Smart Socket: A Novel Approach in Regulating Non-Linear Load Using Power Factor Measurement

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Abstract— Power generation and transmission might turn completely smart within a decade owing to the evolution of smart grid. Even the metering and billing are done smartly and we are being charged for our non-linear load usage, since these meters started measuring the reactive powers and the corresponding losses we make. We might end up in a shock on looking the new electrical tariff, though we are going to be billed for the actual power usage. As consumers we must make ourselves up to their smartness to be economical and more importantly being environmental friendly. This project presents a review on cheap digital socket modules which measures the power factor and monitors the non-linearity characteristics of all equipment which we plug-in to the socket.

Index Items – Non-linear loads, digital socket, smart grid, smart socket, power factor measurement, smart home, domestic load management

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1 INTRODUCTION

Next to industrial, the largest electrical consumer on any country, domestic sector consumes electricity more on day-to-day basis of end usage. The primary usage of this sector varies from simple lighting load to complex consumer durables like LED television and doubly digital surround systems. Irrespective of sectors, the efficiency of the system depends purely on the power factor. The power factor can simply be defined as the ratio between the real and the apparent power. The loads of domestic sector generally fall either as inductive or capacitive characteristics. These loads absorb both active and reactive power from the supply. The active power is converted into useful power such as heat, light, magnetic or mechanical energy. But the reactive power is not converted into any useful energy type. The above mentioned load characteristics determines its non-linearity. A poor power factor results in higher non-linearity and hence it is essential to know the power factor to find any equipment's efficiency.

2 BASIC PRINCIPLE OF POWER FACTOR MEASUREMENT
2.1 Power Factor

The ratio of real power P to the magnitude of apparent power S is defined as power factor [1].Real power contributes to actual work through the transfer of energy. A heater, for instance, generates heat purely through real power. Apparent power is a scalar quantity and is the product of the rms current I_{rms} and rms voltage V_{rms}, as given in Equation.1. If load is purely resistive and consumes all transferred energy, its apparent power is equal to its real power. If, however, apparent power is not equal to the real power, there exist energy storage devices, such as capacitors and inductors, storing and releasing energy during the energy conversion process. If such a case, a byproduct is incomplete net energy transfer to the load.

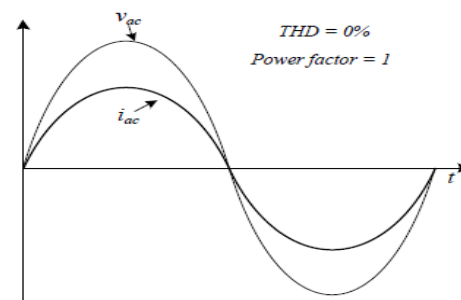$$S = I_{rms} \text{ x } V_{rms} \qquad (1)$$

Fig 1: Ideal Current and Voltage input with unity power factor

Power factor provides a dimensionless measure of useable energy efficiency, with values constrained between one and zero. This relationship is shown in Equation.2. When the sinusoidal source voltage is perfectly in-phase with the sinusoidal source current, as in Figure 1, the power factor is unity.

With unity power factor, the current drawn from the source is minimized and the load appears purely resistive from the input source, thereby enabling maximum power transfer capability.

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

3 CURRENT SENSING

The Current consumed by the load cannot be directly used for measuring power factor since this high current will affect the digital equipment. Hence it must be converted into equalling low level signal and then measured. Various methods of current sensing are listed briefly.

