International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 04 | Apr 2024 www.irjet.net p-ISSN: 2395-0072

Energy Monitoring System Using Smart Grid

Ankit Kumar

Electronics and Telecommunications
K.J. Somaiya Institute of Technology, Sion, Mumbai, India.

Avanish Yadav

Electronics and Telecommunications
K.J. Somaiya Institute of Technology, Sion, Mumbai, India.

Divyank Trivedi

Electronics and Telecommunications
K.J. Somaiya Institute of Technology, Sion, Mumbai, India.

Sunil Patil

Electronics and Telecommunications
K.J. Somaiya Institute of Technology, Sion, Mumbai, India.

Abstract— *In today's time, people are much more aware of the fluctuations in electricity that occur & the pricing or to be precise the bill they receive from the electric power companies. According to our usage we might get a rough idea of how much energy are we consuming but in order to be accurate we need to keep a check on the usage and consumption of the energy. Hence, we have designed this circuit that we call as the "smart grid" which allows us to monitor the live data feed of our energy consumption. In this paper, we design and implement IoT based energy monitoring system that can be used in many applications, such as electricity billing system, energy management in smart grid and home automation. The experimental results showed that the system can successfully record the voltage, current, active power and accumulative power consumption.*

Keywords—Energy monitoring system, IoT, Smart grid

1. INTRODUCTION

As we know, IoT is being widely accepted & implemented in electronic devices & other technologies that help to connect & exchange data with other devices. IoT encompasses electronics, communication & computer science engineering. The increasing population & the economic development over the time has led to the growth in the consumption of electric energy. [1] Here, in our circuit we have used components like: ZMPT101B which is a voltage sensor to detect the single- phase AC voltage, ESP32 which is our Wi-Fi module, LCD display to display our data on the circuit, I2C module which is a serial interface for 16x2 character LCD that converts I2C serial data to parallel data, SCT-013 which is a non-invasive AC current sensor clamp & also few small components like resistors & capacitors.

Our entire circuit has been printed on a PCB board in order to minimize the errors from open wires & interferences. Test readings of a few light bulbs of different ratings such as 200W, 15W & 5W. The live data can we viewed on a spreadsheet. This spreadsheet displays live data & allows us to even store it as per our requirement for any future needs.

2. METHOD

Electromagnetic Induction

It is the principle of production of an electromotive force (emf) across an electrical conductor in a changing magnetic field. In simple terms, the current produced because of voltage production due to changing magnetic field. So as the current flows through the wire magnetic field is produced around it. This magnetic field can be checked or studied to monitor the fluctuations., if any.

Its application can be seen in current transformer theory. The current transformer theory is based on the principle of electromagnetic induction. The current transformer in an electrical device that measures electric current in a primary conductor & transforms the high current into a manageable value in order to be safely measured.

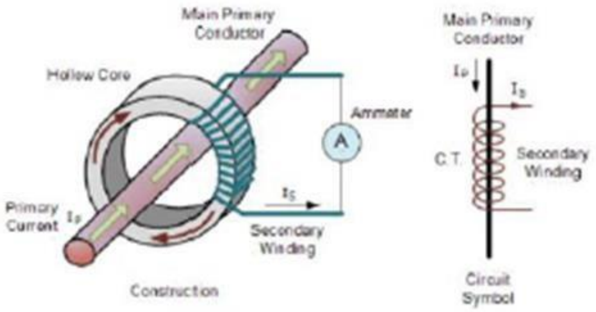

Fig.1: Current Transformer

3. LITERATURE SURVEY

Smart meters are increasingly being installed in homes around the world, largely due to government initiatives aimed at saving energy. This creates a large physical communication network consisting of millions of meters. These meters benefit energy distributors by simplifying transactions such as reading and billing. However, digital communication networks such as smart meters have the flexibility to offer new services. Smart meters can provide value-added services such as displaying energy consumption or managing loads to stay within contractual performance limits. They can also offer general functions such as optimizing heating or lighting based on energy tariffs that can be integrated into home automation systems.

