Direct RESEARCH JOURNALS

Direct Research Journal of Engineering and Information Technology
Vol. 7(7), pp. 136-140, December 2020
ISSN 2354-4155
DOI: https://doi.org/10.26765/DRJEIT14202650
Article Number: DRJEIT14202650

http://directresearchpublisher.org/drjeit/

Review Paper

An In-depth Review of Techniques for Smart Energy Meter Monitoring System

***Bara'u M. Alhassan, Aliyu Tukur, Musa Isah and Nafi'u M. Rumah**

Department of Electrical Engineering, Hassan Usman Katsina Polytechnic, Katsina State, Nigeria.
*Corresponding Author E-mail: yusadeeq@yahoo.com

Received 2 December 2020; Accepted 23 December, 2020

Abstract: Control on electricity theft is inevitable because of its impact on the cost of electricity to consumers and stability of utility companies. The common electricity theft can be in the form of meter tampering, stealing, illegal connections like hookups, bypass, billing irregularities, and unpaid bills. Utility companies have not been achieving maximum profit due to electricity and meter thefts. Detection of electricity and meter thefts by the utility companies will enhance efficiency in transaction and communication with their customers. This is achieved through the use of tamper and meter theft detection units using various technologies. This paper presents a technological review of different types of smart energy meter monitoring techniques and their applications. From these reviews, we are able to derive comparisons of the smart energy meters for better understanding and promotion of research in the area.

Keywords: GSM Module, Zigbee, Arduino, microcontroller, LCD

INTRODUCTION

Energy meters are electronic instruments used to measure the amount of electric energy used by consumers in a circuit within a residence areas, industry or business at any given time. They are often calibrated in the unit of electric energy, kilowatt-hour (kWh).

The major challenge encountered in the existing metering system is the energy theft which reduces the efficiency of electricity transmission in the world. Since meters are positioned within the electricity infrastructure at a key location or node in the network, distributors, retailers and customers intersect with all potentially having a claim to own the meter (Vidyashree, 2017). In Nigeria, this major factor has both technical and commercial losses in the power sector with about 75% loss. However, large percentage ranging between 50-60% of these losses is attributed to energy theft (Chetan and Anish, 2015). This theft could be in form of unpaid bill or illegal connections in the electrical power system.

Researchers have made continuous effort to reduce these technical and non-technical losses, hence advancing into the development of electric energy meters in the last decade (Samarth *et al*., 2017). The conventional electromechanical meters are being replaced by new electronic meters to improve accuracy in meter reading. The electronic meters are also being improved and communication technologies have been incorporated into them to make them smarter (Bhushan and Snehal, 2015) which resulted into the automatic metering system.

Smart metering system is an advanced technology that gathers data from metering devices and sends it to a master station for billing purposes. The data from these devices are obtained remotely without the need to physically access the metering device (Patel and Modi, 2015). Features of Smart Metering Systems include: Time-based pricing, providing consumption data for

consumer and utility, net metering, Failure and outage notification, Energy theft detection etc. (Silviya *et al*., 2014).

These meters reduce the need to visit while taking or reading monthly bill. Modems are used in these smart meters to facilitate communication systems such as telephone, wireless, fiber cable, power line communications. Another advantage of smart metering is complete avoidance of tampering of energy meter where there is scope of using power in an illegal way.

Electrical power theft is the main cause of Non-Technical Losses (NTL) in the electrical power system. The NTL comprises of illegal connections, meter tampering, billing errors etc. out of which electricity theft through meter tampering and direct rigging from the transmission or the distribution line contributes higher percentage of loss of electricity (Adiyansyah *et al*., 2018).

In this paper, the state of the art in the development of different types of smart energy meter monitoring systems is presented. The paper thus reviewed the main objectives, the types, and the benefits of these modern devices.

CLASSIFICATION OF SMART ENERGY METER MONITORING SYSTEMS

Many efforts have been made and papers have been published proposing the different and improved designs of the automatic meter reading system and still the research is ongoing. Different communication technologies could be through wired or wireless technologies. The wired technology includes the use of Power line carrier, coaxial cables, pilot cables, etc. for data transmission from the consumer end to the utility station while the wireless technology includes the use of Global System for Mobile Communication (GSM) technology, WIFI, AMI, Zigbee technology etc. Both systems have their own merits and demerits.

