International Journal of Future Generation Communication and Networking
Vol.14, No. 1, (2021), pp. 4118 – 4124

Design of Single Phase Smart Energy Meter

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Abstract

Energy meters, undoubtedly, have a very important role to play in the power distribution. The proposed system presents single phase electrical energy meter based on a micro-controller. It can measure various supply parameters including voltage, current and power consumed. This electronic meter does not possess any rotating parts and the energy consumption can be easily read from LCD. Besides that, energy consumption is stored in the microcontroller's EEPROM memory. This action is necessary to ensure a correct measurement even in the event of an electrical outage or brown out. As soon as the supply is restored, the meter restarts with the stored value. Such System uses MODBUS RTU communication protocol. To check the performance and then testing of the meters the IS standard IS 13799 can be used.

Keywords—Single Phase, Energy Meter, Microcontroller, IS Standards,

I. INTRODUCTION

India's per capita energy consumption grew 46% over the last 14 years, but it is still a third of the global average, according to the International Energy Agency's India Energy Outlook Report 2015. To track the amount of energy consumption by a consumer, the energy meters are used. Electromechanical energy meters and Electronics energy meters are the commonly used types of energy meters. The electromechanical meters are operated by counting the number of revolutions of the disc hence, the accuracy of these meters is limited. Whereas, electronic meters are the extremely favorable metrology with absolutely no moving parts. These meters use microcontrollers, DSP processors or ASIC for the metrology providing extremely accurate measurements with digital display. As the electronic version of the meters does not possess any mechanical rotating parts, it helps to avoid the tampering by any false person. To improve the energy efficiency, consumer needs to be more aware of their energy consumption. This paper presents a totally electronic single phase energy meter supporting low to medium load. It measures the quantity of electric energy consumed by a residence, a business or an electrically powered device. Electric utilities use the meters installed at customer's premises for billing and monitoring purposes.

II. ELECTRICAL ENERGY COMPUTATION

Equation given below is the basis for the computation of the energy consumption (E) of any given load during a time interval of

$\Delta t=(t2-t1)$:

ISSN: 2233-7853 IJFGCN

$$E = \int_{t1}^{t2} v(t)i(t)dt \ ,$$

where *v(t)* is the supply voltage and *i(t)* is the load current.

The power measurement IC ATM90E26 is used for the purpose of calculating the metering parameters including active power, reactive power, power factor, rms voltage and current, tamper detection etc. The energy consumption is displayed on a LCD.

III. LITERATURE SURVEY

Supply voltage level detector circuit is used in case of the outage. If the microcontroller supply voltage becomes less than 4.2 V, this circuit changes the external interrupt port RBO/INT input from 5V to 0. This forces a program interrupt to occur, that activates the sub-routine that stores the energy consumption value into the microcontroller EEPROM, and next causes the program to go to a background loop, until the normal line voltage is reestablished. This is recognized by a voltage greater than 4.8 V at the external interrupt port, that makes the program to leave the background loop and resume the normal processing. In the event that the microcontroller supply voltage becomes less than predefined level, the disabling circuit is activated. Disabling circuit prevents the controller to work with low voltages levels, close to the minimum allowable value [1]. For measuring the energy consumed, the current transformer (CT) and a potential transformer (PT) will be used to sense the value of load current and supply voltage respectively. Transformer generally performs two major tasks- the first one is to transform currents or voltages from a usually high value to a measurable safe value and the second one is to provide isolation from high current or high voltage circuits. High voltage and current are not directly measured by measuring instruments, higher values are stepped down with a known ratio of PT or CT and then multiply measured value with ratio of transformer to get accurate value for current and voltage. CT is a series connected type of instrument transformer, while PT is a parallel connected type [2]. There are several issues related to the smart meters. Smart meters encourage consumers to conserve energy by helping them maintain the quantity and cost of their energy consumption. Physical damage to the cable might cause discontinuity in data transfer, hence maintenance should be done accordingly. In addition, energy meters are located in open and insecure environments and need proper shelter to be physically secure. Some other issues are software and hardware issues with the smart meter, electric network as well as distribution network failures. Illegal usage of electricity is also a serious issue now a days hence the system is introduced with the tamper detection [3]. Smart meter can be efficient than the conventional energy meters. Drawbacks of traditional energy meters are mentioned below: Strong chance of Energy Theft by anyone in mega events especially, Chance of human error while collecting the data from meter, Electricity user has not his daily update of usage of electricity, It is exceedingly depend on meter reading person who collect all the readings, There is no option of cross checking for readings taking from meters, There is some probability to modify the meter readings while taking snap shot of meter by using different software trappings and there is no privacy and security for metering data. The smart meters are cost efficient so installation come to be far at ease. Minimization of electricity theft and controlling the usage of electricity on end user side to escape waste of power. It generally decreases the manpower to keep record of data usage [4].

