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PREDICTIVE MODEL FOR DEVICE IDENTIFICATION USING MACHINE LEARNING ALGORITHM

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Abstract- *The existing power generation sources are unable to meet the hyper escalating electricity demand. Common solution is to install new generation plants to fulfill the electricity demand which it is not cost-effective. A cheap and effective solution is to monitor all the appliances running inside a building and to use them efficiently. Non-intrusive load monitoring (NILM) is one of the economical techniques to identify the appliances on the basis of their unique load signatures. In this paper, a machine learning based technique is presented to identify the devices for monitoring purposes. A low-cost hardware setup, called Appliance Identification and Management System (AIMS) is developed to identify and control the appliances remotely. The appliance identification algorithm is developed in Python. The hardware setup furnishes consumers with the real-time status of all home appliances on their smartphone and web server. Controlling module is also integrated with the identification hardware to provide smart access to consumer for the remote control of home appliances.*

Keywords: NILM, AIMS, PZEM004T, Python, Real Time Monitoring

I. INTRODUCTION

In today's world, the usage of current and voltage is increasing but the measurement of energy consumption is not measured and thus electricity and money cannot be saved from this. Decreasing energy consumption and cutting costs are important in new era. Especially in residential areas, it is hard to decrease the usage of current and voltage and to save money and energy as they don't have any idea about the power or energy consumption of each house or flat. If a method or process that can detect the energy or power consumed by each house or flat, it will be a great save for everyone. Actually people get the aggregated bill at the end of a month, they don't get the disaggregated bill or disaggregated power consumption list. If one can get the disaggregated energy system and real-time power consumption list, various studies have shown that it can save 12-15% current and money at the same time. Moreover, others suggest that even more power or energy can be saved if accurate, real-time, disaggregated power information is available to consumers.

Now-a-days, interest in home automation system and application is increasing. People are becoming more conscious than before and are interested in saving power for future. There is a growing consciousness in people that can be seen about renewable energy and ecological reasons for reducing energy or power consumption. Even, it is showed that there is also a growing number of companies interested in providing consumers with more detailed electricity consumption feedback and commercial electricity monitors: The Energy Detective (TED), PlotWatt, Bidgely, and Opower, to list a few.

Non-intrusive load monitoring (NILM) or Non-intrusive appliances load monitoring (NIALM) is a useful process that can define the changes in current and voltage and operation of individual appliances based on analysis of complex load measured at the entry of a house. If we can figure out the individual load being used in every appliance at our household, it will assist us with managing bills and with power quality monitoring. A significant reduction in the energy wastage can be achieved through this approach. This is not basically a modern approach as two decades ago G. W. Hart [1] first developed the idea of non-intrusive load monitoring; it is an ancient approach of NILM to collect the signals or metering. Later a lot of remarkable researches were developed to establish the theory of NILM and introduced its innovative applications. However, the increasing use of electronic vehicle battery (EVb) will challenge NILM systems as the previous methods are not suitable for recognizing the variable characteristics of it. Although several researches are going on to establish more accurate approach to EVb load disaggregation, we are proposing an improved algorithm for training free NILM for low sampling rate.

The idea behind NILM is to help people to know how much power they are consuming and where that power is going [1]. Today, many cars have real-time gas mileage feedback, but there is no system for real-time power consumption in the house. Before this feedback for cars was available, the only indication of gas consumption was how frequently one had to refill the tank. Increased fuel prices have spurred advancements in internal combustion engines that have not only improved their efficiency, but have also sought to instruct the user on how to drive more efficiently. This is the type of

impact that NILM systems could potentially have in the home. Instead of paying the vague monthly power bill, consumers can take control of the situation and be surer of where their money is going and exactly what they are paying for. Electricity consumption in residential and commercial buildings plays a huge role in the worldwide energy demand. In 2015, the residential sector accounted for around 27% of the total electricity consumed in the world and has increased by nearly 30% in a decade [1]. It is estimated that there will be around 80% more buildings by the end of 2050 which will bring an exponential increase in the energy demand [2]. More specifically, in Sweden the residential and service sector accounts for almost 40% of energy use [3]. As a sustainability goal of United Nations (UN), Sweden wants to reduce its energy intensity [4] in 2020 by 20% compared to 2008. Hence, energy saving in the residential building is expected to have a significant impact on the reduction of the overall energy consumption. One approach to reducing energy consumption in a building is to inspire positive behaviour change in the residents. Several behaviour studies have concluded that an informed resident can reduce electricity consumption of the building by 5% - 15%. The situation can be improved if residents are made aware of their real-time appliance specific consumption [1]. This can be achieved through real-time monitoring of end-use appliance consumption and providing real-time actionable feedback to its residents through Appliance Load Monitoring (ALM) systems. The goal of the ALM is to provide the real-time electricity consumption of each appliance in a household as well as the entire house. An ALM consists of one or multiple smart metering devices that measure, collect and analyze the total energy consumed. These smart meters, coupled with a home automation system, can be used to develop energy conservation strategies such as re-scheduling of high power demanding appliance to off-peak periods and help its residents to reduce to overall electricity bill. ALM system is also beneficiary to energy providers as it can help create better understanding of specific appliance usage patterns and provide fault diagnosis and remote load monitoring services. ALM can be developed in two manners, one is Intrusive Load Monitoring (ILM) and another is Non-Intrusive Load Monitoring (NILM) [2]. The ILM is a traditional method of deploying sensors at each appliances and monitoring their consumption. This makes the system costly with large installation overheads. On the other hand in NILM, only one smart meter is required per home. The smart meter captures the aggregated data from a single point of source and then this data is disaggregated into appliances using various electrical features, specific to each appliance. Hence, NILM offers an economically viable solution for an ALM system.