THE WIRED TECHNOLOGY

Based on the communication medium used for data delivery, the existing Automatic Meter Reading (AMR) systems can be classified into two categories namely wired systems and wireless systems (Lovell, 2017**)**. In a wired system, the data transfer is performed either through PLC (Power line carrier) or HFC (Hybrid Fiber-Coaxial).

In all the above-mentioned works, different standalone modules are integrated to accomplish the required task. This occupies more space and makes the real-time implementation complex. Moreover, the operational power requirements also add to the complexity. Energy metering through the wire is expensive as it requires infrastructural changes.

Power line carrier-based automatic metering system

Power line communication systems use the existing power cables as a communication medium. This ultimately allows us to both control the devices remotely and also retrieve data from it in a half duplex manner (Darshan and Radhakrishna, 2015). PLC is like any other communication technology whereby a sender modulates the data to be sent, injects it onto medium, and the receiver demodulates the data to read it.

Poonam *et al*. (2015) developed a PLC-based automatic metering system which allows data from energy meter to be sent over existing electric power lines. The strength of the system is the usage of limited cables for communication since it allows the use of existing electric power cables. Therefore, controlling, monitoring, and transfer of consumer's energy data are made possible via existing power lines. The major disadvantage of PLC technology is signal interference and the inability to transmit data on high voltage side of a power system (Cogency, 2014). The two major factors causing PLC meter readings unstable are the electric network signal attenuation and random interference. Because of the attenuation, wave carrier reading system cannot read meters reliably if there isn't any relay or anti-attenuation techniques. The existence of random interference equals to increasing the attenuation of the electric network and decreasing the receiving sensitivity, if the sensitivity of the meter reading device is constant. This affects the meter reading system severely. A system using PLC can make use of existing electrical wires and has a better communication range than wireless communication. PLC is easy to install and maintain. It cannot consistently read the data. The long term interference on the electric network causes the household appliances to over-heat, motor output decreasing etc.

Optocoupler-based automatic meter reading (AMR)

Optocoupler sensor was used to detect the optical pulse generated by the LED present in the energy meter. Based on the sensor output, the energy consumption is computed in the microcontroller (Guhesh *et al*., 2018). Using specialized integrated chips the power rate and power factor are determined. These works are developed with communication medium used being PLC, HFC, and RF. In all the three cases, different standalone modules are integrated to accomplish the required task. This occupies more space and makes the real-time implementation complex. Moreover, the operational power requirements also add to the complexity.

THE WIRELESS TECHNOLOGY

Wireless communication between devices ensures greater

flexibility and system's ease of use. The system's ability to monitor both appliance level and switchboard circuit's level informs the consumer about the balance of each appliance or circuit load. The knowledge of average hourly energy use and electricity cost provides important information that motivates changes to consumer's behavior. A computer connection is available to record measured data and to use it in many computer applications, such as, daily charting energy use data.

Smart microcontroller based energy meter using IoT

In this paper, we focus mainly on IoT's energy monitoring. The proposed design is to implement a very low cost wireless sensor network and protocol for smart energy and web application capable of automatically reading the unit and sending the data automatically for the power users to view their current energy meter reading. By using this system, the users will be aware of the electricity usage in his/her home to reduce the power wastage and cost of consumption. The system consists of a digital energy meter, ESP8266 Wi-Fi module and web applications for management system. The ESP8266 Wi-Fi module will be embedded into the meter and implement the TCP/IP protocol for the communications between the meter and web application. The experimental results show that the proposed system works very well with efficiency, and it is feasible to implement in practical applications for very low cost-build automatic energy meter reading (Samarth *et al*., 2017). When compared to other wireless modules, WiFi is more suitable for this kind of application as it has become one of the common facilities at every residence.
Imran and Prahlada, (2017) uses a Microcontroller based design and implementation of energy meter using IoT concept. The proposed system design eliminates the human involvement in Electricity maintenance. The Buyer needs to pay for the usage of electricity on schedule, in case that he couldn't pay, the electricity transmission can be turned off autonomously from the distant server. The user can monitor the energy consumption in units from a web page by providing device IP address. Figure 1 shows the diagram of a microcontroller-based energy meter.