Ways of illegal electricity usage:

1. A consumer can use some mechanical objects to retard or prevent the revolution of disc of a meter, so the disc speed is reduced and hence the recorded energy is less than the actual value.
2. A consumer can change the electromagnetic field of the current coils with the help of a fixed magnet, thereby reducing the energy consumption recorded.

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3. Illegal users can switch the energy cables at the meter connector box to prevent the flow of current through the current coil of the meter, so the meter does not record the energy consumption.

In digital automatic meter reading the energy meter calculates units of energy consumed based on voltage and current data received from CT and PT. Remote switch ON/OFF functionality is possible with the help of relay-another part of smart meter, the control command being sent from energy provider via power line carrier signal [5].

A. IS Standard:

This standard was introduced in 1993. It specifies static watt-hour meter of accuracy class 1 and class 2 for measuring AC active energy. It applies to:

1. The meters consisting of measuring elements and registers enclosed together in a meter case.
2. Operation indicator and test outputs.
3. Multi-rate tariff meters and meters which measure energy in both directions.

It does not apply to:

1. Meters where voltage across terminals exceeds 600V.
2. Portable meters and outdoor meters.
3. Data interfaces to registers of the meter.

The meter has other Standards inbuilt in it which includes, IEC 60068-2-75 for environmental testing and ISO 75-1 for the determination of temperature of deflection under load. Basically, amongst the class 1 and class 2 of IS13779, we will be using class 1 as its accuracy is more as compared to class 2. The error percentage of lass 1 is: ±1%, while that of class 2 is: ±2%.

B. Test and Test Conditions:

Different tests for checking different parameters required to be carried out. Each of these tests have their own conditions to be checked and IS 9000 is used in some while IS 13779 in some cases

1. Test of Insulation Properties*:* This test includes impulse voltage test, AC high voltage test and insulation test.
2. Test of Accuracy Requirements*:* This test includes test on limits of error, test of meter constants, test of starting conditions, test of influence quantities, test of repeatability of error and test of ambient temperature influence.
3. Test of Electrical Requirements*:* This test includes test of power consumption test, test of influence of power supply, test of influence of short time over-currents, test of influence of self-heating, test of influence of heating and test of influence of immunity to earth fault.
4. Test for Climate Influences*:* This test includes dry heat test, cold test and damp heat cyclic test.
5. Test of Mechanical Requirements*:* This test includes vibration test, shock test, spring hammer test, protection against penetration of dust and water, test of resistance of heat and fire.

C. RS485:

RS485 or EIA (Electronic Industries Association) RS485 is a balanced line, half-duplex transmission system allowing transmission distances of up to 1.2 km. Rs485 is better serial communication than RS232 because, RS232 has a lower transmission speed and the maximum cable length required is short.

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It has a large voltage swing and large standard connectors. No multipoint capability is available in RS232.

Table I : Specifications of RS485

In RS485, the Receiver and Driver pins are the pins that will be connected to IC and Arduino. The power to RS485 pin will be connected to the Receiver pin and driver will be given to the microcontroller pin.

Parameter	Specifications
Mode of operation	Differential
Number of drivers and receivers	32 drivers 32 receivers
Maximum cable length(m)	1200
Maximum data rate(baud)	10M
Maximum common mode voltage(volt)	12-7
Maximum driver output levels(loaded)	± 1.5
Minimum drivers output levels(loaded)	± 6
Drivers output short circuit current limit(mA)	150 to Gnd, 250 to -7 or 12V
Minimum input receiver resistance	12
Receiver sensitivity	± 200mV

D. Power Measurement ICs:

The power measurement IC is needed for the computations of the metering parameters of single-phase energy meter. Some of the manufacturers of such ICs are microchip, maxim and analog devices. The comparison of the power measurement ICs produced by these manufacturers is given below.