II. LITERATURE SURVEY

The need for integration of Cloud and Internet of Things, an agent-oriented and Cloud assisted on Cloud IoT paradigm which based upon the layered reference architecture.

Reference architecture for agent-oriented vision and Cloud - assisted is proposed, a Cloud based IoT paradigm applications scenario is described that have been presented in the literature, and Finally identified and discussed about open issues and future directions.[1]

This proposal is for a low-cost patient healthcare monitoring system model based on lightweight wearable sensors. These sensing nodes are used for real time detection and analysis of healthcare data of patients. The devices are designed to be able to collect and share the gathered data among themselves thereby facilitating information analysis and storage. This also eliminates manual in-efficiencies in the process. For patient data collection, a Arduino based wearable device with Body Sensor Networks is proposed. This is integrated with "Labview" to provide remote monitoring capability. [2]

Heart Rate Variability (HRV) measures variation in time interval between consecutive heart beats. HRV analysis can detect Cardiovascular diseases, Diabetic Mellitus, disease states associated with Autonomic Dysrhythmia like Hypertension and different chronic degenerative medical conditions. Monitoring HRV data will help detection of such diseases. In this research work, the authors propose a low-cost and easy to use Remote HRV Monitoring System based on Internet of Things (IoT) technology for Hypertensive patients. In this proposal, HRV parameters are calculated based on the data retrieved using Wireless Zigbee based pulse sensor. This Arduino based systems transmits the data retrieved from monitoring the patient to a backend server using MQTT an IOT protocol. The application server collects HRV data and plots graphs.[3]

III. PROPOSED METHODOLOGY

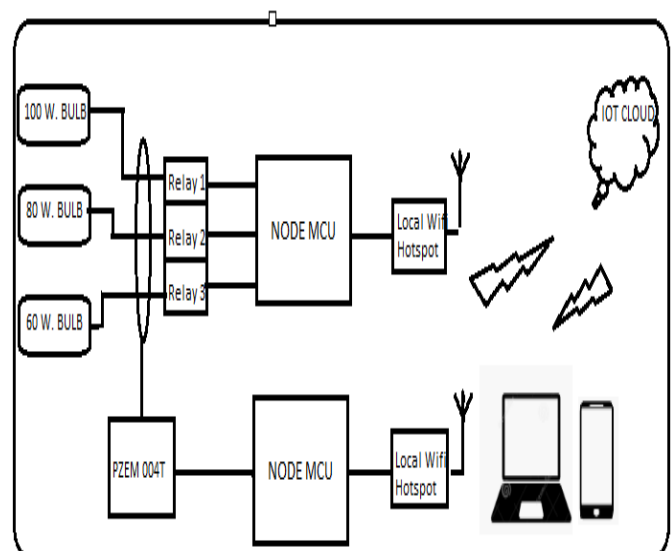




Figure 3.1: Block diagram of IOT based Non-Intrusive Appliance Identification and Controlling

Figure 3.1 Block diagram of IOT based Non-Intrusive Appliance Identification and Controlling. The system uses the Node MCU as a microcontroller. Node MCU uses local Wifi hotspot which configured by user for connecting to the Ubidots cloud. Relay module is used for connecting AC Load. Different bulbs are used. Three Bulbs are (60, 80, 100 watts each) are used which are interface through Relay module and controlled by Node MCU. Loads are controlled through IOT using UBIDOTS cloud. Current are detected by the Non – Intrusive way. Current are detected by using PZEM 004 sensor. Another Node MCU is used to interface PZEM 004T for measurement of current, voltage and power .The Voltage, Current and power are send over cloud through internet using ESP8266 wifi module. User can access the data and controlled the devices through ubidots IOT cloud.

After the preparation of this all data, it is analyzed with machine learning algorithm. During the data analysis stage various forms of technical assumptions are considered which help to select the best fit ML algorithms. Here Simple Linear Regression (SLR) and Multiple Linear Regression (MLR) Supervised Machine Learning Algorithm are used. ML algorithms reveals the hidden correlations in sets of data for detecting data patterns which are abnormal. This pattern of data is reflected in models which are termed as prediction models. After this the prediction models are built, training is provided to them and then they are used to identify the current, voltage and power consumption conditions, normal and abnormal working of home appliance. The prediction models needs training for long time to respond to new data and then deliver the outcome we need.

Machine Learning Techniques Used In the Project (Supervised Machine Learning)

Machine Learning focuses on prediction and can make data analysis and prediction efficient by looking at huge amounts of data simultaneously. It monitors accuracy over statistical importance. The majority of practical machine learning technique uses supervised learning. In supervised Machine Learning which is used in this existing system all data is labeled and the algorithms learns to predict the outcome from the input data .Supervised learning is where we have input variable (X) and an output variable (Y) and we use an algorithm to learn the mapping function from the input to the output. The basic representation can be given in the form of expression below which shows that the output variable (Y) is the function of input variable (X).

$$Y = f(X)$$

The aim in supervised learning is to approximate the mapping function so well that when we have new input data (X) then we can predict the output variables (Y) for that data. It is called supervised learning because the process of algorithm

learning from the training datasets can be considered as a teacher supervising the learning process. We know the correct answers; the algorithm iteratively makes predictions on the training data and is corrected by the teacher. Learning process stops when the algorithm achieves an acceptable level of performance.

