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RESEARCH ARTICLE

EFFICIENT POWER FACTOR MEASUREMENT SYSTEM WITH LABVIEW INTERFACING FOR HOUSEHOLD APPLICATIONS

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Abstract*— Power factor gives the relationship between the input voltage and input current waveforms to an electrical load, powered by an AC source. Most often the AC utility mains will be the source but in certain cases it could also be the output of a motor drive, inverter or other localized AC source. The electrical energy quality is an important factor technically and economically. Accurate power factor measurement is important in any electrical system. This paper presents a simple, cost effective and accurate power factor measurement system implemented using ATmega microcontroller and LabVIEW. In the proposed hardware current measurements are taken using a Hall Effect current sensor and voltage measurements are directly obtained by stepping down the input voltage and converting it to a suitably proportional voltage input to microcontroller. The system is able to effectively measure power factor of appliances consuming power between 20W and 1000W.

***Keywords*— Power Factor, Hall Effect, Microcontroller, Current Sensor, Non-linear load**

I. INTRODUCTION

Power factor is one of the prime concerns for designers of almost every electrical device that consumes significant power from the AC supply. It is an important factor for engineers in heavy-electrical sectors too. There are several engineering practices to enforce conformance with various power-factor norms. In any electrical power system, a load with a low power factor draws more current than a high power factor load, for the same amount of useful power transferred. The drawbacks of high current consumption include significant energy loss in the distribution system, requirement of larger wires and other heavy or bulky equipments. Due to the costs of bulkier equipments and energy wastage, electrical utilities will usually charge a higher cost to industrial or commercial customers if the power factor is low. Hence it is important for consumers to measure the power factor of electrical devices and take necessary remedial measures.

Modern electronic equipment does not represent a completely passive load to the AC mains or powerline. Very often the loads will be showing either resistive characteristics (filament bulbs) or sinusoidal input currents which may be phase-shifted (AC motors). Most of the modern electronic systems use a switchmode power converter that tends to draw current from the powerline in a non-sinusoidal fashion. This input current characteristic may lead to current and sometimes voltage distortions that can create problems with other equipment connected to the powerline. Therefore for accurate power factor measurements it is important to consider the case of non-linear loads. The power factor for a linear load is defined in two ways given by:

$$\text{Power Factor} = P/S = \cos\varphi \qquad (1)$$

where P is the Real Power and S is the Apparent Power

For the linear load case, the power factor can be determined by either measuring the real and apparent powers and doing the division or, alternatively, by measuring the phase shift between the voltage and current waveforms and taking the cosine of this angle. For the nonlinear load case, things get more complex. The phase shift cannot easily be measured due to the non-sinusoidal nature of the current waveform. Consequently, for the nonlinear case, the power factor is best defined as follows:

$$\text{Power Factor} = P/S \qquad (2)$$

II. LITERATURE

Before permeation of semiconductors, the topmost quality measurement of consumers was the cos(φ), and it was easy to measure in sinusoidal case. Nowadays almost every electronic loads contain power supplies, power controlling systems or semiconductors. In this case the shape of the current is not sinusoidal, therefore the simple cos(φ) cannot be a key performance indicator, moreover, it is difficult to be assigned. In non-sinusoidal current or voltage cases a good consumer load key performance indicator is the Power Factor, but assigning the power factor is an even more complicated task.

The most common power factor measurement circuits involve zero crossing detectors, to find phase difference between voltage and current. These systems do not consider the distortion or harmonics occurring in current waveform and hence they are suitable for power factor measurements of linear loads alone. For non-linear loads, to obtain correct power factor readings, the current should be accurately tracked which can be done using Hall Effect sensor.

For most of the existing power factor measurement circuits the current sensors used are shunt resistors, which is a form of direct sensing. The main disadvantage of this type of sensing is the power loss incurred by the sense resistor. Additionally it does not provide measurement isolation from transient voltage potentials on the load. Hence in this proposed measurement system a Hall Effect current sensor, which provides galvanic isolation from the primary circuit, will be used for current sensing. Also the proposed power factor measurement system will be able to provide lossless current measurement of linear as well as non-linear loads. The current and voltage measurements will be read using the ADC inputs of an ATmega -16 microcontroller and it will be interfaced to PC.

