A Comprehensive Review of Smart Energy Meters: An Innovative Approach

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Abstract**—**Energy meter is an important device used for measuring the power. It is used in customers' homes, industries etc. for measuring the electrical power. A lot of modifications and development has taken place in the construction and operation of the energy meters over a decade. In view of above this paper presents a review of the development of the energy meters and their applications. Energy meters and its different types along with the innovation in this field is been discussed in this paper.

Keywords- *smart energy meters, power consumption, digital electronic energy meters.*

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I. INTRODUCTION

Watt hour meter or energy meter is an instrument which measures amount of electrical energy used by the consumers [30]. Utilities install these instruments at every place like homes, industries, organizations to charge the electricity consumption by loads such as lights, fans and other appliances. These meters measure the instantaneous voltage and currents, calculate its product and gives instantaneous power [30]. This power is integrated over a period which gives the energy utilized over that time period. These may be single or three phase meters depending on the supply utilized by domestic or commercial installations. For small service measurements like domestic customers, these can be directly connected between line and load. But for larger loads, step down current transformers must be placed to isolate energy meters from higher currents [30]. As the demand of the electricity is increasing day by day and therefore the utilization of the new and more advanced energy meters have increased.

This paper provides a review about the energy meters and its development. The paper provides a brief idea of the energy meters, their architecture, types, working. It also focuses on the recent advances and developed related to the energy meters.

II. LITERATURE REVIEW

Recent developments in smart metering applications have led to the conceptualization and construction of a new type of energy meter, operating on the basis of event-driven principles [1]. The event-driven metering concepts are applied to represent the information on the electrical load patterns, which have an integral value [1]. This paper explains why these concepts are different from the ones used for event-based applications in other domains, discusses the principles used in the new type of electricity meter, presents the data formats structured in such a way to provide detailed knowledge representation, and shows a number of results on real-case applications [1]. A specific index is defined in order to represent the effectiveness of the event-driven metering scheme illustrated to represent the details of the metered pattern, comparing the results with the ones that could be reached in the most favourable case through regular timer-driven metering [1]. The presentation of specific applications based on real-life datasets highlights the advantages of the event-driven energy metering over the traditional timer-driven metering scheme [1]. The authors propose, design, and implement a low-cost universal smart energy meter (USEM) with demand-side load management [2]. The meter can be used in the postpaid and prepaid modes with flexible tariff plans such as time of use, block rate tariff, and their combination [2]. The smart meter comprises of a potential transformer, current transformer, and microcontroller unit with an embedded communication module [2]. The connectivity among the utility authority, the smart meter, and consumer is established by authority identification number, meter identification number, and user identification number using the cellular network [2]. This paper [3] presents digital implementation of fast discrete Stockwell transform (FDST)

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239 – 243

with automatic scaling for accurate PQ-event detection (ED) and energy metering. Comparative analysis of FDST-based energy-metering algorithm is carried out with existing algorithms such as fast Fourier transform and filter-based design [3]. The results demonstrate that FDST-based energy-metering algorithm surpasses existing algorithms in terms of accuracy, complexity, and adaptability under PQ events [3]. In this paper, a prototype of an energy monitoring device based on an open source concept is presented [4]. This architecture assures several advantages with respect to traditional energy meters, such as easy development of new applications making cost- and time-effective the migration to future smart grid infrastructures and simple adjustments to change in the relevant standards [4]. The development of the induction-type energy meter is discussed [5]. In this paper, measurement equipment for the calibration of energy meters is presented [6]. Its structure and metrological characterization are discussed [6]. To improve its performances without increasing its costs, two online digital compensation procedures have been realized and are shown: one increases the spectral purity of test signals and one corrects the transducer frequency response [6]. Experimental results relating metrological characterization have shown that the so-realized calibrator is suitable for the onsite calibration of energy meters [6].

III. ARCHITECTURE OF ENERGY METER

The energy meter has four main parts. They are the Driving System, Moving System, Braking System and Registering System [31].