Supervised learning problems can be further grouped into regression and classification problems.

Classification

A classification problem is when the output variable let us consider here as Y is a category, such as “red” or “blue” or “disease” and “no disease”. Classification requires the data points to have discrete values e.g. categories. First remarkable data is assigned into categories (classes). Then new input data let us consider here as X is categorized based on significant (remarkable) data and finally decisions are made. Forecasted values are discrete. Classification produces discrete values and dataset to severe categories.

Regression

A regression problem is when the output variable is a real value with continuous output, such as “dollars” or “weight”, in our system it is regarding the key variables of home appliances that is current, voltage and power consumption. Regression requires the data points to have continuous values. First the factors (independent variables) are found. Then coefficients (multipliers) to independent variables are calculated that minimizes the differences between actual and predicted values. Finally a formula is computed. The formula is used to forecast dependent variable (what we want to measure) from independent variables (what we think our target measure is dependent on). The forecasted values are real and uninterrupted that is continuous. Thus regression gives us a continuous result.

Some popular examples of supervised machine learning (Regression) algorithms are

Simple Linear Regression for Regression problems

Linear Regression is a machine learning algorithm based on supervised learning. It performs a regression task. Regression models a target prediction value based on independent variables. It is mostly used for finding out the relationship between variables and forecasting. Different regression models differ based on the kind of relationship between dependent and independent variables they are considering and the number of independent variables or key parameters being used. Linear Regression is used in troubles where the label is of continuous nature Sales of a retail chain, continuous monitoring of any machine in terms of specific parameter related to that machine. It consists of normal least squares method fitting the best line that minimizes the sum of squared errors between the predicted and actual data points. Such

algorithms are mostly used to for decision-making process to solve problems like if it is necessary to replace machine or not , is there any need of maintenance or not, monitoring of machine in industries at particular interval of time is necessary or not, is it working normally or abnormally due to heavy load and many more.

Multiple Linear Regression

Multiple Linear Regression attempts to build the Relationship between two or more features or key variables and a response by fitting a linear equation to observed data. The steps to perform multiple linear Regression are almost similar to that of simple linear Regression. The dissimilarity lies in the evaluation. We can use it to find out which key variable has the highest impact on the predicted outcome and we can also eliminate the key variable or factor which has a lowest impact on predicted outcome and which has not much contribution to the accuracy of prediction. It is the most common form of Linear Regression. Multiple Linear Regression basically defines how a single response variable Y depends linearly on a number of predictor variables.

Flowchart of Proposed System

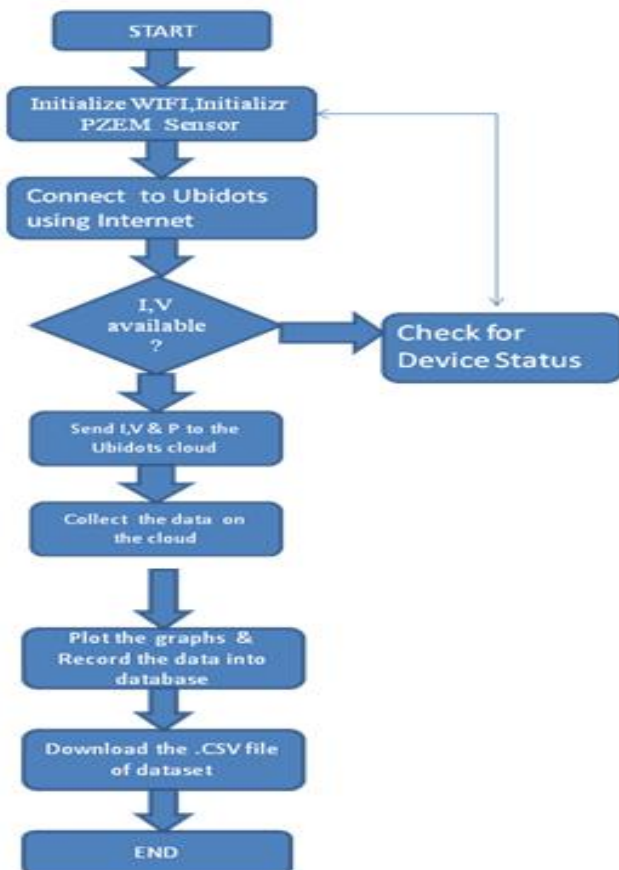


Figure: 3.2 Flow Chart of proposed System Algorithm

Step 1: Power on and Initialize WI-fi ,module , node mcu and PZEM current sensor .

Step 2: Connect to Ubidots cloud using Internet via Node Mcu.

Step 3: If I and V available then send data to ubidots cloud. If I, and V not available go to step 1.

Step 4: Collect the current and voltage value on cloud.

Step 5: Plot the graphs and record the data into database.