In addition, other gas, heat and water smart meters could be connected to this network, increasing its efficiency. This requires smart meters that can effectively communicate with both energy service providers and household systems [1]. Effective network management could be an alternative to a complete network overhaul. However, the integration of smart grid technology offers valuable benefits and operational improvements. However, implementing smart metering systems presents a number of challenges and issues, including significant costs in the billions of dollars [2]. The power adapter and the meter monitor the temperatures in the freezer and the refrigerator and send the data wirelessly using the ZigBee protocol to the monitoring and control device. This data can then be sent to a computer for analysis. Energy-Butler obtains the price information for the next day through the home network from the Internet. Adjusts energy consumption based on the set temperatures of the refrigerator and freezer. This helps shift energy consumption from high-price periods to low-price periods, improving economic efficiency and ensuring stable energy supplies [4].

Improving monitoring capabilities to monitor all critical components in key locations requires the collection of large amounts of data to accurately and quickly visualize the situation. It is very important to create and send alerts when predefined conditions are met and store these alerts in a database for later analysis. This enhances the SCADA system by displaying network status on geographic maps, helping operators respond more quickly. Implementing robust data processing capabilities and gathering data from multiple locations more frequently enables better decision-making to improve efficiency and reliability. Analyzing this data and visually presenting the results helps to identify potential problems, take preventive measures and create accurate forecasts and investment plans.

This ultimately increases reliability while reducing operating costs [5]. Electricity consumption (KWH) in India was 689,537,000,000 in 2011 and earlier it was 156,400,000,000 in 1990. The main reason is the increase in electronic and electrical appliances in the home network (HAN). When we compare the energy consumption between 1990 and 2011, we can hardly find a home without a television, washing machine, refrigerator, etc. Among household appliances, the largest electricity consumption is lighting equipment, which consumes about 30 percent of electricity, followed by refrigerators, fans and electric water heaters, etc. [6] Intelligent infrastructure includes the intelligent energy subsystem, the intelligent information subsystem, and the intelligent communication subsystem. The smart energy subsystem controls the mechanism of production, distribution and consumption of electrical energy. The intelligent information subsystem is responsible for managing the exchange of information related to the measurement, monitoring and operation control of the smart grid system. Meanwhile, the intelligent communication subsystem solves the problems of the communication infrastructure for exchanging data between smart grid systems, devices and applications connected to the smart grid. The intelligent management system is implemented by using smart infrastructure devices to achieve goals related to improving energy efficiency, balancing supply and demand, regulating emissions, reducing operating costs, and maximizing utility value. An intelligent protection system is a subsystem in the intelligent grid that provides advanced network reliability analysis, failure protection, and security and privacy services [7].

The power grid is like a complex adaptive system (CAS) with many parts distributed geographically. It can change quickly as a whole as a result of actions in specific areas. EPRI used CAS to develop modeling, simulation, and analysis tools for adaptive and reconfigurable grid control.

The idea of self-healing distributed power system control involves treating each component as an intelligent agent. These agents cooperate and sometimes compete to optimize the entire system. This approach includes modeling, computation, sensing and control. EPRI began by modeling a bulk energy market where artificial agents represent buyers and sellers. Using this and other projects, EPRI has developed a model with multiple adaptive agents representing the grid and its interconnected organizations. The parameters to be measured in this proposal include consumption rates of electrical equipment, energy production rates of various energy sources, interactive connection of energy sources to the grid, etc.

