

DESIGN OF SMART ENERGY METER FOR INTELLIGENT ENERGY NETWORK

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Abstract: The traditional approach towards energy auditing is not adequate for today's energy monitoring as it lacks the necessary data to estimate energy needs. The objective is to obtain more accurate information from single consumers connected to the low- and medium-voltage grid and to find new ways of making our everyday lives more energy efficient. We offer an innovative solution towards energy auditing and full control over the meters by making traditional energy meters to be smart. These sensor elements are originally deployed for invoicing purposes, they allow a previously unattainable degree of detail in state estimation and other grid analysis functionalities. Including the above functionalities, this allows real-time energy monitoring, Power factor inspection, Load scheduling during peak hours via collected data and energy theft.

Keywords: NODEMCU, Voltage Sensor, Autodesk Eagle Software, Advanced Metering Infrastructure (AMI), The Intelligent Energy Network (IEN), printed circuit board (PCB).

I. INTRODUCTION

Smart meter [1] is a device based on two way communication system between consumers and suppliers including Smart monitoring system. A smart meter is more reliable compared to a digital meter in terms of billing and tampering. It will also increase consumers concern about their electricity usage and at the same time, the Governing body will also be able to monitor power consumption in a better and best way through the information received from Smart Meters. In short, Smart Meter is a next-generation device for a better power distribution system and can be the first step to make a change in conventional Billing and metering

The Intelligent Energy Network (IEN)

Since the beginning of electricity regulation and the emergence of renewable energy sources, utilities have been looking for a means to match consumption with generation. Traditional meters only measure the total consumption and provide no information about when the energy was consumed

at each metered site. In contrast, smart meters are sensor elements that provide accurate high-resolution measurements on both the spatial scale, i.e., on a household level, and the temporal scale, i.e., every hour or 10 seconds, for parts of the low-voltage distribution grid topology for which previously only highly aggregate measurements on the substation and transformer level were available. Most of the current electricity meters can measure the active and reactive energy consumed or produced, the active and reactive power as well as voltage levels. Advanced Metering Infrastructure (AMI) differs from traditional Automatic Meter Reading (AMR) as it enables two-way communications between the meter and the control center of a Distribution System Operator (DSO). Thus, as shown in Fig. 1.1, bi-directional flow of energy and data information can be achieved.



II. PROBLEM STATEMENT

- Traditional electrical meters only measure total consumption of energy, and so provide no information of time in which energy was consumed. They neglect the power factor for non-commercial usage, which leads to inaccurate measurement and improper

energy consumption data.

- Traditional meters are mechanical in nature, i.e., they contain constantly moving parts that need to work in perfect synchronization in order to provide an accurate reading., these meters have a tendency to slow down, resulting in a lower reading.
- Meter readers have a number of difficult tasks assigned to them, to visit each house individually, also problem to deal with extremely protective property.
- Meters cannot measure the high reactive loads, used by a consumer instantly, which causes power factor to decrease and results in increased harmonics. They provide no protection, easy to bypass and tamper, hence a higher chance of power theft.
- Traditional meters are not user-friendly, limited access to users and cannot be monitored.
- The utility has no access to meter remotely and only access the data on site.

Objectives

- Real-time measurement of AC parameters like True-RMS Voltage, Current, Power, Power factor, Energy, considering power factor, with high accuracy, realtime waveform. And Also, to accommodate bidirectional feature for measurement of power export and import.
- Real-time monitor and control by the utilities with wireless data logging and remote access. Also allowing the consumer to interact with meter and monitor usage remotely.
- Implementing increased meter security and protection for software as well as hardware, Antitheft and tamper proof design, to reduce undesired theft and loss power.
- Allows for the utility companies to introduce different prices for consumption on time of use, based on demand and availability of power, faster and lossless billing, and reduced human work of collecting data from individual houses.

Methodology

- Stepping down and attenuating voltage and current signals for measurement, to make microcontroller friendly.
- Sampling voltage and current signals over one cycle, using sampling circuit and ADC, given to microcontrollers.
- Running algorithms to find True RMS voltage and current, followed by Real power and Apparent power.
- Power factor is obtained using voltage and current samples.
- Security and anti-theft are implemented using a master microcontroller and password authentication is enabled.
- Under voltage protection has been implemented using a single channel relay.
- Temporary disconnection of supply from utility due to due payment.
- Data sharing is done via IOT for access via the Android App and IOT dashboard anywhere in the world.

Advantages

A smart meter is more reliable compared to a digital meter in terms of billing and tampering. Due to real-time monitoring and over-use alarm system, users will be able to get their usage data all the time and this will raise more concern about their electricity usage. At the same time, the Governing body will also be able to monitor power consumption in a better and organized way through the information received from Smart Meters.