Table II: Comparison of Power measurement ICs

Parameter	Maxim	Analog Devices	Microchip
Apparent power calculation	Yes	Yes	Yes
Reactive power calculation	Yes	Yes	Yes
Active power calculation	Yes	Yes	Yes
Sensitivity/Accuracy		SNR=88dB	0.1% error across 5000:1 dynamic range i.e 0.5%
Current calculation	Yes	Yes	Yes
Voltage calculation	Yes	Yes (SPI)	Yes (SPI/UART)
Communication	Yes	Yes	Yes
I/N condition safety	Yes	Yes	Yes
Temperature condition	-40ºC to +80ºC	-40ºC to +85ºC	-40ºC to +80ºC

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Operating voltage	3.0V - 3.6V	2.9V - 3.6V	2.8V - 3.6V
Auto Calibration	No	Yes	Yes

IV. METHODOLOGY

A. Block Diagram:

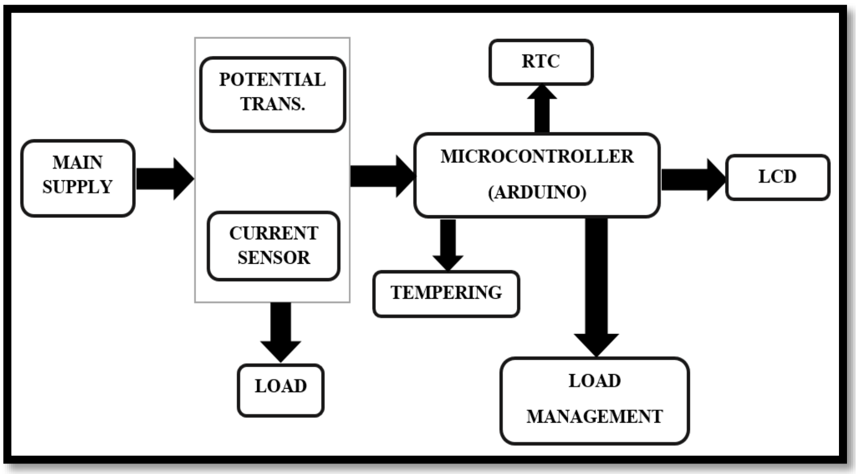

Fig. 1 Block Diagram of Single-Phase Energy meter

B. Methodology

The micro-controller is the heart of the meter. The voltage and the current signals after proper conditioning are sampled. The voltage supply is attenuated using a voltage divider then sampled and converted to digital form by a A/D converter. Similarly load current signal is attenuated, sampled and converted to digital form. The voltage and current sampled values are transferred serially to the micro-controller. The selected micro controller is that possesses relevant characteristics for the current application, such as low cost, EEPROM memory, that stores the measured energy value even in the presence of a power outage. The micro controller processes and stores the energy consumption. The energy is compared to a referred value (Eref) set during a calibration process, where, for a 1kW load, the consumed energy is calculated and accumulated (integrated) for 100 periods of 924ps (a program cycle). The energy consumption is indicated by a 4 digits display. As the above block diagram states, the schematic of meter consists of two main blocks: Voltage Block & Current Block. In voltage measurement, the main power supply is connected to the primary of a 230-4.5 V step down transformer, while secondary of transformer is connected to voltage divider circuit. The value is given to the analog pin of Arduino, where the negative value is converted by giving DC voltage shift to incoming signal. In current measurement, Current sensor (ACS712) is used. It connects in series with load and its output is fed to Arduino directly. RTC (Real time clock) (DS3232) is used to get the real time to count and store into the EEPROM.

V. EXPERIMENTATION AND RESULTS

Proteus simulation software is used for experimentation purpose, in which, after uploading the Arduino Code results can be seen on Virtual Terminal. It shows Voltage, Current, Power, Energy and Power Factor. RTC (Real Time Clock) (DS3232) is used to get the real time to count and store into the EEPROM. Following diagrams shows simulation results.