3.1 Driving System - The electromagnet is the main component of the driving system. It is the temporary magnet which is excited by the current flow through their coil [31]. The core of the electromagnet is made up of silicon steel lamination. The driving system has two electromagnets. The upper one is called the shunt electromagnet, and the lower one is called series electromagnet [31]. The series electromagnet is excited by the load current flow through the current coil. The coil of the shunt electromagnet is directly connected with the supply and hence carries the current proportional to the shunt voltage. This coil is called the pressure coil [31]. The centre limb of the magnet has the copper band. These bands are adjustable. The main function of the copper band is to align the flux produced by the shunt magnet in such a way that it is exactly perpendicular to the supplied voltage [31].

3.2 Moving System - The moving system is the aluminium disc mounted on the shaft of the alloy. The disc is placed in the air gap of the two electromagnets [31]. The eddy current is induced in the disc because of the change of the magnetic field. This eddy current is cut by the magnetic flux [31]. The interaction of the flux and the disc induces the deflecting torque. When the devices consume power, the aluminium disc starts rotating, and after some number of rotations, the disc displays the unit used by the load [31]. The number of rotations of the disc is counted at particular interval of time. The disc measured the power consumption in kilowatt hours [31].

3.3 Braking system - The permanent magnet is used for reducing the rotation of the aluminium disc. The aluminium disc induces the eddy current because of their rotation [31]. The eddy current cut the magnetic flux of the permanent magnet and hence produces the braking torque. This braking torque opposes the movement of the disc, thus reduces their speed [31]. The permanent magnet is adjustable due to which the braking torque is also adjusted by shifting the magnet to the other radial position [31].

3.4 Registration (Counting Mechanism) - The main function of the registration or counting mechanism is to record the number of rotations of the aluminium disc [31]. Their rotation is directly proportional to the energy consumed by the loads in the kilowatt hour. The rotation of the disc is transmitted to the pointers of the different dial for recording the different readings. The reading in kWh is obtained by multiply the number of rotations of the disc with the meter constant [8, 31].

IV. WORKING OF ENERGY METER:

The energy meter has the aluminium disc whose rotation determines the power consumption of the load [31]. The disc is placed between the air gap of the series and shunt electromagnet. The shunt magnet has the pressure coil, and the series magnet has the current coil [31]. The pressure coil creates the magnetic field because of the supply voltage, and the current coil produces it because of the current. The field induces by the voltage coil is lagging by 90º on the magnetic field of the current coil because of which eddy current induced in the disc [31]. The interaction of the eddy current and the magnetic field causes torque, which exerts a force on the disc. Thus, the disc starts rotating. The force on the disc is proportional to the current and voltage of the coil [31]. The permanent magnet controls their rotation. The permanent magnet opposes the movement of the disc and equalises it on the power consumption. The cyclometer counts the rotation of the disc [9, 31].

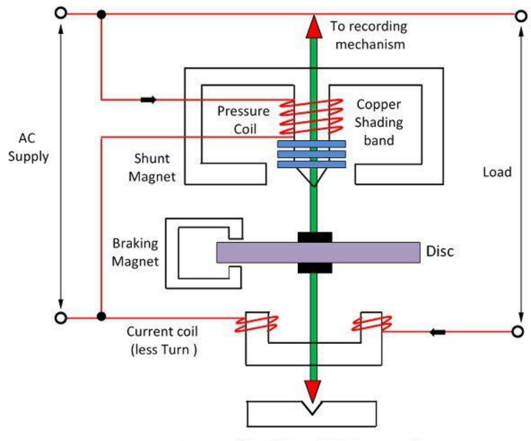

Figure 1: Energy Meter connection diagram [31]

V. Different Types of Energy meters:

Energy meter or watt hour meter is classified in accordance with several factors such as: Type of display like analog or digital electric meter. Type of metering point like grid, secondary transmission, primary and local distribution. End applications like domestic, commercial and industrial. Technical like three phases, single phase, HT, LT and accuracy class meters [30].

5.1 Electromechanical induction type Energy meter:

Figure 2 Induction type Energy meter [30]

It is the popularly known and most common type of age old watt hour meter. It consists of rotating aluminium disc mounted on a spindle between two electro magnets [30]. Speed of rotation of disc is proportional to the power and this power is integrated by the use of counter mechanism and gear trains. It comprises of two silicon steel laminated electromagnets i.e., series and shunt magnets. Series magnet carries a coil which is of few turns of thick wire connected in series with line whereas shunt magnet carries coil with many turns of thin wire connected across the supply [30]. Breaking magnet is a permanent magnet which applies the force opposite to normal disc rotation to move that disc at balanced position and to stop the disc while power is off [30].