3.1 Hall Effect Sensor

The Hall Effect is an ideal sensing technology; in terms of measurement especially at high frequency [2]. The element in Hall sensor is constructed using a thin sheet of conductor with output connections perpendicular to the direction of flow of current. The element responds with an output voltage proportional to the magnetic field strength while subjecting to a magnetic field. The voltage output is minor (μV) and needs additional electronics to achieve useful voltage levels. Combined with the associated electronics, the Hall element together forms a Hall Effect sensor [2].
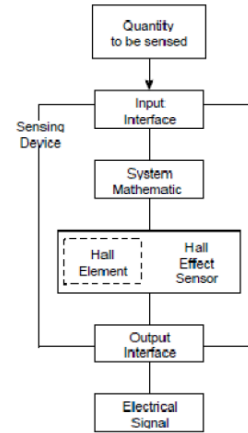

Fig 2: General Block of Hall Effect Sensor

3.2 Current Transformer (CT)

Current Transformers (CT's) are instrument transformers that are utilized to supply a reduced value of current without any change in its frequency to meters, protective relays, and other instruments. Isolation is provided by CT's from the high voltage primary to the low level voltage secondary side. The magnitude of the measured current is stepped down to a value that can be safely handled by the instruments.
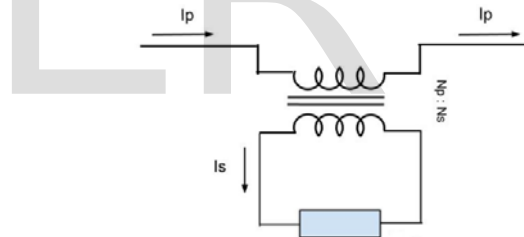

Fig 3: Current Transformer

At present, current sensors (based on CTs) are available as single pack. Here, LA-55P, a current sensor is taken for example. The secondary output of this current sensor is 50 mA, and the conversion rate is 1:1000. LA-55P is shown in Fig.4.
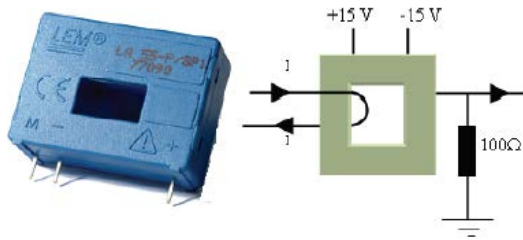
Fig 4: LA-55P Current sensor.

4 VOLTAGE SENSING

Voltage division method or a step down potential transformer can be opted for voltage sensing [2].

4.1 Voltage Division

Voltage Division is the most common way to divide down the line voltage based on Ohm's law. Relationship between input voltage *Vin* and Output voltage *Vout* is as below.
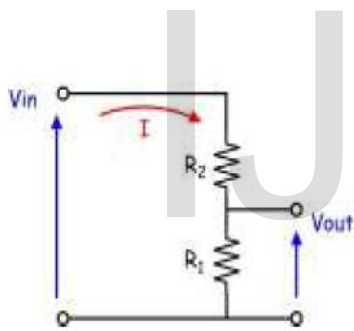

Fig 5: Voltage division method schematic diagram

4.2 Voltage Transformer

Voltage transformers are used to convert higher voltage to lower signals without change in frequency. These signals can be used in relays and any measuring devices. The ideal schematic of Voltage Transformer is given in Fig 5.
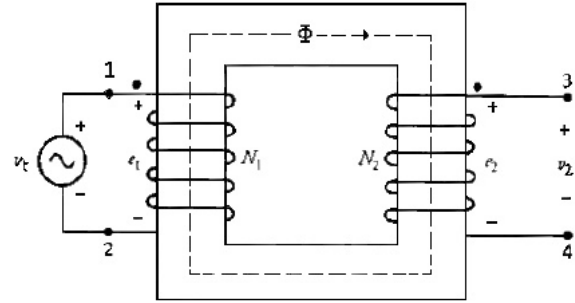

