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IoT based Energy Monitoring in Smart Home using Mobile Application

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***Abstract*—As technology is growing rapidly, the proliferation of new electronic gadgets is at a rapid rate. As the electronic gadgets are increasing, power consumed by them also shoots up at a very faster rate as almost in every home we can have 10 to 15 gadgets. Consumption of power in India stood out to be 3rd largest in the entire globe. Power wastage is done in the houses which may give rise to a situation where one day we face power scarcity. In order to combat this, power consumption by one house should be limited to certain watts so that unnecessary wastage of power may be reduced. An energy monitoring system is proposed here where a user can monitor their power consumption every month by each appliance. A mobile application named Blynk is used wherein the power consumption can be monitored in the smart phone which is an easier way. It also gives an alert in the form of message when a set threshold of power consumed is exceeded. Using the mobile application user can take decision instantly whether he/she want to store or to schedule another power consumption limit. This system is totally built on ESP32, CT sensor and mobile application.**

Keywords —Energy monitoring, IoT, ESP32, CT sensor, Blynk

I. INTRODUCTION

Internet in the modern days is playing an indispensable role in daily life post the Covid pandemic. As everything has become online including education system, it became an unavoidable element in human life. One such technology which makes use of internet is IoT where it delivers agile solutions for all the conventional methods which are a boon. A technology which permits the things around the world to exchange information among each other by connecting is IoT. IoT is now becoming a part of every application which is giving rise to the evolution of smart cities. Home automation as such is an application area where IoT is integrated into a home making it smart. As IoT is being indulged everywhere the demand for electronic gadgets is also at a faster rate. As the gadgets are increasing, power consumption by a particular home also grows up which on a whole gives a tremendous increase in energy consumption considering the whole world.

The energy required to operate the gadgets in home is supplied from an electricity grid which used to operate in a conventional way i.e. only the energy flow used to be from the energy station to home but not vice versa. Advent of modern technology has made smart grid providing energy in a smarter way. With IoT being emerged in every application which provides a bidirectional communication from device to storage and as well services of remote clients which need to be served by captivating the data from the servers and as well as devices. So now the smart grid also provides energy upon the demand of the user where energy conservation may happen in turn reducing the burden on common people provided the whole system is integrated with IoT.

There should be system which keeps track of energy that is consumed by a particular appliance in a home which in turn helps in estimating the amount of energy consumed in the whole month. Sensors are used which can keep an eye about the energy consumption of a particular electronic appliance. A threshold limit will be set which when exceeded alerts the user about it. By this way user can have their own way of estimating the energy consumption in their home. Directly the consumed energy in watts is available in the mobile through Blynk app. These values also can be cached in the cloud for further analysis, in which particular month energy consumption is more or less that helps the user to modify their energy usage.

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II. LITERATURE SURVEY

Observing which electrical appliance in household is consuming what proportion of electricity is usually the key issue in controlling domestic power consumption. In [1] H. U. Sakib et al., proposed an energy monitoring system using IoT. The designed system allows the user to control particular connected Home Appliances through a mobile application.

In [2] U. Ramani et al., using Arduino as controller worked on home automation using IoT. Calculated power consumption by solar and regular meters, ESP 8266 wifi module been used to communicate with cloud. Energy consumption was displayed on a LCD display. For the automation process a mobile application have been used. Monitoring energy management and parallely on energy meter and solar battery can't be done collaterally however they need verified that it will be done.

In [3] A. S. L. K. Gopalamma et al., tend to over that in rising revolution in Industries and also the approaching options square measure wireless medical specialty, versatile integration, standard memory and prognostic maintenance these square measure potential with integration of communication came upon between machine to cloud and role of M2M and D2M square measure vital factors. In sight of that we tend to done an experiment to regulate AC drive with integration of webserver and remote exploitation s7 app and incorporated individual logic and experiment setup and additionally stress the step by step communication between M2M and D2M and individual screens additionally exposed here to clear plan.

Increasing value and demand of energy has led several organizations to seek out sensible ways in which for observation, managing and saving energy. An Energy management system based on the analytics of big data and IoT is designed by A.R. Al-Ali et al in [4]. Using scalable storage and data analytics the system was built, which can remotely monitor the control devices. User can even check the online bill generated through a mobile application.

A prototype designed in [5] by D. Alulema et al., which can remotely monitor electricity consumption in household using XBee technology. Increasing value and demand of energy has led several organizations to search for smarter ways to manage and save energy. The system is based on web application.