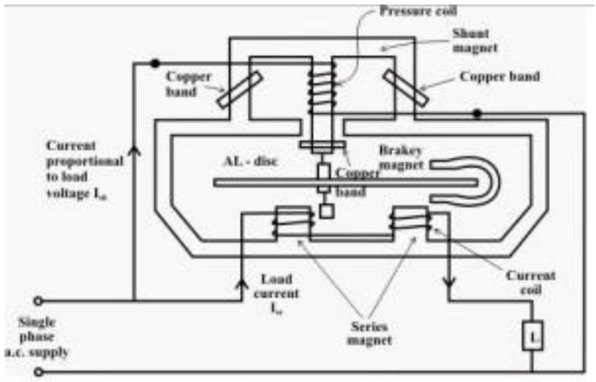

Figure 3 Working of induction type energy meter [30]

Series magnet produces the flux which is proportional to the current flowing and shunt magnet produces the flux proportional to the voltage. These two fluxes lag by 90 degrees due to inductive nature. The interaction of these two fields produces eddy current in the disk, exerting a force, which is proportional to product of instantaneous voltage, current and phase angle between them [30]. Vertical spindle or shaft of the aluminium disc is connected to gear arrangement which records a number, proportional to the number of revolutions of the disc. This gear arrangement sets the number in a series of dials and indicates energy consumed over a time. This type of meter is simple in construction and accuracy is somewhat less due to creeping and other external fields. A major problem with these types of meters is their easy prone to tampering, leading to a requirement of an electrical energy monitoring system. These are very commonly used in domestic and industrial applications [30].

5.2 Electronic Energy meters:

These are of accurate, high procession and reliable types of measuring instruments as compared to conventional mechanical meters. It consumes less power and starts measuring instantaneously when connected to load. These meters might be analog or digital. In analog meters, power is converted to proportional frequency or pulse rate and it is integrated by counters placed inside it. In digital electric meter power is directly measured by high end processor. The power is integrated by logic circuits to get the energy and also for testing and calibration purpose. It is then converted to frequency or pulse rate [30].

5.3 Analog Electronic Energy Meters:

In analog type meters, voltage and current values of each phase are obtained by voltage divider and current transformers respectively which are directly connected to the load as shown in figure. Analog to digital converter converts these analog values to digitized samples and it is then converted to corresponding frequency signals by frequency converter. These frequency pulses then drive a counter mechanism where these samples are integrated over a time to produce the electricity consumption [30].

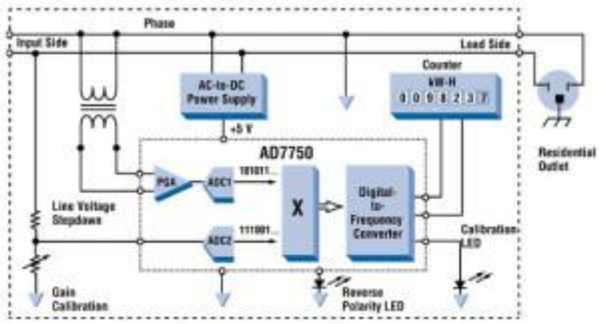

Figure 4 Analog Electronic Meters [30]

5.4 Digital Electronic Energy Meters

Digital signal processor or high performance microprocessors are used in digital electric meters. Similar to the analog meters, voltage and current transducers are connected to a high resolution ADC. Once it converts analog signals to digital samples, voltage and current samples are multiplied and integrated by digital circuits to measure the energy consumed [30].

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239 – 243

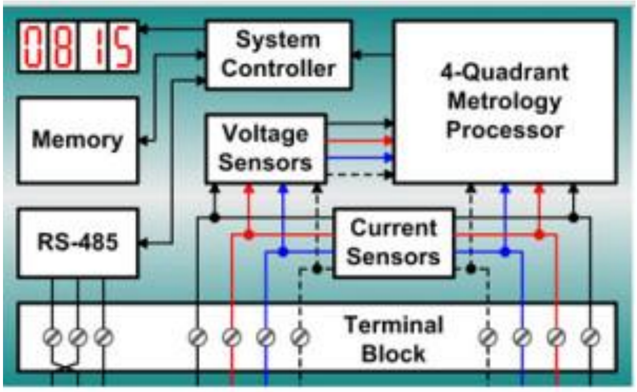

Figure 5 Digital Electronic Energy Meters [30]