In addition, the experiment will monitor real-time energy billing and analyze consumer energy consumption habits and also the energy demand forecast. To this end, it will monitor how the consumer monitors energy consumption and track back energy consumption rates [4][9].
The energy provider requests automatic readings of electricity meters monthly via SMS. The SMS gateway sends requests to all GSM electricity meters. Each electricity meter responds by reading its consumption in kWh via SMS. The SMS gateway collects and stores these readings. It may take some time to load all the readings due to network traffic and weather conditions. Once the measured values are collected, the application terminal updates the database. The e-billing system calculates bills based on tariff rates and sends notifications via email, SMS or hard copy. A web portal allows owners to check and pay bills online. Payment options include online banking or cash at energy provider outlets. Owners can also get meter readings via SMS and monitor usage from anywhere [10].
The implemented USEM is perfectly calibrated for its normal operating range. Measurement accuracy and all features of the USEM are tested under various loads with a wide range of voltage and current. All quantities are compared with a standard Fluke 5502A calibration meter. We measured voltages from 150 to 300 V with the USEM
and compared with the Fluke 5502A. It shows that the USEM gives a small error when the operating voltage is <180 and >240 V. We also compared the current measurements between the implemented USEM and a standard Fluke 5502A calibration meter. The result is shown in Fig. 7b. It shows that the current measurement gives a small error when the operating current is <0.2A and >15A [10].
Grid computing can be described as a world in which computing power is as readily available as electricity and other utilities. According to Irving et al. in "Plug into Grid Computing", Grid computing could offer participants an inexpensive and efficient means to compete (but also cooperate) in providing reliable, cheap and sustainable electricity supplies. Furthermore, potential applications for future energy systems include all aspects that involve computation and are interconnected, such as monitoring and control, market entry and participation, regulation and planning. Grid computing holds the promise of solving the design, management and protection of electric power infrastructure as CAS. That Mentioned in S. M. Amin and B. F. Wollenberg, “Toward a smart grid: power delivery [9]. Finally, in terms of end-user benefits, a number of issues need to be addressed to be effective. The requirement of a good efficient economic interface is again mandatory. This is especially true wherever meter placement is typical in locations that are remote from everyday living spaces, such as basements, cellars or dedicated utility rooms. However, once an effective interface is enabled, a number of services can be implemented that can run and be integrated within the functions and services that fall under the category of home automation and which have so far expanded significantly at the national level. basis. Home automation is associated not only with functions such as security, entertainment and comfort, and care for the sick, elderly and disabled, but also with energy savings. Unfortunately, so far, the more common energy-saving home automation devices ignore the official smart meter mainly due to the lack or complexity of the local interface in favor of other independent and cheap devices to measure consumption, which in turn would be difficult. be integrated into programs for DR policies.

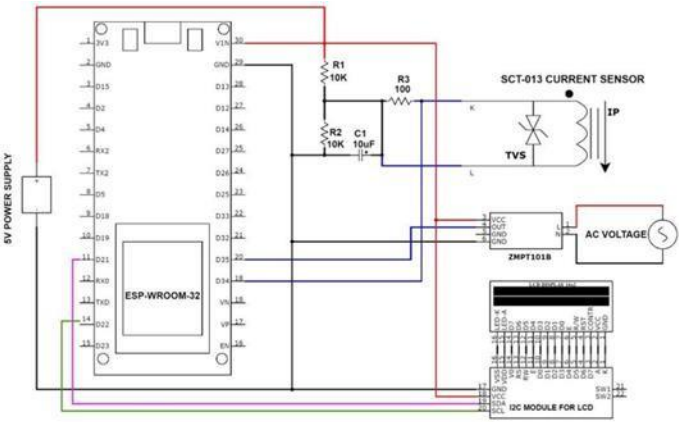

Fig.2: Circuit Diagram

4. METHODOLOGY

As seen in the circuit diagram, we have used SCT-013 (a non-invasive current sensor clamp) that is clamped around the input wire in order to detect the electric current flowing through it. The ZMPT101B is a voltage sensor that detects the AC voltage flowing through & is connected to ESP-32 that acts as Wi-Fi module.
All the components are connected together first through jumper wires onto a breadboard & in order to minimize the errors produced due to the open wires the circuit has been printed on PCB. Allowing us to create a compact system circuit & also minimize the errors or fluctuations produced earlier. The schematic diagram of the PCB can be seen below.

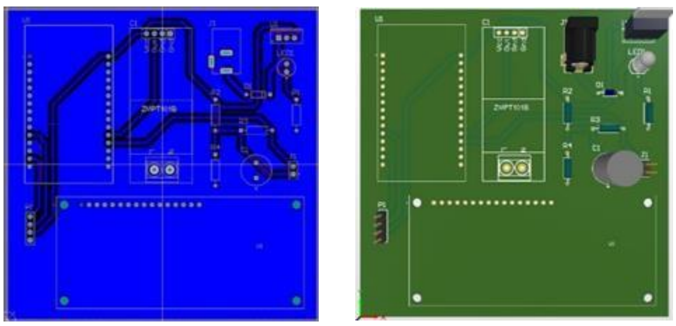
Fig.3: Schematic Diagram (PCB)