In [6] R. F. Eggea et al., presented a way in which energy controlling and monitoring in smart grid is made possible. A mobile application is used which is used to estimate the energy consumption of the user. Power consumption of the user can be reduced by tracking the mobile application as it suggests ways for it to happen.

In [7] M. Ferreira et al., presented ways for monitoring and controlling energy consumption with an android application. The application establishes targets in spending energy and load control it also proposes day to day analysis

In [8] M. B. Soudan et al., proposed a system design using controllers at the electrical appliances in households using sensors. A mobile application was included in the proposed system which acts as medium of communication in between cloud and the system. In [9] A. Nugur et al., proposed a system based on cloud technology which used the IoT gateway and it was called the building energy management.

Using Arduino as controller with 3G connectivity a real time monitoring of solar based home systems was developed in [10] by A. López-Vargas et al., a free software and hardware i.e a novel datalogger has been installed as an experimental prototype. By testing this Data logger in different location robustness of the system was demonstrated. This helped solving problems of PV systems located in isolated locations at low cost. To create awareness among the industrial and home electricity consumers in [11] R. Mathur et al., designed a system which display a real time energy consumption by the particular unit. A feature that sends final estimated bill to cloud hosted database.

In [12] B. Buddhahai et al., discussed about energy monitoring in home using a smart meter which gives the enrgy utilization by each appliance. Awareness on energy utilization is important to estimate how much energy is being consumed by each electronic appliance in home so that users can manage their energy consumption if required.

Management of energy through monitoring in public buildings is of prime consideration where a chance of huge wastage in energy is possible as there will be no person to individually monitor the entire appliances. In [13] Valerio R. M. Lo Verso et al. proposed a system where monitoring and managing of energy in public buildings is done. A system is tested in different buildings where this system is feasible to be equipped with the already existing technologies in the buildings.

In [14] W. Li, T. Logenthiran et al proposed a system in smart home that is integrated with machine learning technology. This application of machine learning in smart home leads to a self-analytical home where it can be able to predict the cost energy consumed in the home. A realistic study was made on one home in the city of Singapore.

In clustering the devices are grouped according to their homogeneity in any aspect and are made to talk to each other and communicate their data to a cluster head that is elected. In [15] Sowmya et al. proposed a system in smart home where the homogenous devices are clustered to reduce the number of internet connections to send the data to the controller layer. Also the bandwidth consumed by each device to send the data to controller layer also reduces which is proven to be effective in terms of performance evaluation.

In [16] Sowmya et al. have proposed a robotic car which can be monitored from a remote place and it changes its directions basing upon the gestures. The car is built with raspberry pi as the main controlling unit.

Internet of things technology is integrated in the mining field, where a server stores the temperature, humidity and concentration of gas in the mine which is proposed by Teju at al. in [17].

In [18] Teju et al. discussed about the smart card authentication which was achieved through Sha-256, an

algorithm used to encrypt the data. In modern days use of smart cards is increasing which also reminds us of the safety of the user data. So this algorithm imparts encryption in smart cards which has its own advantages.

In an IoT system performance of the network is important and there are many ways in which this can be improved. In [19] Sowmya et al. have discussed various ways and technologies how the improvement of performance can be done. One more issue in IoT networks that need to be considered is heterogeneity. The devices and protocols used for effecting communication among devices are not the same in every layer. So in order to establish communication among different layers protocol conversion need to be done which is done using many ways including hardware and software. Pavitra et al. in [20] have discussed some ways of protocol conversions.

In [21-24] various authors have proposed a system which is used to monitor energy in a smart home. Energy consumption is monitored and if the energy value exceeds a particular set threshold value it gives an alert message to the user to his mobile home.

III. Working Principle

The circuit that is designed in this paper works on the principle of electromagnetic induction. The electromagnetic induction states that a current carrying conductor produces a magnetic field around it. SCT-013-020 is a CT (Current Transformer) sensor that plays a key role. The maximum amount of current that this sensor is given by the last value it displays. The mechanism through which the sensor can detect the current is electromagnetic induction, where a conducting wire carries current around it.

The circuit works as a simple smart meter in which it can calculate or measure current, voltage, power consumption and its cost if needed. This design can be afforded by the middle class people as the components used are affordable and it is easy to operate. Here all the final outputs will be displayed in any mobile application like BLYNK app or in LCD or OLED screen.

