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Artificial Intelligent Meter development based on Advanced Metering Infrastructure technology

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ABSTRACT

Smart meter is an advanced energy meter that measures energy consumption in residential, commercial and industrial facilities with additional information related to the power system. This paper aims to review system functions of the latest smart meter technology which incorporates Advanced Metering Infrastructure (AMI). The paper also proposes future smart meter with some modification and improvement of AMI technology by introducing Artificial Intelligence Metering (AIM) techniques where the energy consumed by consumers' appliances is fully supervised by AIM. The AIM function is almost the same as AMI technology, but with some enhancement including schedule of various appliance usage by customers, PV integration and power quality monitoring. These modifications can facilitate consumers to manage their energy usage wisely, meanwhile promoting green technology to the community.

Contents

1. Introduction

The development of Advanced Metering Infrastructure or AMI system has brought the greatest change in the technology of energy metering. The technology upgrades from mechanical rotating disc energy meter to electronic energy metering device and then to intelligent energy meter, called automatic meter reading (AMR) [1,2]. This technology helps send energy consumption data from buildings, factories and houses to the utilities for load curve, power quality analysis and consumers' billing purposes [3]. In the meantime, the Advanced Metering Infrastructure (AMI) is also introduced to integrate the meter with grid and households for

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better analysis of transmitted power and usage. The AMI technology includes two-way communication between utility companies and customers' smart meter [4,5]. This device communicates with consumers and utilities through power line carrier and this is aimed to help households to consume energy wisely [6]. The AMI can be defined as a 'smart meter' device due to its user-interface ability and provision of all parameters that are related with users' energy consumption as well as utility companies [7]. The parameters that are employed in AMI system are energy consumption, real power, reactive power, power factor, voltage, current, and maximum energy demand [8]. These parameters will ensure the energy usage quality at receiving end and provide information on current energy price to consumers. Moreover, most of the smart metering devices are able to record the activities of households through energy consumption profile [9,10].

Nowadays, many countries especially developed countries have implemented AMI technology in their power system. Enel SpA in Italy, BC Hydro in Canada, Oxxio Company from Netherlands and many utility companies in Europe, Australia, Japan and Korea have invested millions of dollars to install AMI devices in residential areas [11]. Several issues were reported by these companies regarding energy crisis, cyber security issues, smart meter robustness, communication signal and financial investment [12]. These issues are future challenges in order to develop a better Advanced Metering Infrastructure system. Therefore, in this paper, several ideas of AMI system improvement are proposed so as to reduce or eliminate some current issues.

The remaining part of this paper is organized as follows. Section 2 presented a review of the Advanced Metering Infrastructure system. In this section, the AMI system from the perspective of communication protocol, meter self control system, remote supervision and power consumption monitoring by consumers is presented. System software was also discussed along with data collection and encryption. In Section 3, future smart meter is proposed where Artificial Intelligent Meter model is introduced. There are three main functions of the proposed model including, home appliances scheduling, photovoltaic integration and power quality monitoring. Finally, Section 4 concludes the paper.

2. The Advanced Metering Infrastructure system

In order to deploy Advanced Metering Infrastructure system into electric distribution system, seven systems inside the smart meter need to be considered namely, system communication, system control, remote communication and monitoring, system security, remote software upgrade and data collection and encryption [13]. The following sections describe various technologies used in the aforementioned sub systems.

2.1. Communication system

Communication system in smart meter technology is a priority function since energy consumption data of consumers need to be accurately recorded in real-time or near real-time by the utility. Generally, data from smart meter will be transmitted to utility for load curve analysis and billing purposes. According to [14], integration between Demand Side Management (DSM) program and AMI system improves load management in distribution network and maximize energy efficiency. The existence of two-way communication in AMI system assists DSM program to achieve real-time pricing for billing charge. At the same time, load curve can be updated almost every minute to estimate time of maximum daily load in distribution area. With real time load curve analysis, energy price and tariff can be revised frequently so as to satisfy customers and utilities. The energy time-varying pricing can be categorized into three types which are time of use (TOU) pricing, critical peak pricing (CPP) and real time pricing (RTP) [9]. TOU pricing is less efficient compared to CPP in terms of energy price fluctuations against time. However, the most efficient energy pricing is RTP where it can be achieved whenever the AMI system is fully deployed in distribution network. The advantage of this pricing is that it reduces load demand during peak time according to consumers' concern about high bill charges. Eventually, it decreases load demand during peak time as well as excessive energy wastage.

AMI communication technologies can be divided into two approaches namely wired communication such as power line carrier (PLC) and wireless communication such as radio frequency (RF), Zigbee, Bluetooth, WiFi, WiMAX, General Packet Radio Service (GPRS) etc. The wireless protocols are selected based on five factors namely good transmittable range, high security, good bandwidth and quality data transmission as well as least latency [12]. The radius of network coverage for wireless communication protocol is varied upon power transmission and frequency. Generally, high frequency requires more power to be transmitted yet its radius is smaller when compared to low frequency. From the literature review, the wired communication specifically the PLC is the most suitable and applicable protocol by many companies since data is only transmitted through existing power cables or grid network [12]. Khalifa et al. [15] surveys four communication protocols available for AMR device and one of them is PLC. The authors highlighted frequency selection, propagation speed and distance as main specifications for PLC implementation. Since the data travels through voltage signal, the voltage level carried is also considered. Although PLC provides low maintenance cost and has good efficiency, it suffers from limited bandwidth and difficulty in supporting large scale network [15]. In that case, integrating several communication protocols with PLC might overcome its drawbacks such as WiFi, Micro-power Wireless, Optical Fiber etc. [16,17]. Instead of communicating through power cables, wireless communication technology is an alternative data transmission medium between households and utility. There are seven reliability aspects for both communication protocols which are type of network, range of network, quality of signal, cost of network devices, cyber security, terrestrial difficulties and availability of signal [12]. The future prediction of communication traffic is another consideration as signal congestion occurs due to same bandwidth between communication signals. This can cause signal interference in the network and data might be interrupted during transmission [18]. Therefore, selection of signal protocol is critical to ensure the data is not corrupted when transferring, due to noises and interferences from other communication signals. Table 1 shows different communication protocols and their parameters which can serve as guide when integrating a particular type of protocol for the smart meter application.

2.2. Control system

The control system is one of the built-in systems in smart meter devices where it functions as self-monitoring and controlling consumers' utilities. For example, Cao et al. [19] conducted an experiment for water flowing system controlled by AMR meter. Water sensors located at the main pipe measure the water flow velocity and transmit it to AMR meter to record and monitor. A proposed error estimation algorithm is programmed into AMR system device as a feedback component to water flow activity. In general, the function of feedback system in the meter device as illustrated in Fig. 1 is to calibrate output values by controlling input values in smart metering system. Normally, external and internal noises in practical operation interrupt the system which frequently