Advantages of Smart Meter are:

- Consumers will get more accurate bill according to their usage.
- Consumers will be more concerned about their electricity usage due to the real-time monitoring system.
- The utility can trip the meter for any unusual cases.
- All data stored in the database and consumers can see their usage update using their Unique user id and password.
- A smart meter is more reliable compared to the digital meter.
- Under voltage protection.
- A smart power distribution system with a smart meter will be able to detect and stop 'Theft of electricity'

Design And Circuitry

Circuitry design of energy meter is done for required ratings of the meter. The Smart Energy Meter is designed for 2500VA; that is voltage rating of 250VAC and current rating of 30A. Sensors are picked and designed to take 20% more value of meter ratings. Controller's circuit is designed for clock speed to match its operating frequency as well as ADC maximum sampling rate. I/O pins are connected to all peripherals in the design itself.

Autodesk EAGLE software

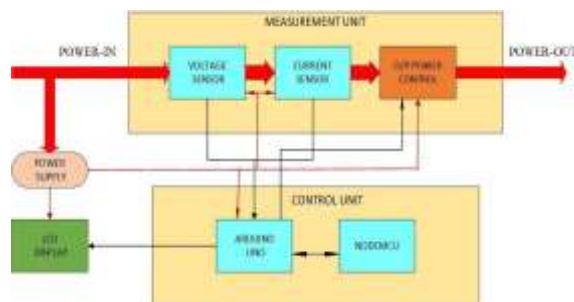
EAGLE is abbreviated as Electronic Design Automation (EDA) application with schematic capture, printed circuit board (PCB) layout, auto-router, and computer-aided manufacturing (CAM) features. EAGLE will be abbreviated as Easily Applicable Graphical Layout Editor and is developed by CadSoft Computer GmbH. The company was acquired by Autodesk Inc. in 2016. EAGLE includes a schematic editor, for designing circuit diagrams. Schematics are stored in files with .SCH extension, the parts are defined in device libraries with .LBR extension. The Parts can be placed on many sheets and connected together through ports. The PCB layout stores the board files with the extension .BRD. It allows back annotation to the schematic and auto-routing to automatically connect traces based on the connections defined in the schematic.

EAGLE includes Gerber and PostScript layout files as well as Excellon and Sieb & Meyer drill files. These are complicated standard file formats accepted by PCB fabrication companies, but given EAGLE's typical user base of small design firms and hobbyists, many PCB fabricators and assembly shops also accept board files of EAGLE (with extension .BRD) directly to export optimized production files and pick-and-place data themselves. The smart meter design and circuitry is done with this software

using various available libraries.

I. IMPLEMENTATION

The SEM comply with the metering standards regarding reliability and accuracy and developing a meter as a complete unit is easier to meet the standard than developing it in modules. However, modularization represents an important way to design smart meters in practice and the metering component is usually sealed in a complete module, which can be later connected with other modules. Making a smart meter an open structure and adding more functions by connecting it with other modules can largely facilitate the innovation and deployment of smart meters. In addition, it is easier for modularized systems to achieve interoperability. Different meters can use different modules to measure energy flows while using the same module to communicate [5].



Features

The features we have included in our SMART Meter are,

- Multifunctional 1-Phase real-time measurement
 - True RMS voltage & current
 - Power & energy consumed.
 - Power factor, Lead & Lag.

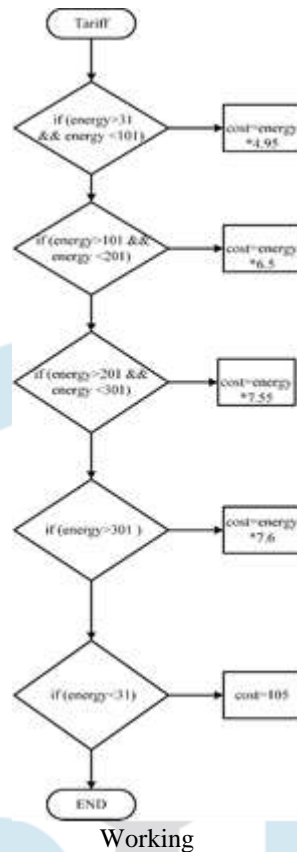
Real power, Reactive power, Apparent power

- Real-time Waveform Capture
- Precise real-time energy auditing.
- Automated billing through the server.
- Power factor inspection and monitoring.
- Disconnection of the supply in due payment.
- Display of AC Status, parameters, and Warning
- EEPROM support
- Undervoltage protection.
- Upgradeable Firmware & Software/App Support
- Communications
 - Standard UART with firmware access
 - Wi-Fi COM with IOT support
- Programmable Logical Controller / Microprocessor based system
- Event and Data logging
- Meter Security and self-protection & Anti-theft

PROGRAMMING

Programming has been done in various modules, so it would be easier to update the firmware and to troubleshoot. Such various modules formed are as follow: Modules can be referred as function in the following master and slave code.