Step 6: Download the .CSV file for machine learning to know the status of Appliance Identification and Management.

IV. HARDWARE SOFTWARE DESCRIPTION

Node MCU ESP8266 12E Module



Figure: 4.1 Node MCU Module

NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Es press if Systems, and hardware which is based on the ESP-12 module. The term “NodeMCU” by default refers to the firmware rather than the DevKit. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Es press if Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson, and spiffs

Features

Supports Lua (alike node.js) and Arduino C programming language. Version: DevKit v1.0

Breadboard Friendly

Light Weight and small size.

3.3V operated, can be USB powered.

Uses wireless protocol 802.11b/g/n.

Built-in wireless connectivity capabilities.

ARDUINO SOFTWARE

Arduino is an open source computer hardware and software company, project, and user community that designs and manufactures single-board of the microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical and digital world. The project's products are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL),[1] permitting the manufacture of Arduino boards and software distribution by anyone.

Arduino boards are available commercially in preassembled form, or as do-it-yourself (DIY) kits. Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards or Breadboards (*shields*) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler tool chains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

UBIDOTS SOFTWARE

Ubidots is an Internet of Things (IoT) data analytics and visualization company. We turn sensor data into information that matters for business-decisions, machine-to-machine interactions, educational research, and increase economization of global resources. Ubidots exists as an easy and affordable means to integrate the power of the IoT into your business or research. Ubidots technology and engineering stack was developed to deliver a secure, white-glove experience for our users. Device friendly APIs (accessed over HTTP/MQTT/TCP/UDP protocols) provide a simple and secure connection for sending and retrieving data to and from our cloud service in real-time. Ubidots' time-series backend services are performance optimized for IoT data storage, computation, and retrieval. Our application enablement platform supports interactive, real-time data visualization (widgets), and an IoT App Builder that allows developers to extend the platform with their own HTML/JS code for private customization when desired. Ubidots exists to empower your data from device to visualization.



Figure 4.2: logo of Ubidots software

The basics components of any Internet of Things application powered by Ubidots are: Devices, Variables, Synthetic Variables Engine, Dashboards, and Events. Within this article we will address each of these concepts as they relate to Ubidots IoT Development and Deployment Platform and how you can better organize your Ubidots Apps to best connect with the users. Once your devices, variables, and general Application is assembled, give your App some layers with Ubidots Device Management to learn more about Ubidots internal architecture and how you can use Apps, Organizations, and Users to efficiently connect your data with those who should be using it. The Contents are as follows: A Ubidots' device is a virtual representation of a data-source or simply, an asset taking sensor data and transmitting said data

through a connection protocol to Ubidots' cloud. All devices are different, but the standard setup on any device entails:

- A library that should be installed in the device's IDE. (not required)
- Filling parameters for authentication and connection such as a TOKEN (i.e. the unique ID for each account or user), device and variable labels (i.e. devices and variables unique identifiers in Ubidots), Wi-Fi SSID and Password, depending on the device and the requirements.
- Making API request (i.e. a call from a device to the web server). Ubidots' libraries spare the need to manually make these requests. However, if you're working with a device not currently in the list of supported hardware, you can choose a connectivity protocol such as MQTT or HTTP and make a request using the API accordingly.

SPYDER SOFTWARE

Spyder is a powerful scientific environment written in Python, for Python, and designed by and for scientists, engineers and data analysts. It offers a unique combination of the advanced editing, analysis, debugging, and profiling functionality of a comprehensive development tool with the data exploration, interactive execution, deep inspection, and beautiful visualization capabilities of a scientific package.

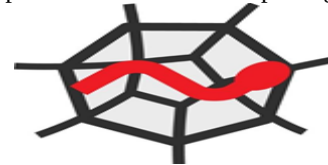


Figure 4.3: Logo of Spyder

Beyond its many built-in features, its abilities can be extended even further via its plugin system and API. Furthermore, Spyder can also be used as a PyQt5 extension library, allowing you to build upon its functionality and embed its components, such as the interactive console, in software

V. RESULT

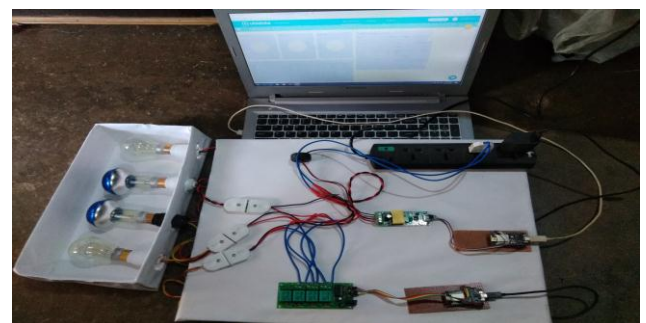


Figure 5.1 Complete Hardware setup of proposed system

The complete hardware setup consisting of two nodes. Microcontroller ATMEGA 328 ,Relay module ,current sensor and 4 bulb use as a load. One node consisting of controller , current sensor. Another node made up of Relay module, microcontroller and load having 4 bulb. Load Device 1= 40 watt ,Device 2=60 watt(30 watt x2=60 watt) ,Device 3= 80 Watt.Here 2 30 watt bulb are use to make 60 watt.