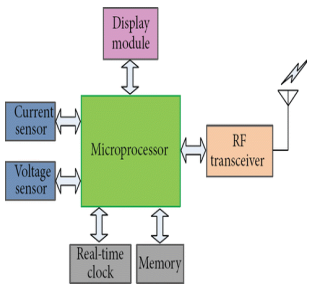

Figure 1: A microcontroller –based wireless energy meter.

Theft detection unit connected to energy meter will notify company side when meter tampering occurs in energy meter and it will send theft detect information through PLC modem and theft detected will be displayed on the terminal window of the company side. Wi-Fi unit performs the IoT operation by sending energy meter data to web page which can be accessed through IP address. The Hardware interface circuit consists of PIC18F46k22 Microcontroller, MAX232, LCD display, theft detection unit, Triac switch circuit, DB18B20 temperature sensor, PIR sensor, PLC modem, and ESP8266 Wi-Fi module. Wi-Fi unit performs the IoT operation by sending energy meter data to web page which can be accessed through IP address (Ashna and George, 2013).

Smart electric metering system based on GSM/IoT

Arduino and GSM based smart energy meters for advanced metering and billing system is able to read and send data via wireless protocol using GSM technology through GSM modem, capable of managing the meters as well as the line connections (Rahman *et al*., 2015). Smart Energy Meter uses SMS or/and Wi-Fi to send the power/unit data to cloud, so that user can access the data room module Apps and websites. Using cutting edge technology smart energy meters will save money, labour, efforts and time and at the same time it will effectively monitor the electricity consumption, usage and fraud. It is safe and easy to use and user friendly. The metering system uses cheap components which will decrease the overall cost of the equipment increasing its affordability and penetration in non-metered areas.

This paper proposed and demonstrated Smart Energy Meter that the uses mobile phone via Short Message Services (SMS). Arduino UNO, main controller, was the interface between energy meter and Global System for Mobile communication (GSM) module. GSM module connects the energy meter to users' mobile phone. Real Time Clock (RTC) DS1307 was used to get the real time to count and store the usage into the EEPROM. The proposed system demonstrated its capability to check the current usage (bill), notify when reaching the limit, and reset the usage (bill) successfully, only via accessing GSM-based mobile phone (JayChand *et al*., 2015). Shraddha *et al*. (2014) designed a GPRS and web based automatic metering system. The system utilizes the internet and GSM modules to monitor electricity consumption. The strength of the work is the ability to obtain real time data from energy meters and its supports for wide coverage area communication and easy maintenance. The system is however, capital intensive due to the cost of managing and maintaining a web services.

The GSM based system was designed to mitigate the following limitations as identified by existing

Table 1: Comparison

Technology used	Communication protocol	Complexity	Cost	Reliability	Coverage
GSM	Stable	Low	Low	High	High
PLC	Very Stable	High	Low	Low	Very High
ZigBee	Least Stable	Low	Medium	Low	Low
WiMAX	Stable	Medium	Medium	Medium	Low
MIXED	Varies	Varies	Varies	Varies	High with GSM
RFID	Least Stable	Medium	High	Medium	Low

literatures:

(a) Reduces management, maintenance, and start-up cost significantly.
(b) Incorporating energy theft detection system through remote disconnection.
(c) Effective data transfer speed with better coverage when compared with Bluetooth and ZigBee technology.
(d) Reduces design complexity and easy to deploy when compared with the microprocessor based AMS.

ZigBee-Based Automatic Metering System

Li Quan and Gang, 2017) presented an AMR that utilized ZigBee technology to build up home area networks of connected metering devices. The shortcomings of this study include: the great intervention of consumers to take pictures of meter reading before it can be monitored remotely and it is capital intensive to build a ZigBee network rather than using the existing networks. However, ZigBee devices are easy to operate and consume less energy but they are extremely limited in resources including processing, memory, and power. Dhananjayan and Shanthi, (2014) presented a GSM and ZigBee based Automatic Meter Reading System. The system proved to correctly take electric energy reading of large power consumers. It utilizes power saving techniques of current consumption as low as 2.5mA. The strength of the work reduces the cost of using only ZigBee network by using GSM technology with the ZigBee modules. This therefore reduces cost in meter reading and provides efficient services to their consumers. Limitations include slow communication process for many users since ZigBee transfers information at low data rate as compared to GSM technology which can make the communication process slow.