Master Code



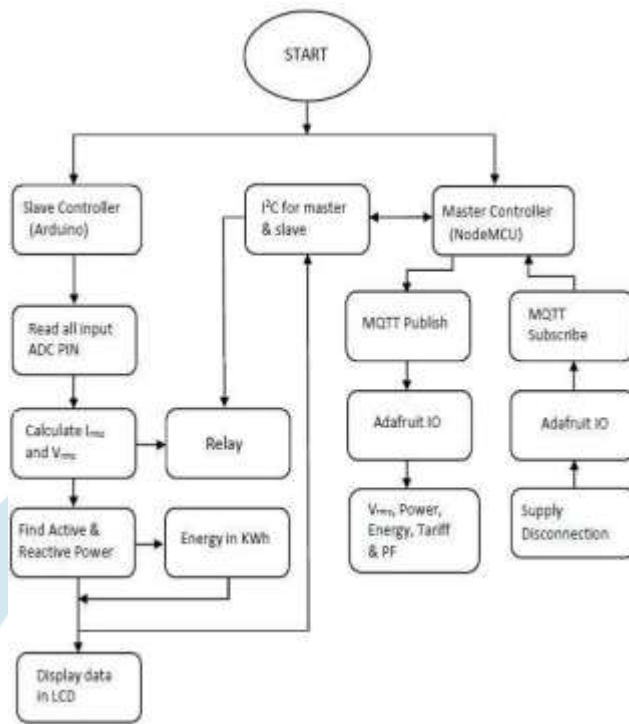
Working of the Smart Energy Meter

This proposed system consists of two basic sensors, one is ACS 712 which is a current sensor with a current handling capacity of 30A. ZMPT101b, a precision voltage sensor can replace the potential transformer and the conventional voltage divider circuit to measure the voltage. The ZMPT101b has integrated transformer and Op-Amp circuitry which gives proportional ADC output. The analog output of the sensors will be processed by a microcontroller – Atmega 328P, which is embedded on the Arduino development board, turns this analog output to digital set-points. Then the processed data will be displayed on an LCD for user reference And an Electromagnetic Relay is used to enable disconnect and reconnect of the supply in under-voltage condition and also it can be controlled by the utility in case of due payment of the customer.

All sensor data collection will be provided by the Arduino board and is considered as slave controller in the proposed energy meter. An open source platform NODEMCU based on ESP-12 Wi-Fi module is used as a master controller, which provides main controls and enables data uplink with the server.

The connection between the master and slave node is provided using I2C communication. With I2C, data is transferred in bytes. Each data has an address frame that contains the binary address of the slave, and one or more data frames that contain the data being transmitted. The data also includes start and stop conditions, read/write bits between each data frame.

The NODEMCU will send the request MQTT to the server. Once the NODEMCU handshakes with the server, the data available from the meter will be published to the server. The server platform has a visual dashboard, it will be easier for the utility provider to monitor the smart energy meter. The dashboard visibility is provided to the consumer to have inspection about their energy consumption.



Flowchart of Energy Meter

RESULTS

The results obtained out of this project, Smart Energy Meter, are interpreted and discussed for different conditions and tests performed.

Measurements test Results

Readings of Smart Energy Meter under different loads and conditions are given below.

Measurements for different supply voltages with constant load

Supply Voltage	Multimeter Measured	Smart Meter Measured	Percentage Error
150 V	152.1 V	152.22 V	0.079 %
170 V	171.6V	171.68 V	0.047 %
190 V	191.8V	192.18 V	0.198 %
210 V	213.5 V	213.65 V	0.070 %
230 V	233.4V	233.53 V	0.056 %
250 V	254.6 V	254.77 V	0.067 %
270 V	275.1 V	275.78 V	0.247 %

Table 10.1 Readings for different supply voltages

Measurements for different types of loads

	Resistive Load	Inductive Load
V _{rms}	225.18 V	228.06 V
I _{rms}	0.73 A	0.70 A
Active_P	165.11 W	151.86 W
Reactive_P	0.37 Var	46.2 Var
PF	1	.95 lag

Table 10.2 Readings for different types of loads

CONCLUSION AND FUTURE SCOPE

CONCLUSION

A fully working Smart Energy Meter with Real-time measurement of AC parameter, dedicated communication channels are developed. The faults occurring in the household and any power theft that may occur by bypassing the meter is detected. It can also detect over and under voltages from the supply.

The meter is able to communicate through the Wi-Fi channels to the consumer and the utility respectively. Remote control of the meter is achieved by the communication channel which allows the utility to shut down the supply to meter whenever necessary such as the occurrence of a fault in supply or unpaid bills by the consumer.

Each meter connected to the network can be monitored through the server. Data regarding instantaneous power consumption and charges regarding used power. If the customer has not paid the bill, automatic control in the server will disconnect the supply to the meter. Unnatural loading can also use to be cut down by the service provider. Hence complete mobile control over the load centers can be achieved using this model.

With the help of Smart Energy Meter, this utility can access remotely for the consumption of every consumer and generate periodic bills without having to visit the site for meter readings. The meter allows the user to track their consumption in real-time with the help of an online web portal.

Future Scope

In the present scenario, with the introduction of renewable sources of energy, it is important to upgrade the power grids into smart grids. The first step towards a smart grid is the ability of the energy meter to measure power bi-directionally which is achieved by the usage of Smart Energy Meter.

In order to maintain a smart grid, a lot of data has to be gathered, analyzed and stored for future use. The Smart Energy Meter provides a solution to this by measuring various parameters and sending this data to the utility for analysis and storage purposes.

The application of smart metering technologies and other more comprehensive applications enabled by smart energy meters have significant advantages over conventional energy networks. Moreover, the future direction of the development of IENs seems increasingly clear.

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