The circuit consists of below mentioned components. They are

1) ESP32 DevKit board
2) ZMPT101B voltage sensor
3) SCT-013-020
4) HI-Link 5V supply
5) LCD display
6) Resistors
7) Capacitors

Fig. 1 indicates the connections of the circuit made

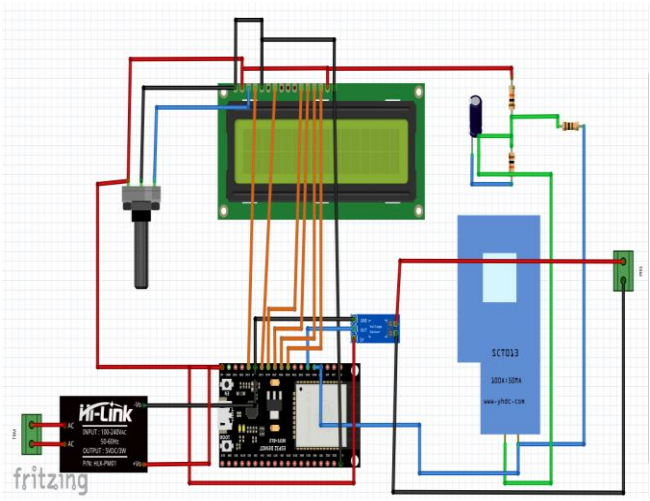

Fig. 1. Smart meter using ESP32 and SCT-013-020

ZMPT101B is a voltage sensor which when used in the circuit protects the whole circuit from voltage fluctuations as it can withstand a voltage up to 250V. For measuring the whole house power consumption no need to use this module and so connection can be decreased.

A. *Configuring the BLYNK Application:*

After creating an account in the app following steps need to be followed for a successful configuration

1) A token of authentication is sent to an E-Mail using which user has created an account.
2) After creating and successfully logging into account, need to create a new project.
3) After creating the project the hardware should be selected i.e. which microcontroller or module is to be used.
4) Now user requires an auth token which is a unique identifier for every single project that is created in the BLYNK app.
5) The auth token is sent to the respected mail that user already registered. Then click on the create button.
6) In the project section click on the add widget, so that it creates a part which helps for operating the hardware form the mobile.
7) Adding widget is very simple as it follows drag and drop format.
8) After adding all the widgets then configure their pins either the pins used are analog or digital or virtual pins.
9) Run button is pressed which enables the users to observe their values/ recordings of the project.

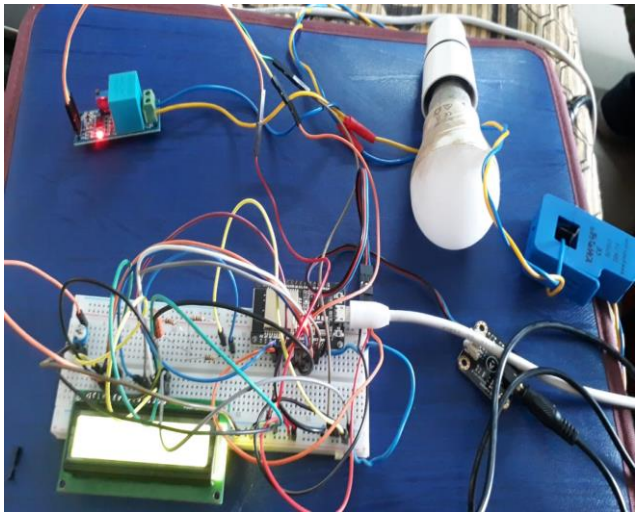

Fig. 2. Hardware model of the project

IV. Methodology

ESP32 kit which is dumped with the code into the microcontroller is placed in the above circuit. Connections are made as per the circuit diagram and are ensured that there are no loose connections in the circuit which may lead to erroneous errors in the output.

Now the plug is connected to the 240V AC supply and switched on. Then the 240V AC supply is converted to 5V DC which is used to power up the ESP 32 board and voltage sensor. Now the CT sensor is clamped to the live wire or the neutral wire of the mains that is in home. If the CT sensor is clamped to live and neutral wires then the CT sensor cannot detect the current precisely and gives the false readings.

From whichever wire the current has be measured, CT sensor is clamped to it where it gives an analogue value which is sent to ESP32 for further processing. In between the voltage sensor ZMPT101B comes into picture where it looks after the voltage fluctuations and the analogue value from the senor is given to ESP32 through this voltage sensor.

Here Emon(energy monitoring library) is used for monitoring the power consumption. The objects for the above library are defined and the calibration values are set because initially the readings are false. Now the BLYNK timer object is defined to handle the sending of data to the BLYNK mobile application.

The password, SSID and auth token of the local wifi router are defined. The milliseconds and kilowatt hour are to be initialized. They are started from the 0 values. The senor values are retrieved and calculated by using the following calculations:

1) Emon.calc(20,2000) real, apparent power, Vrms, Irms and power factor are calculated.
2) kWh = kWh + emon.apparentPower * (millis() - lastmillis) / 3600000000.0 (1)

by using equation (1) power is calculated.