ISSN: 2233-7853 IJFGCN

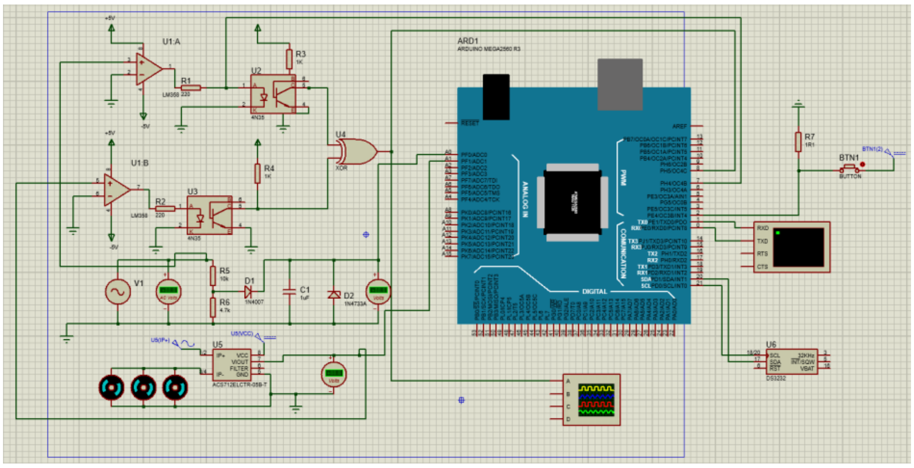

Fig. 2 Simulation diagram of Energy Meter

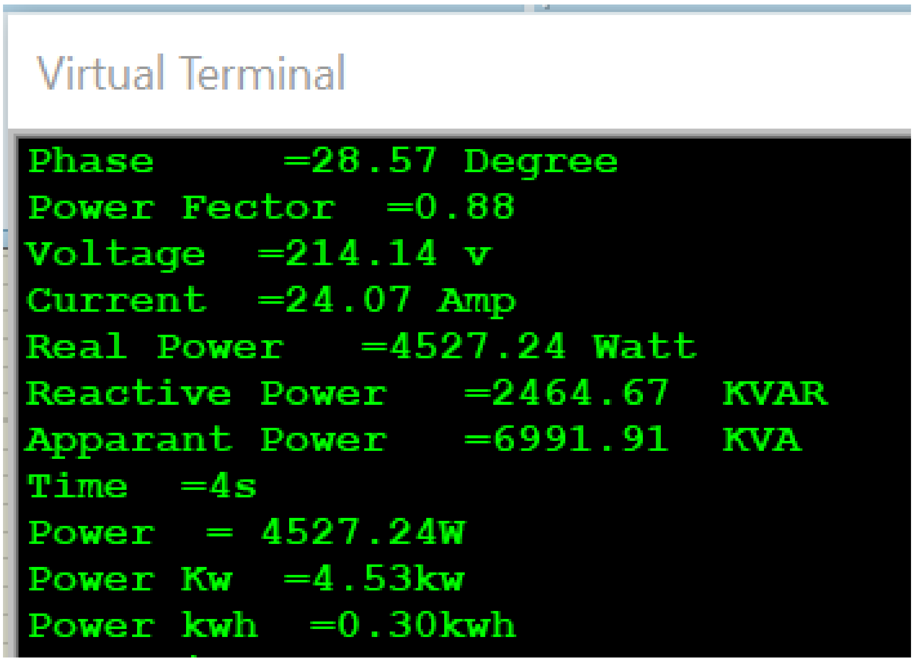

Fig. 3 Output of meter parameters on virtual terminal

VI. Conclusion

The described energy meter measures the electrical energy consumption with the help of microcontroller, as an alternative to the conventional electromechanical meters. This micro-controller-based meter doesn't possess any rotating parts, which helps preventing the frauds caused by tempering. The production cost of the system is lower and it is more precise than the conventional electromechanical energy meters. As the measured values are displayed using LCD, it is easier to monitor the energy consumption.

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ISSN: 2233-7853 IJFGCN

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