Wireless monitoring of household electrical power meter using embedded RFID

The wireless data monitoring of electrical power meter in a household by using the embedded acstive RFID tag module with WSN platform is employed. Active RFID by ZigBee protocol is used to monitor the value and to identify the electrical power meters. The ZigBee modules embedded into the electrical power meter act like wireless sensors that monitor the electricity consumption value of electrical power meter and transmit the data value with the RF signal to the portable reader. The relayed signal is applied to facilitate some daily life processes, save time, and reduce cost and error in information system that can be committed by humans. This work is the first attempt to combine an embedded RFID and WSN technology into a single platform with household power meter and improve the heterogeneous functionality in data transfer regardless of power meter type. The scope of this paper is limited to the proposed hardware communication reliability compared to the standalone system communication.

In this part, the proposed embedded active RFID tag module architecture is presented. The proposed embedded active RFID tag module is designed to support the heterogeneous electrical household power meter. Smart RFID tag modules are capable of measuring instantaneous voltage and current of the electrical circuit which it is connected to. The RFID tag module draws its power supply from the electrical power meter, which contains a power management circuit faction that transforms the voltage source of active RFID power supply of 3.3 V (Shreedhar et al., 2016). The embedded device contains a microcontroller as well as a software programme that determines the behavior of the active RFID tag, and communication is created between devices. In this work, ZigBee is applied to act as a wireless sensor to monitor the value of the power consumption from the electrical household power meter and send information to the reader.

Automatic meter reading system (AMR) using WiMAX technology

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates (Bihl and Hajjar, 2017). WiMAX supports mobile, nomadic and fixed wireless applications. The reading unit identifies the disk rotation of the energy meter and the data is stored in a microcontroller. So it is not required to change the current analog energy meter. An external module is added with the current energy meter. In the communication unit, WiMAX transceiver is used for

wireless communication between meter end and the server end because of its wide coverage area. In the data receiving and processing unit meter reading is collected from the transceiver which is controlled by another microcontroller. There is a computer application that will take the data from the microcontroller. This will also help to avoid any tampering or break down of energy meter. This system is cheap, flexible and supports high speed data transfer over long distances. WiMAX has security vulnerabilities in both PHY and MAC layers, exposing to various classes of wireless attack including interception, fabrication, modification, and replay attacks. Weather conditions like rain could interrupt the signal (Birendra *et al*., 2017). Table 1 compares the various technologies that have been used in smart energy meter monitoring.

CONCLUSION

The benefits of smart meters and implementation of smart cities are clearly emphasized. Reliability of data delivered over both wired and wireless technologies are analyzed. It is also observed that IoT-based energy meters powered by the cloud technologies can bring in revolutionary systems at low expenditure. Based on all the systems surveyed, their advantages and drawbacks, this paper presents the features that make up an ideal AMR system and provides an overall insight into the various methodologies applied for AMR so far thus providing a base for further research in this area. Based on the performance criteria considered, it has been concluded that, GSM-based system results in high coverage and reliability with minimal cost and complexity. Although wireless energy meter monitoring systems still have some limitations to what they can achieve intelligently, the future still holds a lot of promise for these systems. Researchers especially in the field of artificial intelligence (AI) are working hard to find ways to overcome these limitations in order to make them completely efficiently. From this paper it is evident that wireless energy meter monitoring systems are the way forward for power utility companies. Other suggestion would be to include a web/mobile interface that gives a real-time feedback of the energy consumption, maybe even give the amount of energy consumed by every device in every room and also give energy conservation tips too, based on the data obtained. The real-time data thus obtained can also be used to build a prediction model over it, for predicting the energy demands trends of the future, over any given time period.

REFERENCES

Adiyansyah WI, Fatimah BM, Norfadzlia BMY, Siti ACA (2018). *"GSM-Based Smart Energy Meter with Arduino",* International Journal of Applied Engineering Research, Vol. 13, No. 6, pp. 3948-3953, 2018.

Ashna K, George SN (2013). *GSM based automatic energy meter reading system with instant billing,"* in Automation, Computing, Communication, Control and Compressed Sensing (iMac4s), 2013 International Multi-Conference on , vol., no., pp.65- 72, 22-23.