The values from current sensor and voltage sensor are given to GPIO pins 35 and 35 of ESP32. And the whole results are displayed in LCD or OLED display.

For every 5 seconds the data will be uploaded to the BLYNK application. Serial monitor is another way through which we can track the data.

V. Results

The values that are displayed in the Blynk app or serial monitor of arduino or LCD display are shown in figures 3,4,5 and 6.

Fig. 3. Consumed power of the appliances in BLYNK

The values of power consumed by the appliances will be updated for every 5 minutes where a user can be able to

monitor these parameters. This updating of values is possible through the energy monitoring library emon.

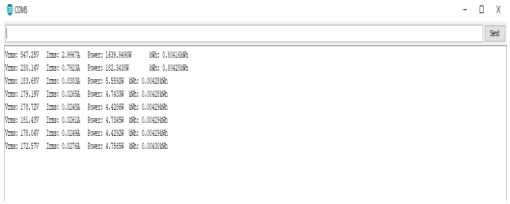

Fig. 4. Readings in serial monitor of arduino

The readings that are recorded in arduino serial monitor, BLYNK app and the LCD display must be same otherwise the user should note that there are some misconnections in the circuit and it is to be rechecked.

Fig. 5. The LCD display showing Vrms and Irms

Fig. 6. LCD display showing the power and kilowatt hour

The power consumption values of the appliances are tabulated to observe the power consumed by each appliance in the home and are shown in TABLE I.

TABLE I. POWER VALUES CONSUMED BY DIFFERENT APPLIANCES

S. No	Device	Date	Time stamp	Vrms = (V)	Irms (I)	Power (W)
1	Fan	10-03-2021	05:28: 24 PM	183.68	0.0303	5.5592
2	Fan	11-03-2021	04:30: 42 PM	178.72	0.0248	4.4286
3	Fan	12-03-2021	04:45: 26 PM	181.43	0.0261	4.7345
4	Fan	13-03-2021	05:10: 03 PM	178.04	0.0249	4.4292
5	Fan	14-03-2021	04:49: 58 PM	172.57	0.0276	4.7565
6	Light	10-03-2021	05:30: 55 PM	54.53	0.0152	0.8288
7	Light	11-03-2021	04:45: 44 PM	61.48	0.0245	1.5062
8	Light	12-03-2021	04:50: 23 PM	53.26	0.0186	0.9906
9	Light	13-03-2021	05:20: 45 PM	57.47	0.0114	0.6551
10	Light	14-03-2021	05:08: 56 PM	56.21	0.0176	0.9892
11	AC	12-03-2021	08:52: 45PM	547.25	2.9967	1639.9490

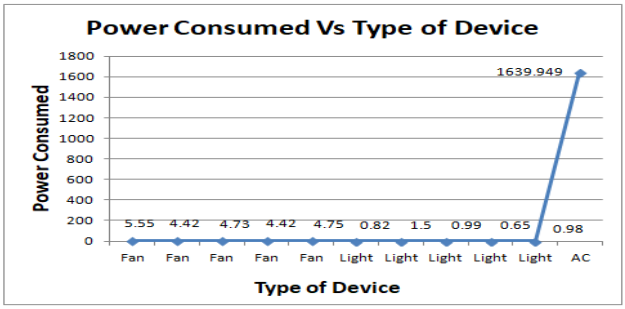

Fig. 7. Graph showing power consumed Vs Type of device

A graph is plotted between power consumed and the type of device that is used for experimentation and it can be observed that the power consumption of fan and light are almost minimal whereas it is tremendously increased for an AC.

Experiment is conducted basically on fan, light and AC which are the most common appliances in any home. The power consumption values of one fan, one light and an AC are collected per day for five days and as observed from the above table that power consumption by fan is more compared to that of light as fan will be used throughout the day whereas light will be used only at the night time.

Power consumption by AC is much more than fan and light. The power consumption may depend on several factors such as environmental conditions, time of the day i.e. morning/night, availability of people inside the home etc. So if a system as mentioned above is installed in every home, it gives the power consumption of the whole home on a monthly basis basing upon which one can estimate the consumption for next month and plan to conserve energy.

VI. CONCLUSION

The model proposed here can be used for measuring both the individual appliance and the household power consumption. The circuit is very simple and is of very low cost and can be afforded by the middle-class families. Using the mobile application user can take decision instantly whether he/she want to store or to schedule another power consumption limit. This system is totally built on ESP32, CT sensor and mobile application.

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