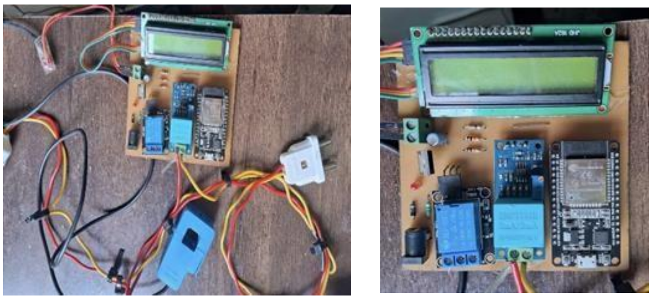

Fig.4: Printed Circuit Board Design

5. EXPERIMENTAL RESULTS

Through our system we have successfully managed to monitor the voltage, current & power consumption as seen in Fig.4. Here we can see that the values are shown for when the appliance is running & as and when we turn off the appliances all the ‘values return to zero’. In this way we have managed to do the test run on light bulbs of different Watts. The circuit is capable of monitoring heavy appliances also such as juice mixer or grinder, hair dryer, etc. In this section, the operation of the developed IoT energy meter is demonstrated.

The implementation took place experimentally at our laboratory. Comprising gauges indicating the active values of voltage, current, and power, the dashboard also featured graphs representing the measured energy data over time. Energy data was collected from the energy sensor node and transmitted to the server. Each sensor possessed a unique ID and transmitted data every 20 seconds throughout the day. This design allows for the deployment of multiple sensor nodes, with data from each node simultaneously displayed on the dashboard.

Fig.5 (a, b, c) respectively show the results obtained while monitoring the appliances, since the data obtained is in large amounts, it is not possible to show entire data but an instance of each can be seen.

714	April 23, 2024 at 07:49PM	powerMeter	67.15V	117.28mA	9.09W
715	April 23, 2024 at 07:50PM	powerMeter	67.58V	127.54mA	9.26W
716	April 23, 2024 at 07:50PM	powerMeter	77.52V	119.57mA	9.81W
717	April 23, 2024 at 07:50PM	powerMeter	0.00V	0.00mA	0.00W
718	April 23, 2024 at 07:50PM	powerMeter	0.00V	0.00mA	0.00W
719	April 23, 2024 at 07:50PM	powerMeter	0.00V	0.00mA	0.00W
720	April 23, 2024 at 07:50PM	powerMeter	0.00V	0.00mA	0.00W
721	April 23, 2024 at 07:50PM	powerMeter	0.00V	0.00mA	0.00W
722	April 23, 2024 at 07:50PM	powerMeter	0.00V	0.00mA	0.00W
723	April 23, 2024 at 07:51PM	powerMeter	217.82V	417.30mA	90.01W
724	April 23, 2024 at 07:51PM	powerMeter	306.78V	407.39mA	125.98W
725	April 23, 2024 at 07:52PM	powerMeter	212.69V	528.76mA	112.71W
726	April 23, 2024 at 07:52PM	powerMeter	210.57V	423.74mA	89.31W
727	April 23, 2024 at 07:52PM	powerMeter	266.77V	439.75mA	117.32W
728	April 23, 2024 at 07:52PM	powerMeter	265.41V	321.90mA	85.34W
729	April 23, 2024 at 07:52PM	powerMeter	262.55V	300.93mA	78.95W
730	April 23, 2024 at 07:53PM	powerMeter	0.00V	0.00mA	0.00W
731	April 23, 2024 at 07:53PM	powerMeter	265.27V	449.85mA	118.79W
732	April 23, 2024 at 07:54PM	powerMeter	256.49V	1041.40mA	267.11W
733	April 23, 2024 at 07:54PM	powerMeter	264.00V	503.21mA	132.63W
734	April 23, 2024 at 07:54PM	powerMeter	267.96V	443.48mA	118.97W
735	April 23, 2024 at 07:54PM	powerMeter	260.84V	856.39mA	222.30W
736	April 23, 2024 at 07:54PM	powerMeter	269.23V	489.25mA	131.57W
737	April 23, 2024 at 07:55PM	powerMeter	264.80V	622.27mA	164.43W
738	April 23, 2024 at 07:55PM	powerMeter	269.22V	458.39mA	123.16W
739	April 23, 2024 at 07:55PM	powerMeter	267.97V	437.57mA	117.22W