There are no instruments that measure power factor directly. The power factor in a single-phase circuit (or balanced three-phase circuit) can be measured with the wattmeterammeter-voltmeter method, where the power in watts is divided by the product of measured voltage and current. The power factor of a balanced poly phase circuit is the same as that of any phase. The power factor of an unbalanced poly phase circuit is not uniquely defined. A direct reading power factor meter can be made with a moving coil meter of the electro dynamic type, carrying two perpendicular coils on the moving part of the instrument. An oscilloscope with current and waveform probes can be used to gauge the phase shift but only if the voltage and current wave-shapes are reasonably similar. Another electromechanical instrument is the polarized-vane type. This type of instrument can be made to register for currents in both directions, giving a four-quadrant display of power factor or phase angle.

The above discussed methods are accurate only if voltage and current are sinusoidal; loads such as rectifiers distort the waveforms from the sinusoidal shape. Simple multimeters will usually misread to some extent when presented with distorted waveforms; a good digital multimeter may make a good effort at reporting the RMS value of even a moderately distorted waveform, but will be challenged to record power factor. In [1] Jill C. Duplessis, discusses the limitations of traditional power factor measurement systems.

Recently new types of digital power analysers are available for measuring real power. In these analysers the instantaneous voltage is multiplied by the instantaneous current and then integrated over some time period to get the average value of real power. The precision power analysers provided by Yokogawa manufacturers is able to provide measurements of real power, apparent power and reactive power with high precision. From these reading it is possible to manually calculate power factor. But for household or consumer electronic purposes these power analysers is not a good option as they are very costly.

In [2] Hiscocks detailed the power factor measurement of linear and non-linear loads by applying FFT algorithms for additional power and harmonic analysis. Haddouk et al. in [3] presents instrumental platform controlled by LabVIEW for the power measurement and electric circuit characterisation. With the advent of new wireless devices, effective power monitoring and remote control of electrical devices was possible as suggested by Chang et al in [4]. The paper presented by Dieme and Badenhorst [5] used a multiplug energy meter with four prioritised AC outlets, control and protection. The system was developed by putting together a multiplug, an energy meter, an overcurrent protection and a data logging systems as one unit.

In [6] a power factor measurement circuit for AC motors was implemented using PIC microcontroller. Here a Hall Effect current sensor, LA 55-P was used in current sensing part of the circuit. But in this paper, the current waveform was assumed to be sinusoidal. In [7] Kuhendran, proposed a power meter using AVR microcontroller. In this power meter shunt resistors were used for current sensing. In [8] M.C. Gonzalez et al. proposed an educational tool for monitoring electrical power components in induction machines by integrating hardware and software elements. This paper presented a computational tool which helps to measure active power, apparent power, reactive power and power factor of induction machines at different frequencies. Here Hall Effect based voltage and current sensors were used and the readings were monitored using LabVIEW. LEM LTS06-NP and LEM LV25-P were the current and voltage sensors used respectively.

III.MEASUREMENT HARDWARE

The proposed system is designed for single phase. To implement a pleasing measurement, the system should acquire the working current and voltage of the load systems very accurately. For that, the components must be selected whose outcome will produce a zero or low minimal voltage drop when dealing with power electronic applications. Hence in the proposed system current sensing is done by Hall Effect current sensors, providing high accuracy, high linearity and minimal voltage drop. The basic hardware structure for this system is shown in figure 1.

All the readings to be measured are sensed and given to the 10 bit ADC of ATmega16 microcontroller. In this measurement system three inputs are given to ADC of the microcontroller. The energy meter is connected between the supply and the load. This meter actually measures the energy consumed by the load. The rated value for the energy meter used here is 3200 imp/KWh. Therefore the LED in the energy meter blinks 3200 times when 1unit of energy is consumed. From this, the energy consumed when the LED blinks once is calculated to be 1125000 Watts ms. To find the actual power consumed by the load the time between two LED blinks of the energy meter is to be measured and this time interval will be given as one of the inputs to the ADC of ATmega-16 microcontroller.