Fig 6: Potential or Voltage Transformer

Based on these voltage transformers, Voltage sensors are available which give safe low output voltage to the measuring instruments. The voltage signal can be adapted using LV-25P voltage sensor of which conversion rate is 220/5 [2]. LV-25P voltage sensor is demonstrated in Fig.7.
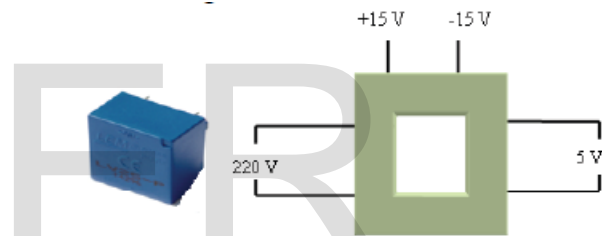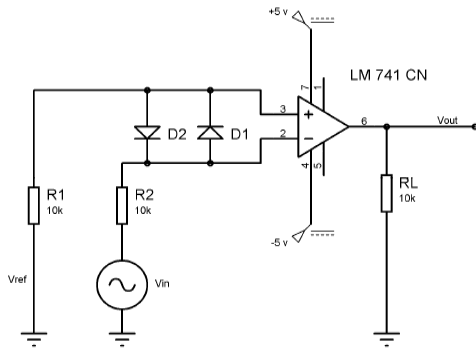

Fig 7: LV-25P Voltage sensor
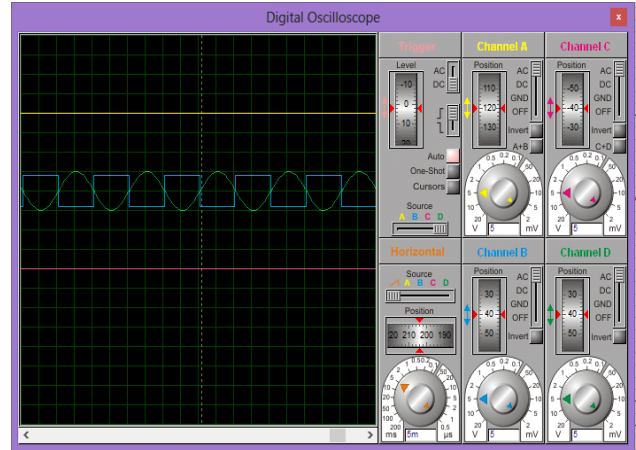
5 ZERO CROSSING DETECTORS

Zero crossing detectors are analog circuits used to detect zero crossing instants of signals. Here both voltage and current signals can be sensed through these zero crossing detectors.

There are several circuits possible which can detect the zero crossing instants of current and voltage signal from current and voltage sensors respectively.

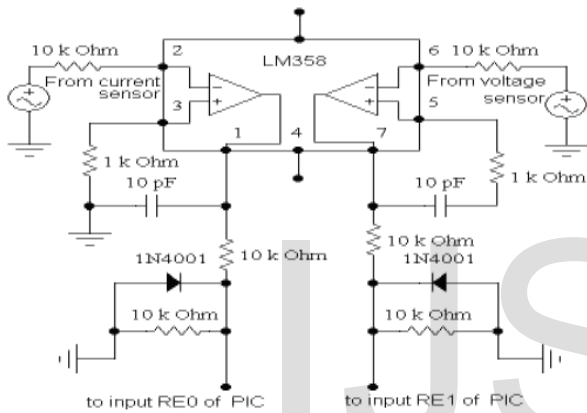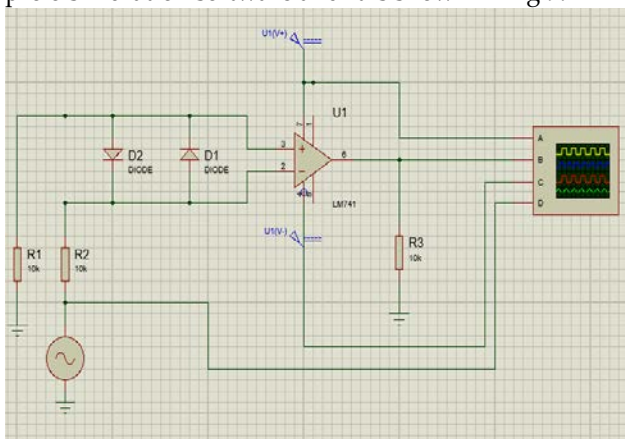Two simpler and efficient circuits are given as follows:

(a)

(b)

Fig 8: Zero crossing detectors using (a) LM741 [2] and (b) LM358 [3].

