47.232	52.809	65.13
Light Bulb and Laptop Charger and Motor	626.41	684.3	679.74	645.38	632.04	616.54	656.39	646.16	635.99	659.27	648.22

Table 3 shows the comparison of results of the experimental values or tests to the ideal or theoretical value. The percent error is shown here. It can be seen in this table that most of the percent error in the readings were from TVL B 20% as experimental and theoretical are compared. The only appliance that showed a very large error in percent as the amplifier that affected the combined reading of the amplifier and the other appliance that was being tested with the amplifier. The proponents can assume that the reason for that is that the amplifier is not playing music or an audio during the testing which largely affected the results of the testing.

Equations

Formula 1 is the basis for proponents. Since the focus of this study was not on getting the power factor, the proponents were going to use an ideal power factor or one. The equation used was for the AC 3-phase amps to watts.

$$\text{Watt} = 1.732 \times \text{PF} \times \text{amp} \times \text{volt} \qquad (1)$$

Formula 2 was used by the proponents to calculate the percent error.

$$\text{Error} = \left| \frac{(Experimental\ Value - Theoretical\ Value)}{Theoretical\ Value} \right| \qquad (2)$$

TABLE 3. COMPARISON OF RESULTS (WATTS)

	Comparison (Watt)		
	Test Results in Average	Ideal	% Error
Light Bulb	15.075328	15	0.502186667
Laptop Charger	50.538028	65	22.24918769
Motor	583.897036	571.56	2.158484848
Amplifier	5.545864	30	81.51378667
Light Bulb and Laptop Charger	65.990932	80	17.511335
Motor and Amplifier	595.016476	636.56	6.526254242
Amplifier and Light Bulb	17.148532	45	61.89215111
Laptop Charger and Amplifier	65.130128	95	31.44197053
Light Bulb and Laptop Charger and Motor	649.260984	651.56	0.352847934

CONCLUSION

The researchers tested functionality of the system by using different appliances that was being plugged-in to the sockets, the proponents can conclude that:

The proponents were able to design a system which allows the user to monitor home energy consumption;

The proponents were able to include the use of an android application to remotely control the relays connected to the electrical lines and view the energy consumption;

The system has a database that can be used by the user to view the past readings of energy consumption;

The proponents were able to designe an android application that has both the monitoring and the control of the system;

The system was able to read current to get the power reading and control electrical lines.

FUTURE DIRECTIVES

The recommended idea was formed based on the trials and errors that have been experienced by the proponents after creating and developing the system. The recommendation has divided into three parts:

The proponents recommend to used ADE7757 or ADE7816: The user can use and IC for measuring energy like ADE7757 or something similar or close. ADE7757 outputs a digital signal which by the use of Arduino, can be used with pulse input reading.

The proponents recommend to have a safety features like tripping since the research was about energy monitoring. The future researchers can add a safety features that can notify if there are trippings that happen in electric lines. The features that can be add by the future researchers is that the can set limit for the electrical if the set limits reach the electrical lines' connection will automatically off.

*The proponents recommend to have stable internet connection s*ince the research uses Internet of things in monitoring energy consumption and controlling appliances; therefore, the proponents recommend having stable internet to have process of data to the database and

android application. Slow internet can affect the retrieval of data and the graph that has been display in the android application.