This step is very important because the quality and the quantity of data that has been gathered will directly determine how good is the prediction model .The process of gathering the data depends upon the application for which the data is been collected. Here we are building a project for predictive maintenance of home appliances hence it is necessary to collect the real time data. Firstly an integrated system of Pzem-004T with Node MCU ESP8266 using Ubidots IoT firmware is built the main component for data collection used here is Pzem-004T meter which gives the corresponding current ,voltage and power consumption reading of home appliances . This meter collects the data which is numeric in form and display it in dashboard of Ubidots explorer app, but the collected data cannot be used directly for performing the analysis process as there might be a lot of missing data, extremely large values, unorganized text data or noisy data. Therefore, to solve this problem Data Preparation and data Processing is done.

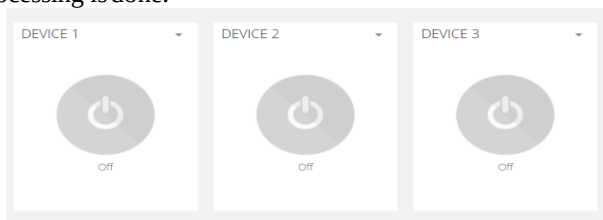
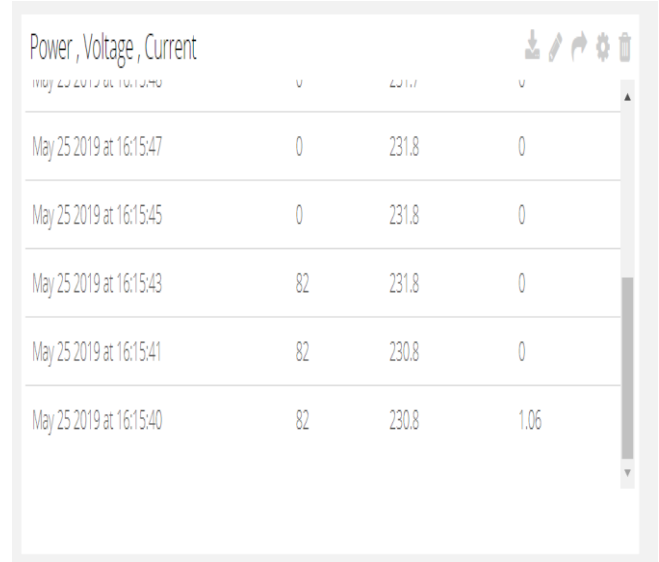


Figure:5.2 UBIDOTS Dashboard of 3 devices

Dashboard is used for 3 devices which can be shown in figure 5.2. They are operated remotely to make the individual devices on and off. It is designed and shown on Ubidots.



Time	Power (W)	Voltage (V)	Current (A)
May 25 2019 at 16:15:47	0	231.8	0
May 25 2019 at 16:15:45	0	231.8	0
May 25 2019 at 16:15:43	82	231.8	0
May 25 2019 at 16:15:41	82	230.8	0
May 25 2019 at 16:15:40	82	230.8	1.06

Figure 5.3 collect the data voltage, current and power on 25 may 2019

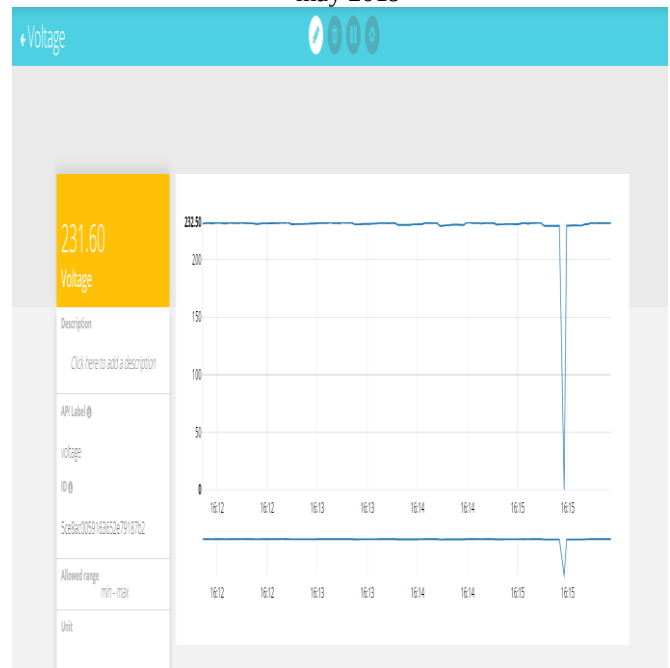


Figure:5.4 Graph plotted between Voltage and Time.