Fig.5a: Results for a hair dryer

powerMeter

Sheet2 Sheet1

	A	B	C	D	E
1	DATE & TIME	EventName	Voltage (V)	Current (mA)	Power (W)
2	March 20, 2024 at 11:30PM	powerMeter	564.62V	59.68mA	34.19W
3	March 20, 2024 at 11:30PM	powerMeter	548.39V	54.57mA	30.06W
4	March 20, 2024 at 11:30PM	powerMeter	554.14V	54.62mA	30.28W
5	March 20, 2024 at 11:30PM	powerMeter	557.37V	55.21mA	30.96W
6	March 20, 2024 at 11:30PM	powerMeter	551.37V	57.23mA	31.74W
7	March 20, 2024 at 11:31PM	powerMeter	558.76V	60.85mA	34.18W
8	March 20, 2024 at 11:31PM	powerMeter	549.53V	57.51mA	31.72W
9	March 20, 2024 at 11:31PM	powerMeter	544.99V	52.27mA	28.49W
10	March 20, 2024 at 11:31PM	powerMeter	548.38V	53.75mA	29.48W
11	March 20, 2024 at 11:31PM	powerMeter	533.86V	59.88mA	31.99W
12	March 20, 2024 at 11:31PM	powerMeter	528.96V	54.41mA	28.75W
13	March 20, 2024 at 11:31PM	powerMeter	541.47V	60.74mA	33.09W
14	March 20, 2024 at 11:31PM	powerMeter	547.15V	54.36mA	29.75W
15	March 20, 2024 at 11:32PM	powerMeter	539.42V	52.94mA	28.58W
16	March 20, 2024 at 11:32PM	powerMeter	544.15V	53.80mA	29.27W
17	March 20, 2024 at 11:32PM	powerMeter	558.15V	57.89mA	32.54W
18	March 20, 2024 at 11:32PM	powerMeter	540.16V	51.80mA	28.01W
19	March 20, 2024 at 11:32PM	powerMeter	533.77V	50.35mA	26.91W
20	March 20, 2024 at 11:32PM	powerMeter	560.71V	60.90mA	34.35W
21	March 20, 2024 at 11:32PM	powerMeter	533.32V	55.20mA	29.63W
22	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
23	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
24	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
25	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
26	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
27	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
28	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
29	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
30	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
31	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
32	March 20, 2024 at 11:33PM	powerMeter	0.00V	0.00mA	0.00W
33	March 21, 2024 at 08:04PM	powerMeter	0.00V	0.00mA	0.00W
34	March 21, 2024 at 08:04PM	powerMeter	0.00V	0.00mA	0.00W
35	March 21, 2024 at 08:04PM	powerMeter	0.00V	0.00mA	0.00W
36	March 21, 2024 at 08:04PM	powerMeter	0.00V	0.00mA	0.00W
37	March 21, 2024 at 08:04PM	powerMeter	0.00V	0.00mA	0.00W
38	March 21, 2024 at 08:04PM	powerMeter	0.00V	0.00mA	0.00W
39	March 21, 2024 at 08:04PM	powerMeter	0.00V	0.00mA	0.00W