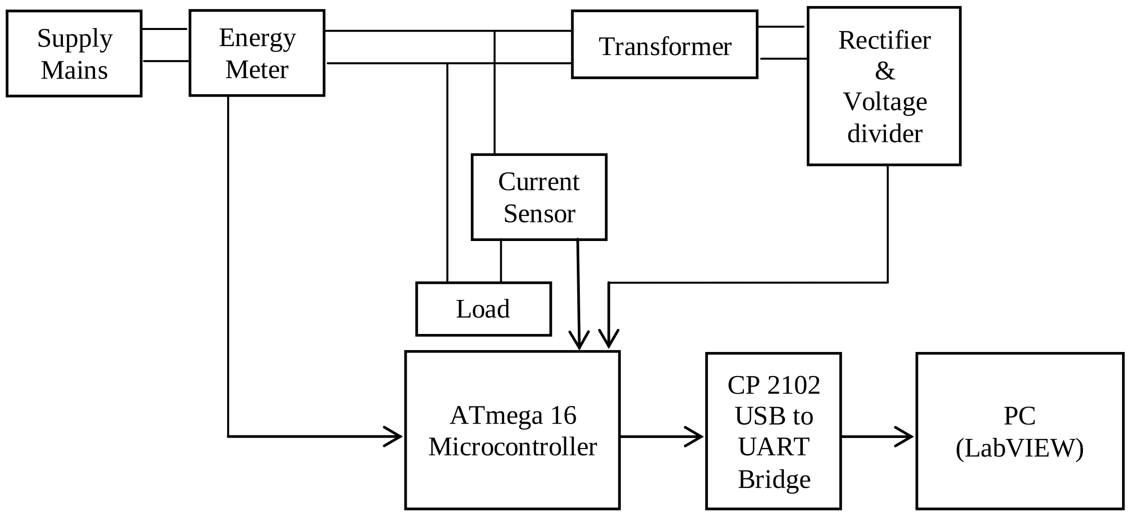

Figure 1: Block diagram of Power factor measurement system

The voltage from the supply mains will be always between 220V-250V. This voltage output is stepped down, rectified and is converted to a voltage value below 5V because voltages above 5V cannot be given as input to microcontroller ADC. This converted voltage output is the second input to ADC of ATmega-16 microcontroller. For current sensing the Hall Effect sensor, ACS 712 was chosen as it was found to be most suitable based on previous analyses. The sensor is connected in series with the load and it gives a voltage value corresponding to the sensed current. This voltage output from the current sensor forms the third input to the ADC. Thus time interval (T), current (C) and voltage (V) are the three ADC inputs.

Program for ATmega16 was written in IAR Embedded workbench for AVR. The hex code is burned to ATmega using AVR Dude GUI burner. The microcontroller is programmed in such a way so as to send characters V, C and T respectively prior to sending the voltage, current and time interval readings to the PC from the transmitter section of the microcontroller.

The voltage, current and time interval readings obtained by the microcontroller, will be then transmitted to PC/laptop using CP 2102 USB to UART Bridge. The microcontroller output can be viewed using LabVIEW software and the necessary conversions and power factor calculation also will be done in LabVIEW.

The components used in the proposed Power factor measurement system are listed below:

- Single phase energy meter.
- 230/9 V Transformer.
- ATMEGA 16 microcontroller.
- Hall Effect Sensor-ACS712.
- CP 2102 USB to UART Bridge.

A. ATmega 16 microcontroller

The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. The ATmega16 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits. The flowchart for ADC initialization and further conversion using the 10-bit ADC of ATmega-16 is given in figure 2.