Microprocessor also calculates phase angle between voltage and current, so that it also measures and indicates reactive power. It is programmed in such a way that it calculates energy according to the tariff and other parameters like power factor, maximum demand, etc. and stores all these values in a non-volatile memory EEPROM [30]. It contains real time clock (RTC) for calculating time for power integration, maximum demand calculations and also date and time stamps for particular parameters. Furthermore it interacts with liquid crystal display (LCD), communication devices and other meter outputs. Battery is provided for RTC and other significant peripherals for backup power [30].

5.5 Smart Energy Meters:

It is an advanced metering technology involving placing intelligent meters to read, process and feedback the data to customers. It measures energy consumption, remotely switches the supply to customers and remotely controls the maximum electricity consumption. Smart metering system uses the advanced metering infrastructure system technology for better performance [30].

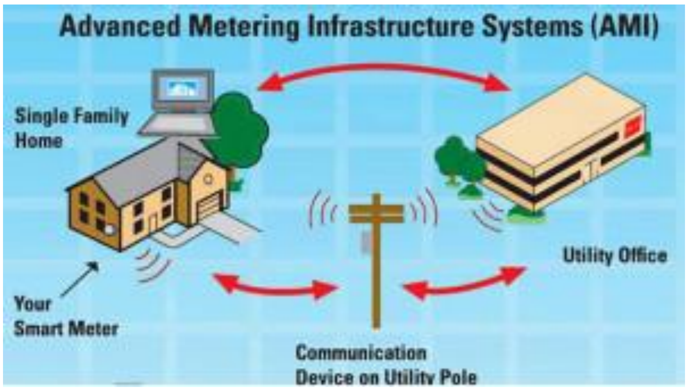

Figure 6 Smart Energy Meters [30]

These are capable of communicating in both directions. They can transmit the data to the utilities like energy consumption, parameter values, alarms, etc. and also can receive information from utilities such as automatic meter reading system, reconnect/disconnect instructions, upgrading of meter software's and other important messages [30]. 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, fibre 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. This is all about types of energy meter and their working. Hope you are satisfied with this article. We express our gratitude to all the readers [7, 30].

VI. ADVANCEMENTS IN ENERGY METERS

Advancements in smart meters are discussed in [10]. Collaborative Internet of Things (C-IoT), for future smart connected life and business is discussed in [11]. Internet of Things based on smart objects is described in [12]. Discussion on smart grid advances in today's dynamic and rapid growing global economic and technological environment is provided in [13]. Zheng et al. [14] provided an overview on smart meters in smart grid. Smart meters and its development are discussed in literature [15-17]. The paper systematically reviews the development and deployment of smart energy meters, including smart electricity meters, smart heat meters, and smart gas meters by Sun et al. [18]. Evolution of smart metering systems is discussed by Zivic et al. [19]. Alahakoon and Yu [20] discussed smart electricity meter data intelligence for future energy systems. Alimardani et al. [21] proposed uses of smart meters in state estimation of distribution networks. Distribution system state estimation based on non-synchronized smart meters is discussed in [22]. Ciuciu et al. [23] discussed social network of smart metered homes and SMEs for grid-based renewable energy exchange. Smart meters as part of a sensor network for monitoring the low voltage grid is explained by Dede et al. [24]. Cluster analysis of smart metering data [25] and short term electricity forecasting using individual smart meter data [26] are discussed in literature. Hao [27] developed smart meter deployment optimization for efficient electrical appliance state monitoring. Zhang et al. [28] developed economic optimization of smart distribution networks considering real-time pricing. Experimental study and design of smart energy meter for the smart grid was proposed in [29].

VII. CONCLUSION

Recent advancement and development in energy meter is discussed in this paper. A lot of recent innovations related to the smart meters and its utilization is reported in the literature. Internet of Things (IoT) is a recent development in area of technology and can be used along with the energy meters to make them more reliable and smart in nature. Evolution of smart metering systems along with IoT is discussed in

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239 – 243

literature. A review along with the innovations to make meter smart in nature is discussed.

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