Fig.5b: Results for 3 different light bulbs connected in serial connection

1390	April 24, 2024 at 04:23PM	powerMeter	0.00V	0.00mA	0.00W
1391	April 24, 2024 at 04:23PM	powerMeter	0.00V	525.03mA	0.00W
1392	April 24, 2024 at 04:23PM	powerMeter	40.29V	623.37mA	26.14W
1393	April 24, 2024 at 04:24PM	powerMeter	27.46V	486.71mA	14.01W
1394	April 24, 2024 at 04:24PM	powerMeter	18.79V	565.91mA	10.83W
1395	April 24, 2024 at 04:24PM	powerMeter	17.76V	538.69mA	9.70W
1396	April 24, 2024 at 04:24PM	powerMeter	29.69V	523.25mA	16.09W
1397	April 24, 2024 at 04:25PM	powerMeter	20.97V	518.66mA	11.52W
1398	April 24, 2024 at 04:25PM	powerMeter	34.92V	509.13mA	16.95W
1399	April 24, 2024 at 04:25PM	powerMeter	43.22V	506.76mA	22.51W
1400	April 24, 2024 at 04:25PM	powerMeter	8.64V	558.80mA	4.92W
1401	April 24, 2024 at 04:25PM	powerMeter	13.67V	576.69mA	7.84W
1402	April 24, 2024 at 04:26PM	powerMeter	38.08V	459.46mA	17.20W
1403	April 24, 2024 at 04:26PM	powerMeter	9.01V	580.46mA	5.38W
1404	April 24, 2024 at 04:26PM	powerMeter	9.90V	539.65mA	6.55W
1405	April 24, 2024 at 04:26PM	powerMeter	30.90V	514.02mA	15.51W
1406	April 24, 2024 at 04:26PM	powerMeter	27.52V	537.50mA	14.83W
1407	April 24, 2024 at 04:26PM	powerMeter	17.51V	533.64mA	9.01W
1408	April 24, 2024 at 04:27PM	powerMeter	0.00V	562.49mA	0.00W
1409	April 24, 2024 at 04:27PM	powerMeter	0.00V	519.15mA	0.00W
1410	April 24, 2024 at 04:27PM	powerMeter	0.00V	561.97mA	0.00W
1411	April 24, 2024 at 04:27PM	powerMeter	32.22V	568.42mA	21.75W
1412	April 24, 2024 at 04:27PM	powerMeter	0.00V	0.00mA	0.00W
1413	April 24, 2024 at 04:27PM	powerMeter	0.00V	0.00mA	0.00W
1414	April 24, 2024 at 04:27PM	powerMeter	0.00V	0.00mA	0.00W

Fig.5c: Results for a mobile charger

6. CONCLUSION

A low-cost energy monitoring system is designed for monitoring the energy & tracking applications. The results of the project bespeaks the system's ability to successfully monitor voltage, current, active power. In subsequent work, system can be further developed to gain more insight into the energy usage profile and learn to automatically detect the appliances in use.

REFERENCES

[1] S. M. Amin and B. F. Wollenberg, "Toward a smart grid: power delivery for the 21st century," IEEE Power and Energy Magazine, vol. 3, no. 5, pp. 34-41, 2005.

[2] F. Benzi, N. Anglani, E. Bassi, and L. Frosini, "Electricity Smart Meters Interfacing the Households," IEEE Transactions on Industrial Electronics, vol. 58, no. 10, pp. 4487-4494, 2011.

[3] A. Zaballos, A. Vallejo, M. Majoral, and J. M. Selga, "Survey and Performance Comparison of AMR Over PLC Standards," IEEE Transactions on Power Delivery, vol. 24, no. 2, pp. 604-613, 2009.

[4] R. Rashed Mohassel, A. Fung, F. Mohammadi, and K. Raahemifar, "A survey on Advanced Metering Infrastructure," International Journal of Electrical Power & Energy Systems, vol. 63, pp. 473-484, 2014

[5] A. M. Vega, F. Santamaria, and E. Rivas, "Modeling for home electric energy management: A review," Renewable and Sustainable Energy Reviews, vol. 52, pp. 948-959, 2015.

[6] E. Taktak and I. B. Rodriguez, "Energy Consumption Adaptation Approach for Smart Buildings," in 2017 IEEE/ACS 14th International Conference on Computer Systems and Applications (AICCSA), 2017, pp.1370-1377.

[7] M. Beaudin and H. Zareipour, "Home energy management systems: A review of modelling and complexity," Renewable and Sustainable Energy Reviews, vol. 45, pp. 318-335, 2015.

[8] K. Athira, A. R. Devidas, M. V. Ramesh, and V. P. Rangan, "User centered energy management scheme for smart buildings," in 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2017, pp. 1296-1302.

[9] H. G. R. Tan, C. H. Lee, and V. H. Mok, "Automatic power meter reading system using GSM network," in 2007 International Power Engineering Conference (IPEC 2007), 2007, pp. 465-469.

[10] M. Wasi-ur-Rahman, M. T. Rahman, T. H. Khan, and S. M. L. Kabir, "Design of an intelligent SMS based remote metering system," in 2009 International Conference on Information and Automation, 2009