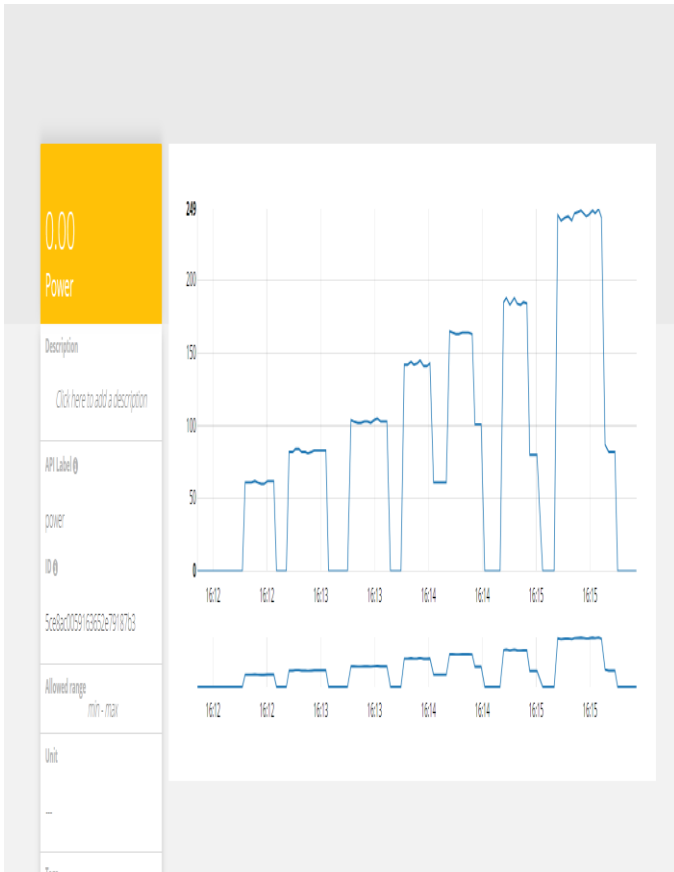


Figure:5.5 Graph plotted between Power and Time.

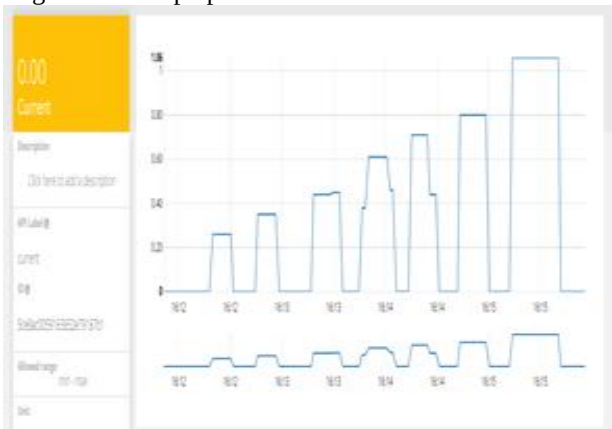


Figure: 5.6 Graph showing Current versus Time.

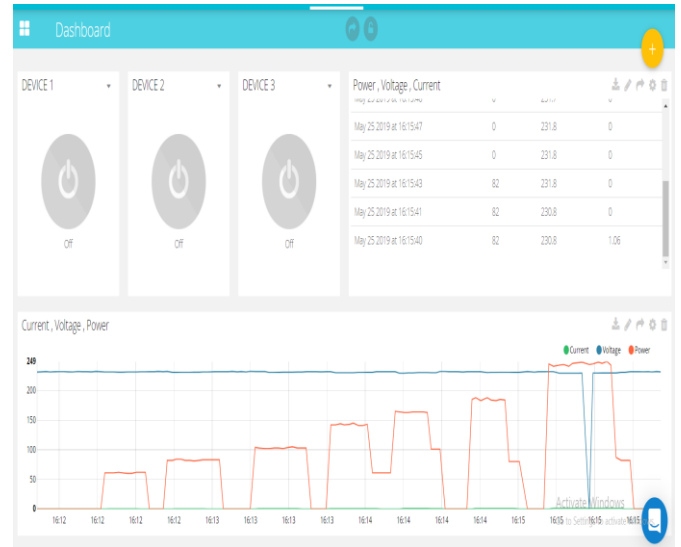


Figure:5.7 Complete Dashboard showing 3 devices status, value and Graph.

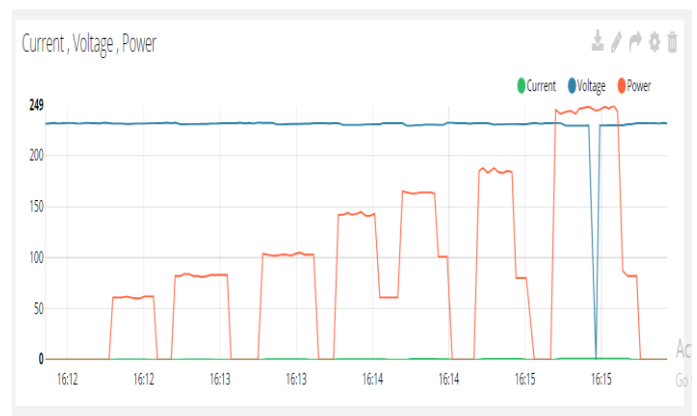


Figure:5.8 Dashboard showing Graphical representation of current, voltage and Power.

