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IoT Based Power Monitoring System for Smart Grid Applications

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Abstract—Internet of Things (IoT) is widely used in smart energy monitoring, industrial automation, and a variety of applications. At various stages of Smart Grid (SG), IoT devices are deployed to monitor and control grid statistics for reliable and efficient delivery of power. Although IoT integration in the SG domain provides manifold benefits, the challenges in IoT-SG integration needs to be solved for the efficient operation of the grid. In this paper, firstly an overview of SG and IoT based SG system is provided. This project describes the IoT based power monitoring system that is capable to measure and analyze the electrical parameters such as voltage, current, active power, and energy consumption of loads. IoT based software application 'ThingSpeak' is used to obtain the real-time electrical data of consumers. Based on this data, the consumer and electric power companies in the SG paradigm can better manage their consumption to reduce billing costs.

Keywords-Smart homes, Power monitoring, IoT aided SG, ThingSpeak.

I. INTRODUCTION

In the future generation of power grids sensors, actuators, and transducers are expected to play a crucial role in providing real-time energy monitoring services [1]. IoT [27] has become an enabling technology to provide novel solutions to the challenges in the power grid system. IoT enabled sensors are used pervasively in the power grid system to share their useful information through internet and web applications, enabling improved grid management [2].

The integration of Information and Communication Technologies (ICTs) and IoT in SG ensure reliability, cost-effectiveness, and intelligent features with minimal human intervention. Two-way communication is the key requirement in the paradigm of IoT among smart devices and components [3]-[4].

Smart homes are developed by the integration of smart electric meters and IoT [5]-[6]. For deployment in smart cities, an IoT assisted real-time Zigbee mesh WSN based Automatic Meter Reading (AMR) system is implemented in [7]. The proposed system provides a reduction in peak loads with improved Demand Side Management (DSM) [5]. Sensors, communication [25]-[26], and control mechanisms will play a vital role in achieving reliable and secure power grids. A survey on potential communication technologies for the connectivity of devices in the SG is presented in [8].

Motivated by the above progress in IoT and their deployment in power grids, we have proposed an IoT assisted power monitoring system for SG. It provides benefits to both consumers and utility companies to analyze and manage their resources. This paper provides an implementation of IoT based power monitoring using ThingSpeak software where the consumer can get the electrical parameters of the load data. A literature review is provided that highlights existing research in the area of SG, IoT, and IoT aided SGs.

In this paper, our contributions include the following:

- The implementation of IoT assisted power monitoring system is provided with the integration of an open-source ThingSpeak IoT platform, which provides to analyze load information of consumers.
- The hardware design enables to access of electrical parameters of loads including current, voltage, active power, and energy of connected loads.

The rest of the paper is organized as follows. Section II provides a literature review and system implementation is discussed in Section III. Section IV provides a hardware prototype and results followed by conclusions in Section V.

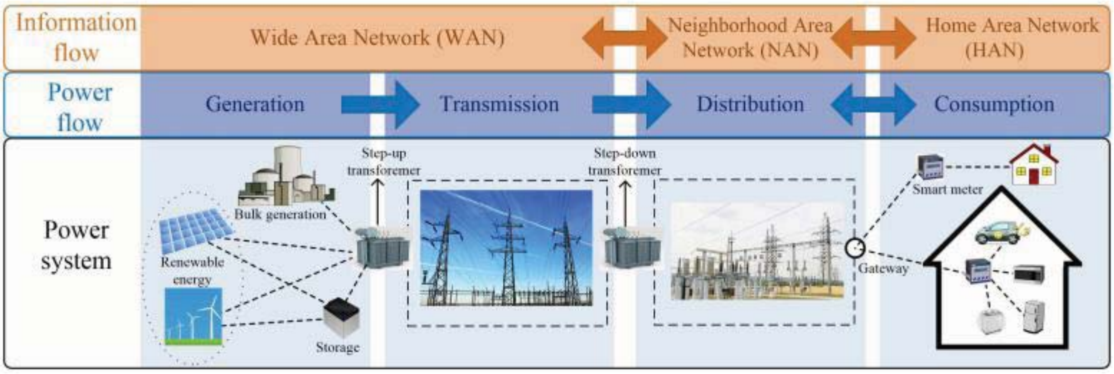

Fig. 1: An overview of SG architecture [10].