The circuit in Figure 8 (a) is simulated using proteus pro 8 simulation software and it is shown in Fig 9.

(a)

(b)

Fig 9: Simulated circuit shown in (a) and its outputs are shown in (b).

6 PROPOSED TECHNIQUE

Since the zero crossing instant is found using analog circuits, it is easy to calculate the power factor and the efficiency using micro- controllers. We can use any microcontroller to process these outputs from Zero crossing detectors. Mostly PIC controllers are preferred since they are cheap, easy to configure and program and it has got ICs with in-built ADCs.

Microcontroller through capture module ccp1 (for voltage ZC) and ccp2 (for current ZC), measures the phase delays between the voltage and current square-waves yielded by the zero crossing detectors. The rising edges of the square-waves of both the signals at same time instant are observed by Microcontrollers. The time lag evaluated by the Microcontroller is in terms of power factor of the enduring load.
 Thus power factor of load is evaluated. At last the RMS value of current and voltage signals are read by the Microcontroller.

The low power factor included with current and voltage signals are corrected in the algorithm of the Microcontroller. The instructions of the Microcontroller monitor the behaviour of the running load on the basis of current depleted by the load and the results were shown on LCD.

Figure 10 shows the flow chart of the micro controller module's monitoring of the load. In the flow chart, microcontroller measures the line voltage Vrms

an Irms through ADC pins (AN0 and AN1) on real time basis. The measured voltage and current signals which have been converted into square waves after zero crossing are provided to Microcontroller input pins (any i/o port) that are fundamentally the input of capture module of the Microcontroller. If the zero crossings of voltage and current signals acquired by the Microcontroller are not in phase then it will be shown through the power factor value in the LCD screen.
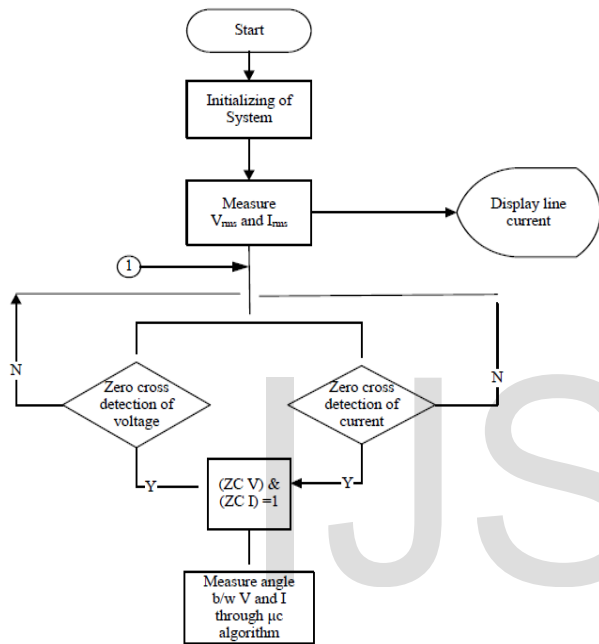

Fig 10: Flow chart of Power Factor Measuring Algorithm

➤ Vrms and Irms are read by the Microcontroller using ADC ports.

➤ The zero crossings of voltage and current signals, which are converted to square-waves, are provided to Microcontroller.

➤ Power Factor is measured by the Microcontroller from manipulating of capture module for V and I signals.

➤ The cos inverse of phi (ϕ) gives us the power factor.