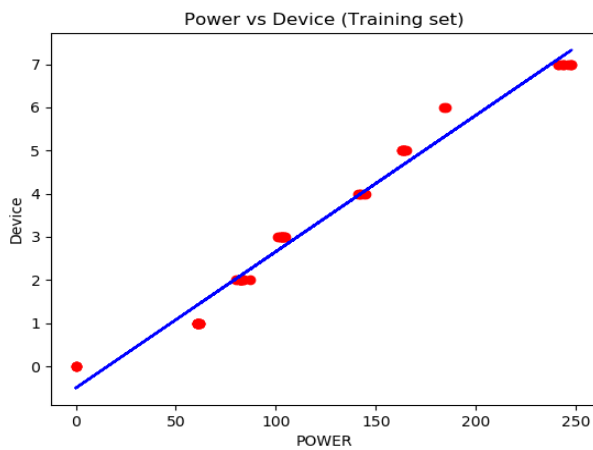


Figure 5.9: Graph plotted between Devices and Power in Training set

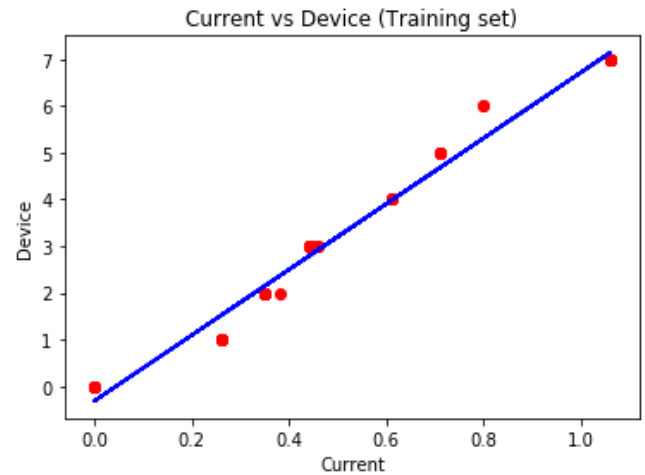


Figure:5.11 Graph plotted between Current and Devices in Training set.

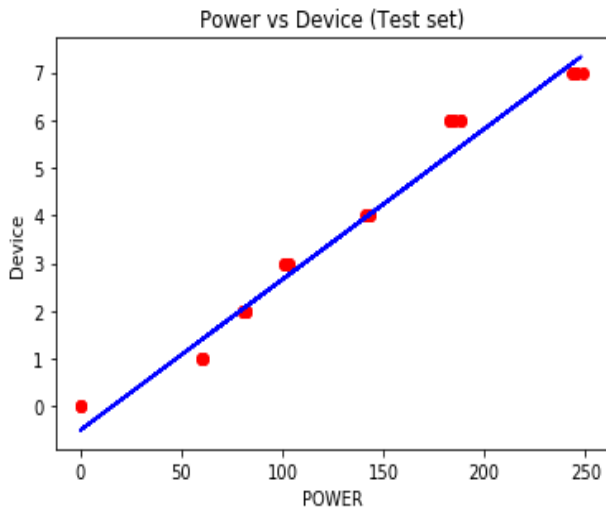


Figure:5.10 Graph plotted between Power and Devices in Test set.

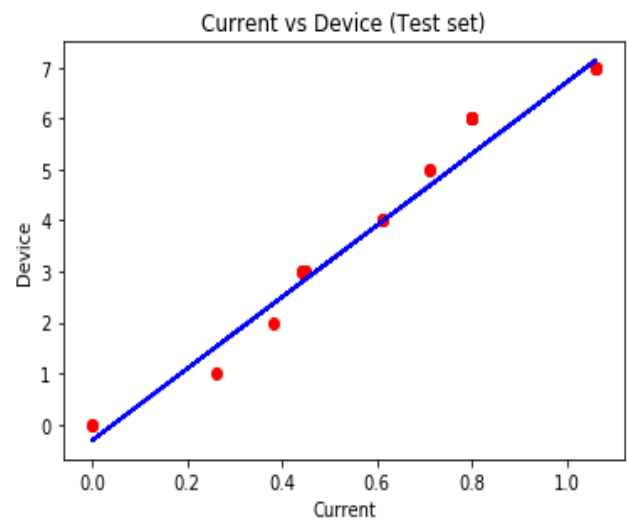


Figure:5.12 Graph plotted between Current and Devices in Test set.

Getting Predictions From The Existing Model

Machine Learning uses data to answer the questions so prediction is that step where we finally get to recognize the answers for our questions. The power of ML is that we were able to determine the performance of our home appliances under test for predictive maintenance using our model rather than using human judgement and manual rules.

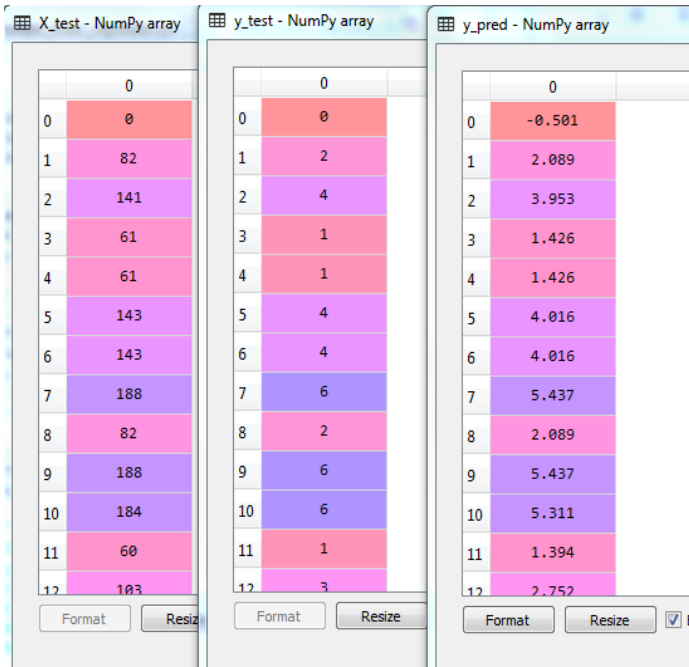


Figure 5.13: Comparison Of Input Test Data, Output Test Data And Predicted Output Data When Simple Linear Regression Algorithm Is Applied To Collected Dataset Of power vs device.