II. LITERATURE REVIEW

The traditional power system is being transformed into an intelligent, secure, efficient, and reliable SG [9]. There are different information flow networks in the SG domain; Home Area Network (HAN), Neighborhood Area Network (NAN) and a Wide Area Network (WAN). SG modernizes the generation, distribution, and consumption sections of the power system with power and information flows. An overview of SG architecture is provided in Fig. 1, which presents the main subsystems and networks in SG [10].

SG provides various features such as advanced metering infrastructure (AMI), load balancing, and fault detection and control [11]-[12]. One of the key concerns in SG is the connectivity of devices that needs monitoring and analysis. IoT is a technology that provides this automation in the SG paradigm. The integration of IoT devices in SG (such as sensors and smart meters), various functions related to connectivity and automation aspects can be effectively provided throughout the power system [13].

SG devoid of the IoT technology is not possible. There are different forums addressing the SG and IoT integration including special issues on Smart Grid Internet of Things [14]. Several attempts have been done to cover the IoT aided SGs. A general vision of SG is provided in [15]. A vision of SG in the paradigm of IoT is presented by Al-Ali and Aburukba [16] with a focus on the SG communication layer. In [17], the authors provided a detailed survey on AMI and smart metering to address the problems of power quality and reliability in the conventional grid. However, the authors did not cover other key features of IoT aided SGs such as architectures and applications. In the domain of smart cities, IoT plays a dominant role and sensors will enable the management and control of the cities [18].

Smart metering deployment in the power system involves various challenges. The benefits and challenges due to the deployment of smart meters are presented in [19]. An overview of SG technologies such as IoT, smart metering, and Energy Management System (EMS) is provided in [20].

The monitoring, control, and analyzing the data are the primary tasks in the SG. Billions of monitoring devices are installed at power generation plants, distributions centers, transmission towers, and consumer premises [21]. At the distribution level of the SG, monitoring of electrical parameters like voltage, current, active power, power factor, etc has a crucial role in improving grid efficiency. Moreover, reliable communication infrastructure is required to send received information to the consumer gadget or utility company. A WSN based power monitoring for a single-phase electric system is developed in [22]. The authors have used power sensing and communication modules to send load consumption data at periodic intervals to the utility. Furthermore, a power theft algorithm is proposed that can help utility companies to detect power theft. However, the developed system is costly and not suitable for implementation on a large scale [22].

There are different types of devices that are used in the SG system for monitoring, analysis, and control purposes. The next section provides an implementation of IoT assisted monitoring setup that can be used in SG.

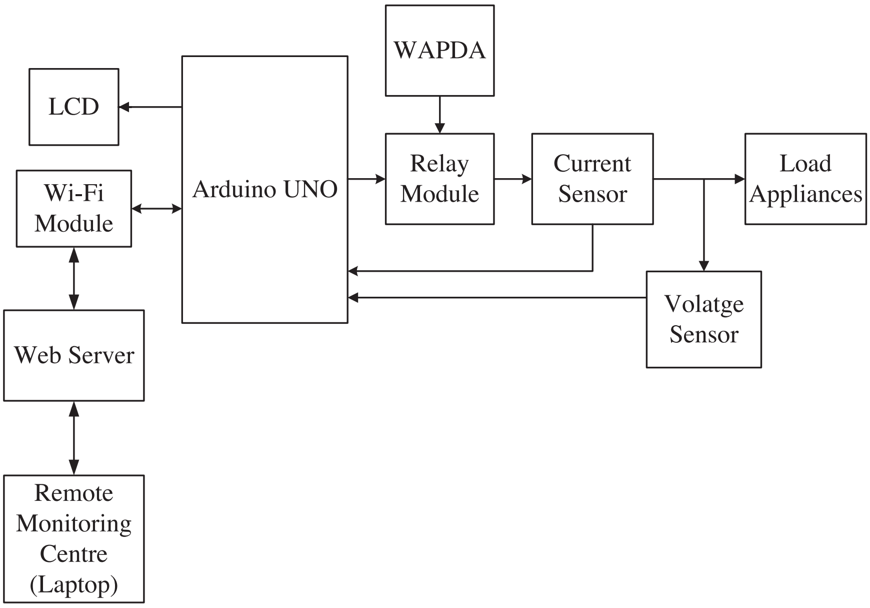

Fig. 2: Block diagram of an IoT based power monitoring system.

