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Design and Development of Cost Effective IoT based Smart Meters for Smart City Households with Harmonic Analysis

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Abstract: The nonlinear loads that are used in households such as computers, fluorescent lamps, AC voltage regulator base fans, refrigerators, air conditioners, etc., causes electric pollution as they distort their current waveform and eventually distort the common voltage waveform thereby causing damage to the equipments. There is an increasing trend in the use of nonlinear loads and considering the Electric Vehicle scenario, harmonic will be a large problem in households in few years. In this work, a cost-effective energy meter is designed and harmonics measurement up to 25th harmonic is incorporated into the system. The results were verified with standard meters. Then the data is uploaded to a cloud platform from where the consumer can view his consumption at any time.

Introduction:

Electricity has become an integral part of our daily lives. The growth of every sector in our country depends upon the availability of electricity. Nowadays, due to the tremendous growth of non-linear loads such as the usage of power converters, UPS, Rectifiers, Induction ovens, battery chargers, etc., the quality of the power delivered to the end user is highly reduced. As per IEEE 519- 2014 standard, the allowable deterioration for LT lines (<1 kV) is 5%. In this work, a cost-effective energy meter is designed and harmonics measurement up to 25th harmonic is incorporated into the system. The data is uploaded to a cloud platform from where the consumer can view his consumption at any time. Fast Fourier Transform (256 point) algorithm is used to compute the harmonics. The voltage is sensed through a high precision potential transformer based sensor and the current is sensed through a Hall Effect based sensor. Then the values are fed into the microcontroller and various power related parameters are calculated by instantaneous power calculation technique. A display is provided for the user to view the parameters. The experimental values are verified using 3 standard meters: FLUKE 434 series II power quality analyzer, FLUKE 317 clamp meter and MECO PLH 5760. The experimental values were reasonable with the standard meter values. The experimental setup was tested using a TRIAC based lamp load and a variable RL load. A large current harmonics was injected into the system and the values were compared. The experimental setup was close to accurate and had an error of +/- 3 %. The data were uploaded to a cloud platform called ThingSpeak. Various fields were created in that platform and the waveforms were plotted.

Materials and Methods:

Instantaneous power concept is used in calculating the total real power consumed by the appliances in the home. It is the most accurate method in calculating AC power. The results are always true in all kinds of loads; resistive, inductive, capacitive and even the modern harmonics-rich nonlinear loads. It is the product of instantaneous voltage and instantaneous current across an element. By calculating the active power all the other parameters can be calculated by basic formulae.

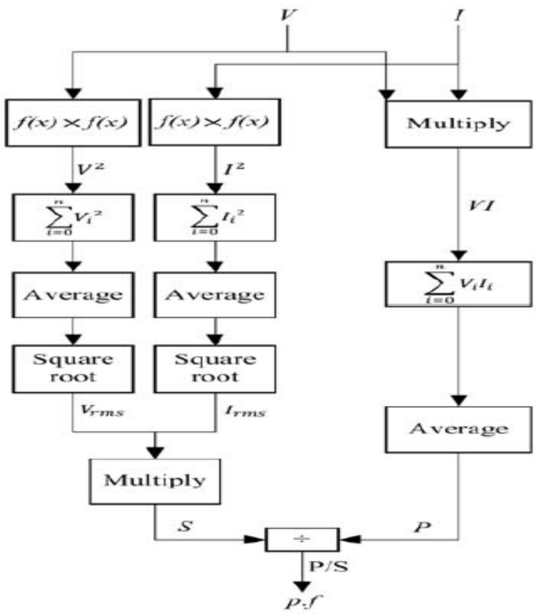

Fig 1: Flow chart for computation

Current sensor (ACS712) and voltage sensor (ZMPT101) will be the main sensing elements used. Computation of various parameters like active power, reactive power, power factor and harmonics can be done by energy measurement ICs such as ADE9153, ADE7880, etc., which have inbuilt DSP processor. But we are using the microcontroller itself for this purpose which saves the additional cost.

The output from the voltage and current sensor is given to the MCU which process the data and displays the information in an LCD. For this purpose

ATMEGA 2560 is used and the parameters are displayed in a 20x4 LCD.

The communication can be established by a GSM or a Wi-Fi module. We are using a Wi-Fi shield called ESP8266. Load break switches are to be incorporated to control certain loads in accordance to energy consumption. IoT forms a hub for this system interface and takes care of remote monitoring and control. The data is uploaded to "ThingSpeak", which is an open IoT platform with MATLAB analytics.

Results and Discussion:

The maximum deviation of the developed meter from the standard meter was calculated to be **4 %** while measuring less than 5% THD. As the harmonics injected increases, the deviation reduced to less than **2 %.** So the developed meter is fairly accurate when compared with the power quality meters available in the market.

With proper calibration of voltage and current sensing modules, the meter's deviation can be bought to less than 1%

Conclusion:

The progress in technology about electrical distribution network is a non-stop process. In the present work wireless meter reading system is designed to continuously monitor the meter reading. It avoids the human intervention, provides efficient meter reading, avoids the billing error and reduces the maintenance cost. It displays the corresponding information on LCD for user notification. The advantages of Smart Energy Meter are it requires less manpower, there is no need to chase payments, power theft detection is possible, bill is sent to the consumer with due date, the meter can act as either prepaid or post-paid meter, can minimize the power consumption in a house.

This work can be improved by establishing communication from the consumer to the meter, so that controlling of loads can be done by the meter. Once we are able to send a message from the consumer and decode it properly in the microcontroller, Power Line Carrier communication technology can be incorporated in this module.

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