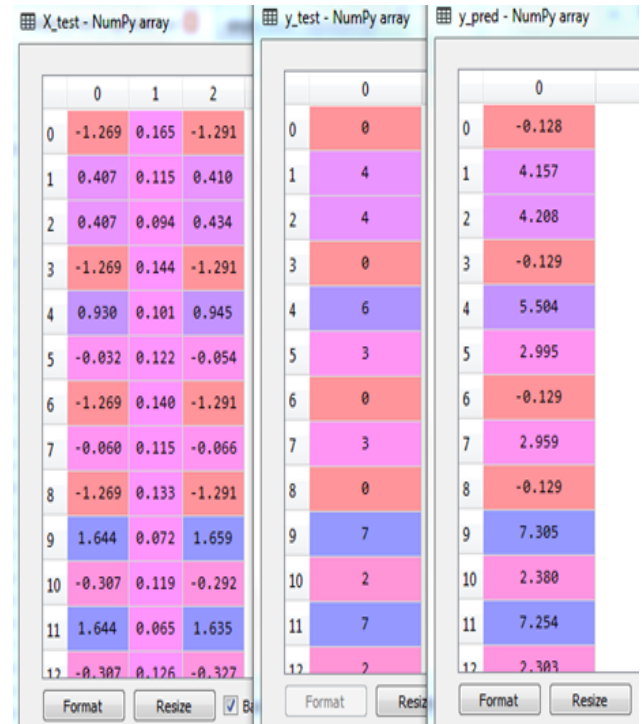


Figure 5.15: Comparison Of Input Test Data, Output Test Data And Predicted Output Data When Multiple Linear Regression Algorithm Is Applied To Collected Dataset of current, voltage and power.

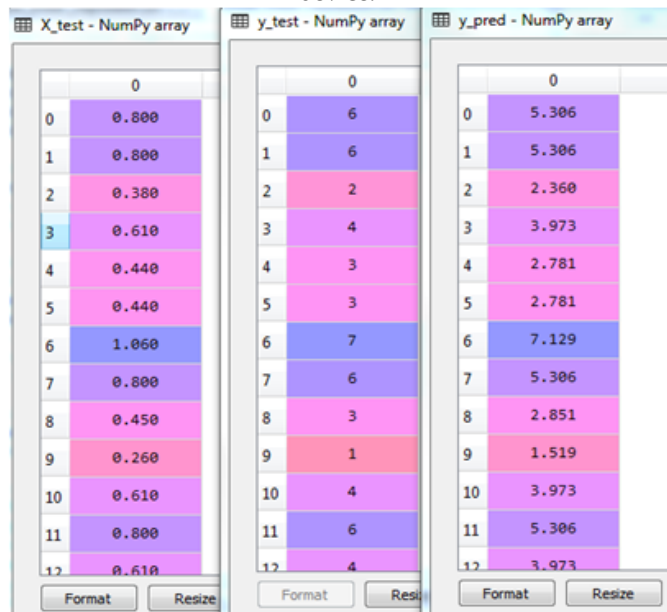


Figure 5.14: Comparison Of Input Test Data, Output Test Data And Predicted Output Data When Simple Linear Regression Algorithm Is Applied To Collected Dataset Of current vs device

In order to demonstrate the proposed system, we are comparing our system with the previous system according to the user specifications and technical specifications. The Table 5.1 & Table 5.2 shows the comparison of proposed system with the previous system on the basis of some parameter according to the user specifications and technical specification respectively.

Table 5.1: Relevance of Proposed System as per User Specification

Sr. No.	User Oriented Metrics	Earlier Method	Proposed Approach
1	Resource Requirement	More	Less
2	Speed	Low	High
3	Understand Ability	Complex	High
4	Security	Less	High

Table 5.2: comparison of Current sensor of Proposed System as per Technical Specification

Sr. No	FCT 30A	PZEM 004T
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1	O/P Analog Accuracy 60%	Non Invasive method accuracy 99%.
2	Voltage sensor =70%	Voltage sensor output 99%.
3	Power = Not define	Power= 99%.

VI. CONCLUSION

These project provides consisting of NODE MCU module integrating with relay module. To meet the energy saving targets set by governments, it is vital to motivate average consumers to make energy saving decisions. Feedback for energy use has been found to be an effective way to decrease energy use. Therefore, a need for a cheap solution for a wide deployment of energy usage feedback systems in households exists. A prototype application for providing feedback about individual appliance use in real-time to consumers was presented. The system was tested in a real test environment and was observed to give accurate appliance use statistics on average. Events were correctly identified 96.1% of the time and the total energy estimate was within 11.3% of the real consumption. NILM provides a cost-effective solution for appliance identification and monitoring because of single point sensing. Besides steady-state features, transient parameters also provide sufficient information for the identification of appliances. AIMS identifies the electrical appliances using PZEM 004T that features machine learning algorithm.

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