Bhushan DS, Snehal SG (2015). *"A Review Paper on Automatic Meter Reading and Instant Billing",* International Journal of Advanced Research in Computer and Comm. Engineering, Vol.4, Issue 1, Jan 2015.

Bihl TJ, Hajjar S (2017). "*Electricity theft concerns within advanced energy technologies*", IEEE National Aerospace and Electronics Conference (NAECON), 2017, 271–278

Birendra k, Sahani T, Akib T, Ranjeet P (2017). *"IoT Based Smart Energy Meter", International Research Journal of Engineering and Technology (IRJET)*, Vol. 4, No. 4, Apr -2017.

Chetan B, Anish V (2015). "*Smart meter: Pay first and then use it with theft detection*". Journal of Emerging Technologies and Innovative Research 2(5), 2015 1427–1432.

Darshan N, Radhakrishna KA (2015). *"IoT Based Electricity Energy Meter Reading, Theft Detection and Disconnection using PLC modem and Power optimization", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 4, No. 7, pp. 6482-6491, July 2015.

Dhananjayan R, Shanthi E (2014). "*Smart Energy Meter with Instant Billing and Payment",* International Journal of Innovative Research in Computer and Comm. Engineering, Vol.2, Issue 1, Mar 2014.

Guhesh S, Maheedar S, Pravin T (2018).*"Distribution line monitoring system for the detection of power theft using power line communication",* Energy Conversion (CENCON), 2014 IEEE Conference on page 55 – 60 13-14 Oct. 2018 page 55 – 60.

Imran S, Prahlada K (2017). IOT Based Electricity Energy Meter Reading Through Internet *International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)*, Vol.3, No. 11.

JayChand UD, Namitha D, Arina, Glennie F (2015). *"Prepaid Energy Meter with GSM Technology".* International Journal of Innovative Research in Computer and Communication Engineering 3(3), 2015, 2048–2054.

Li Quan-Xi, Li Gang (2017). "Design of remote automatic meter reading system based on ZigBee and GPRS", ISBN 978-952-5726-10-7,Proceedings of the Third International Symposium on Computer Science and Computational Technology(ISCSCT '10), Jiaozuo, P.R.C. 2017.

Lovell H (2017). *"Mobile Policies and Policy Streams: The Case of Smart Metering Policies in Australia".* Elsevier: Geoforum, 81(2017):100-108.

Patel U, Modi M (2015). "*A Review on Smart Meter System*", International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, Vol. 3, No. 12, December 2015.

Poonam B, Ankitha S, Deepali H, Rupali SK (2015). "Automatic Meter Reading for Electricity using Power Line Communication". International Journal of Advanced Research, 2(3): 982-987. 2015.

Rahman MM. Islam, MS, Salakin A (2015). *"GSM based smart energy meter for advanced metering and billing system*", Electrical Engineering and Information Communication Technology (ICEEICT), 2015 International Conference on, IEEE, 2015, 1–6.

Samarth P, Sneha M, Meghana N (2017). *"Smart Energy Meter using internet of Things (IoT)*", *VJER-Vishwakarma Journal of Engineering Research*, Vol. 1, No. 2, Pp. 222-229, June 2017.

Shraddha M, Pallavi V, Kavita M, Bhusari VK (2014). *"An Intelligent and Smart Wireless Electronic Automatic Energy Meter Reading System",* International Journal of Scientific Research and Education, Vol.2 Issue, 2014.

Shreedhar AJS, Kolvekar Y, Rahul R, Shashank S (2016). *"IoT Based Smart Energy Meter",* Bonfring *International Journal of Research in Communication Engineering*, Vol. 6, Special Issue, pp. 89-91, November 2016.

Silviya M, Meena K, Vinodhini S, Thillai TJ (2014). "GSM Based Automatic Energy Meter System with Instant Billing", International Conference on Signal Processing, Embedded System & Communication Technologies, Vol. 3, April 2014.

Vidyashree MS (2017). "GSM Based Smart Energy Meter to Implement Billing System and To Control Electricity Theft", *International Journal of Current Engineering and Scientific Research (IJCESR)*, Vol. 4, No. 1, 2017.