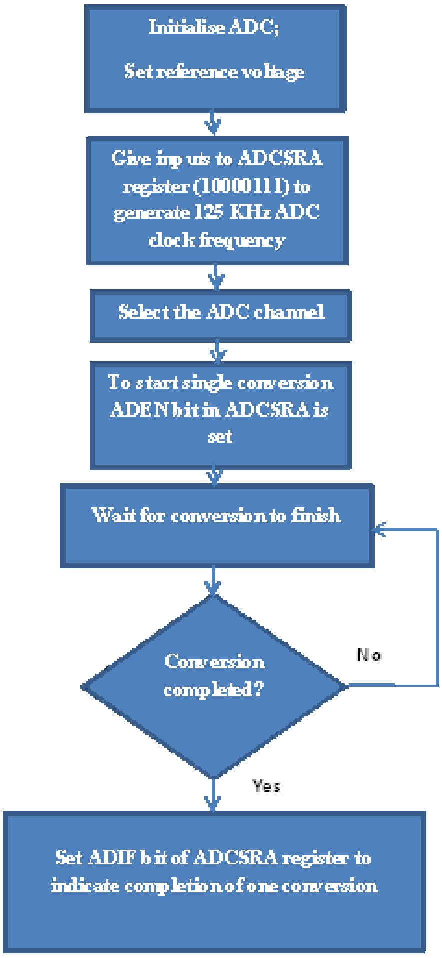

Figure 2 Flowchart for ADC Initialisation and conversion

B. LabVIEW Programming

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphical programming language that uses icons instead of lines of text to create applications. The current, voltage and time interval readings transmitted by the microcontroller will be converted to the corresponding decimal values using LabVIEW. From the energy meter readings, real power can be calculated. The voltage and current readings are multiplied and averaged over 10 samples to obtain apparent power measurement. The ratio of real power to apparent power gives the power factor measurement.

The flowchart for power factor calculation programming in LabVIEW is given in figure 3. The COM port corresponding to the CP2102 USB to UART bridge should be manually selected and given in the VISA select tab of the LabVIEW programme. After selecting the correct serial port the programme is executed. The programme enters the calculation loop when the LED in the energy meter blinks for the first time. The micro controller is programmed in such a way that it sends the data in the format “V:abcC:xyz” continuously, where abc and xyz represents corresponding voltage and current ADC outputs, and whenever LED blinks in the energy meter, corresponding time interval between the two blinks will be send in the format “T:pqrst” where pqrst represents the time interval reading from ADC. The current and voltage ADC readings will be converted to their true values by appropriate calculation. The time interval information between two LED blinks can be used to calculate the real power (P). Average of the product of voltage and current for 10 samples were taken to calculate apparent power (S).