REFERENCES

[1] A. Bonganay, J. Magno, A. Marcellana, J. Morante and N. Perez, Automated electric meter reading
and monitoring system using ZigBee-integrated raspberry Pi single board computer via Modbus – IEEE Xplore Document.2014
[2] G. Srikanth, Automated Electric Meter Reading and Monitoring System usingZigbee-Integrated Raspberry Pi Single Board Computer via Ethernet.2015.
[3] D. Kunal, (2016). Smart Home Automation using IOT. (onlineavailable at: http://www.ijarcce.com/upload/2016/february-16/IJARCCE%20131.pdf. Accessed 15November, 2017).
[4] M. Mnati, (2017). A Smart Voltage and Current Monitoring System for Three Phase Inverters Using an Android Smartphone Application. [online] mdpi.com. Available at: http://www.mdpi.com/1424-8220/17/4/872/pdf (Accessed 15November 2017).
[5] M. V. R. Vatsa, Raspberry Pi based Implementation of Internet of Things using Mobile Messaging Application - 'Telegram'. http://www.ijcaonline.org/archives/volume145/number14/vatsa-2016-ijca-910847.pdf (Accessed 15 November 2017).
[6] A. Kurde and V. Kulkarni (2016). IOT Based Smart Power Metering.http://www.ijsrp.org/research-paper-0916/ijsrp-p5757.pdf (Accessed 15 November 2017).
[7] H. R. Esmaee, Apply Android Studio (SDK) Tools. https://www.ijarcsse.com/docs/papers/Volume_5/5_May2015/V5I4-0764.pdf (Accessed 15 November 2017).
[8] S. Sivasubramanian, S. Sivasankaran and S. ThiruNiraiSenthil, (2014). A Proposed Android Based Mobile Application to Monitor Works at Remote Sites. https://www.ijsr.net/archive/v3i2/MDQwMjE0MDE=.pdf (Accessed 15 November 2017).
[9] S. Sankaranarayanan, (2014). Smart Home Monitoring using Android and Wireless Sensors. http://www.mecs-press.org/ijem/ijem-v4-n2/IJEM-V4-N2-2.pdf(Accessed 15 November 2017).
[10] B. Kale, (2015). Smart phone based real time wireless data logger system. http://www.allsubjectjournal.com/download/952/52.pdf (Accessed 15 November 2017).
[11] A. Singh, Android Application Development using Android Studio and PHP
Framework.http://research.ijcaonline.org/rtfem2016/number1/rtfem45109.pdf (Accessed 15 November 2017).

[12] J. Akash, Implementation of Web Application Using Laravel Framework. http://www.ijesmr.com/doc/Archive-2017/May-2017/8.pdf(Accessed 15 November 2017).
[13] P. Vani, (2014). Database Administration in Raspberry using A Server Machine. http://ijiet.com/wp-content/uploads/2014/03/6.pdf (Accessed 15 November 2017).
[14] E. Diya, (2016). Smart Energy Meter Using Android Application and GSM Network. https://www.ijecs.in/issue/v5-i3/36%20ijecs.pdf(Accessed 15 November 2017).
[15] K. Dushyanth, G.Chowdary, and N. Prasad, (2012). A Low-Cost Energy Management System That Compares Power Consumption of Electronic Home Appliances. http://www.iosrjen.org/Papers/vol2_issue9%20(part-5)/B0290610.pdf(Accessed 15 November 2017).
[16] M. Lee, Y. Park, K. Jung and J. Yoo, Android Platform based Power Consumption Monitoring System. http://www.iiis.org/cds2012/cd2012sci/sci_2012/paperspdf/sa521cy.pdf(Accessed 15 November 2017).
[17] A. Mahmud, (2013). Design and Hardware Implementation of a Digital Wattmeter. http://www.ajer.org/papers/v2(12)/ZB212244251.pdf(Accessed 15 November 2017).
[18] M. Suthar, K. Suthar and A. Borole, (2017). Design and Implementation of Smart Energy Measuring System using MQTT Protocol.http://www.ijsrd.com/Article.php?manuscript=IJSRDV5I21237 (Accessed 15 November 2017).
[19] S. DeBruin, B. Campbell and P. Dutta, Monjolo: An Energy-Harvesting Energy Meter Architecture. https://web.eecs.umich.edu/~prabal/pubs/papers/debruin13monjolo.pdf(Accessed 15 November 2017).
[20] J. Jayanand, Exploring IOT Application Using Raspberry Pi. http://oaji.net/articles/2015/1858-1428151269.pdf (Accessed 15 November 2017).