III. SYSTEM IMPLEMENTATION

A. System Overview

The proposed system consists of monitoring, communication and analysis units. The monitoring setup comprises of ACS712 current sensors and voltage sensing circuit connected to consumer loads. The communication unit consists of Arduino and WiFi module. The analysis unit is a remote application on consumer mobile that can be access to obtain voltage and currents, load profiles, energy consumption, etc.

B. System Design

The block diagram of an IoT based power monitoring system is shown in Fig. 2. WiFi based node is deployed that consists of a consumer's load, voltage and current sensors, Arduino UNO, and a WiFi (ESP-8266) communication module. The Arduino is interfaced with sensors to gather load data and saves it in internal memory [24]. WiFi fetches load data from Arduino through a UART interface and communicates the load data with the server. WiFimodulates acts as a gateway between the monitoring side and the webserver.

C. Software Application

ThingSpeak is an open-source IoT platform is used to store, analyze, and retrieve data from loads [23]. The stored information enables utility companies and consumers to observe load data on gadgets and computers. The stored information gives load patterns, provides dynamic billing and helps to better adjust demand and supply of electricity between generation and consumption.

IV. HARDWARE PROTOTYPE AND RESULTS

The hardware design of IoT based power monitoring system is shown in Fig. 3. The loads are connected to this hardware setup to evaluate its performance. For local display, LCD is used to show the real-time results of the load, and the WiFi module communicates load data to ThingSpeak application.

Fig. 3: Hardware prototype of IoT based power monitoring system.

The hardware is tested using different loads for current, voltage, power, and energy. LCD provides a local display and WiFi sends real-time data to the ThingSpeak for storage. After a simulating program, our device receives data from the cloud through MQTT. MQTT is a protocol for collecting device data and communicates that data to the server. The device is controlled through ThingSpeak.

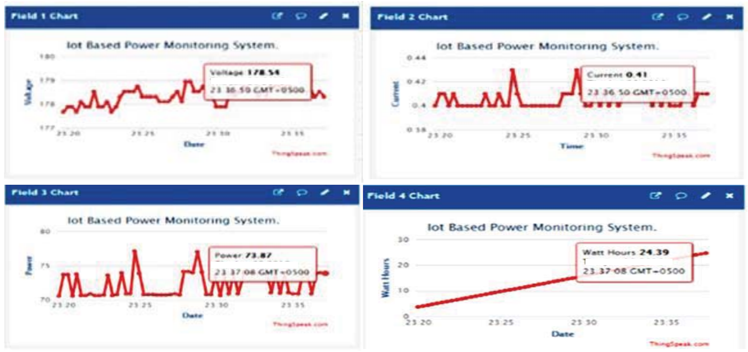

Fig. 4: Electrical measurements (voltage, current, power, and energy consumption) of load.

Fig. 5: Load status at different periods.

The electrical measurements (voltage, current, power, and energy consumption) of the load is depicted in Fig. 4. It shows electrical parameter information at different instants. The consumer can visual load information at any time (hourly, weekly, or monthly).

The load's ON-OFF scenario is depicted in Fig. 5 where 0 and 1 represents an ON load and OFF loads respectively. It provides information to a layman about the loads ON or OFF status.

V. CONCLUSIONS

Intelligent operations in power system infrastructure are crucial needs of modern grid systems. SG is a new and improved grid that solves various problems of efficiency and reliability in the traditional grid. In this paper, the implementation of an IoT based power monitoring prototype is presented. ThingSpeak is used as a software tool to access consumer load data at the remote end. The large scale installation of proposed design requires to develop cost-effective power sensing and monitoring devices that can be easily integrated into the consumer premises. In the future, authors are interested to develop a cloud-based smart metering system for the deployment in smart cities.

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