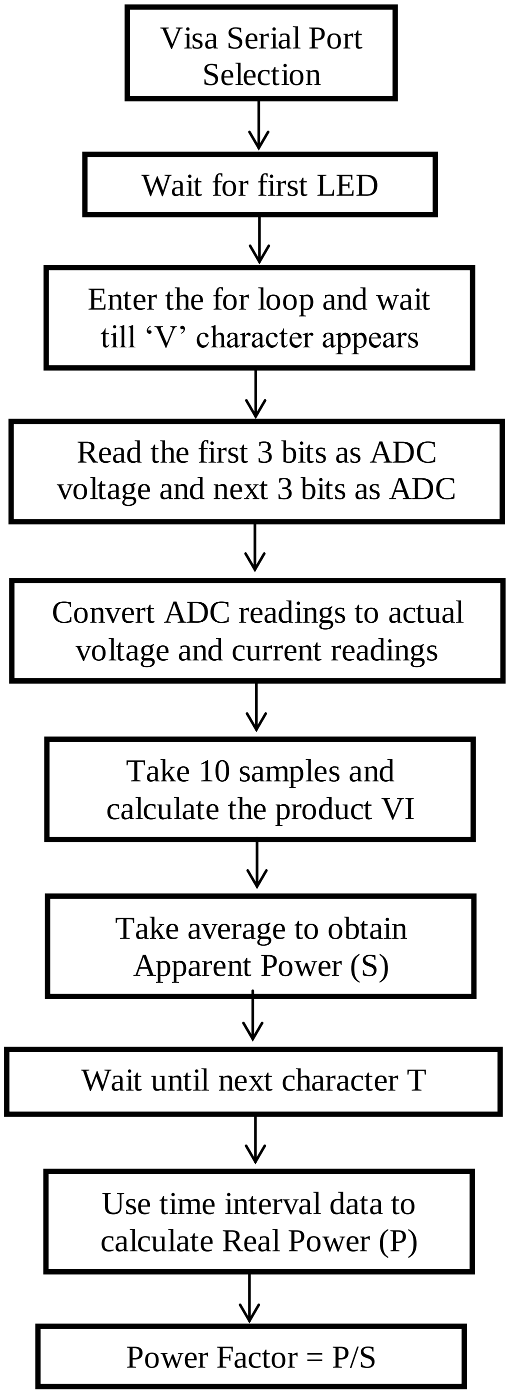

Figure 3 Flowchart for LabVIEW programming

IV. RESULT ANALYSIS

The proposed power factor measurement system was checked for accuracy. This system was used to measure the power factor of few household electrical devices. The actual power factor readings of these devices were obtained using the Yokogawa meter based power factor measurement system available at the Electrical Testing Laboratory, College of Engineering, Trivandrum. The results are tabulated in Table I. From the comparison of these readings it can be seen that the proposed power factor measurement system has error less than 7%. The main advantage of this system is that it is able to automatically compute and display the power factor of the connected load and the system is affordable and cost effective. The system works well for measurement of equipment with power rating between 20W to 1000W. The screenshots of different power factor readings obtained using the proposed system is also shown in the following figures.

TABLE I
COMPARISON OF POWER FACTOR MEASUREMENT RESULTS

Load Connected	**Actual Power Factor**	**Power Factor measured using the proposed system**
Filament Lamp	1.000	0.98
Table Fan	0.6845	0.644001

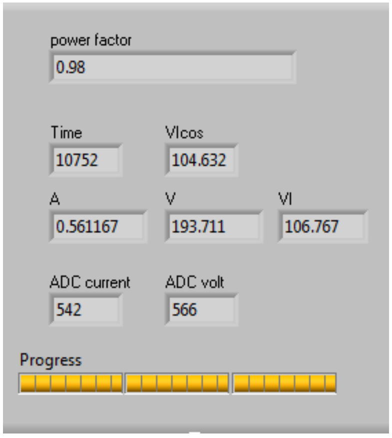

Fig 4: PF of Filament lamp

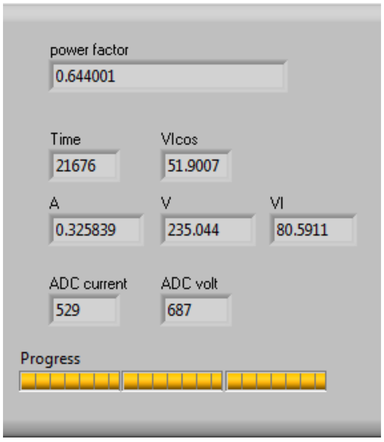

Fig 5: PF of Table fan

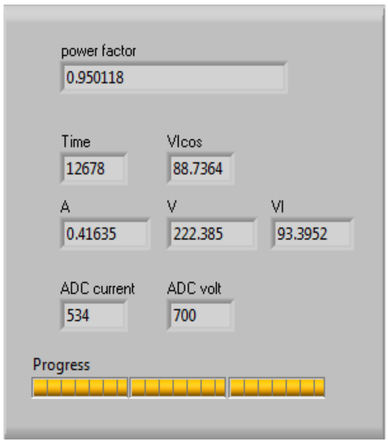

Fig 6: PF of Vaporizer

V. CONCLUSION

An efficient and automated power factor measurement circuit is proposed in this paper. In this system ACS 712 Hall Effect sensor providing good sensitivity and sufficient accuracy was used for current sensing. This sensor is able to accurately track the current readings and thus makes accurate power factor measurements possible for linear or non-linear loads. The system was found to have good accuracy. The proposed system is simple, consumes comparatively less space and is less costly. The drawbacks of this system is that it can measure power factor of appliances consuming power between 20W and 1000W only and this is due to the limited ratings of components used. In future, wireless transceivers and receivers may be connected to the power factor measurement system so that the automated system can predict power factor for a remotely placed electrical appliance and may be modified to generate warnings if power factor goes below a critical value.

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