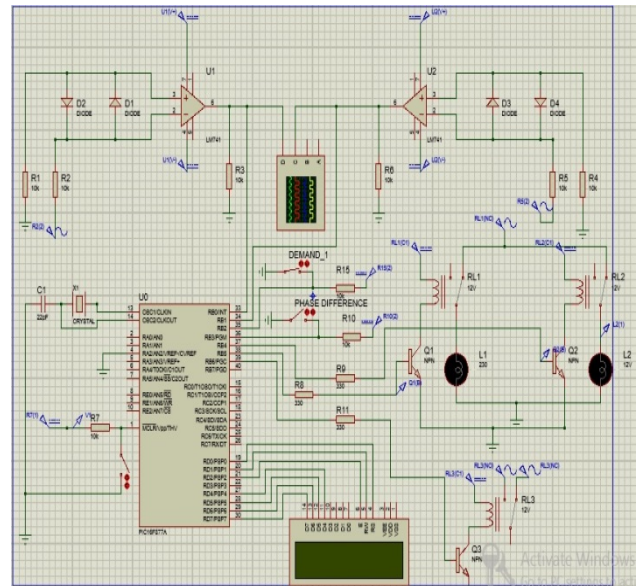The entire proposed circuit is shown in Figure 11.

Fig 11: The proposed Circuit of the Smart Socket.

Now the load can be easily switched on and off by connecting it to micro-controller through relay circuits. When the demand is raised, the controller tries to turn off the most non-linear load and reduces the demand.
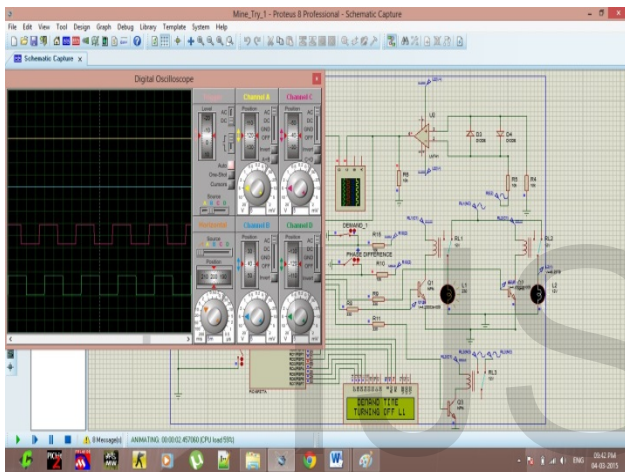
7 SIMULATION AND RESULTS

The proposed system is simulated in proteus pro 8 and the results obtained are shown in the following Figure 12.

In the simulation, when demand time is raised manually by signaling the microcontroller, it checks the power factor. The controller now turns off the load automatically and checks the power factor again. If the power factor is improved the controller sustains the action otherwise the loop will be repeated until load is regulated properly.
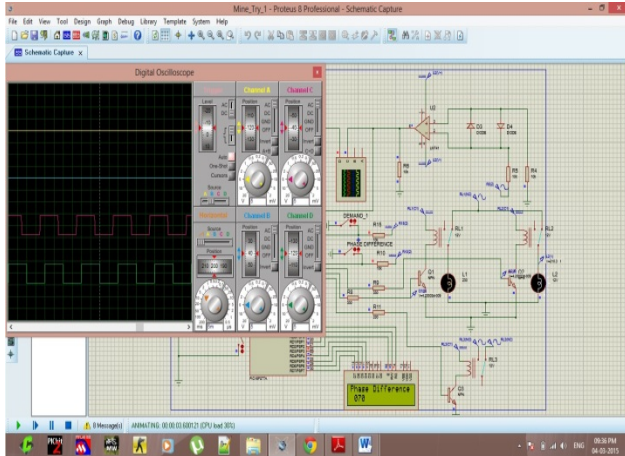
(a)

(b)

Fig 12: Simulated results for proposed circuit
  (a)PF measurement under normal operation
  (b)Load regulation when demand is raised

8 CONCLUSION AND FUTURE ASPECTS

In this study, the cosϕ measurement circuit is designed to display the power factor of the load connected. When this design is printed using PCB technique, it can be used to mount with the socket and the instant power factor of the instrument can be monitored and the user can easily identify the non-linearity of the appliance at one look. Further it can be developed by integrating all the sockets with a central system. This monitoring will be helpful not only in efficient use of appliances but also in identifying the culprit instrument instantly in case of abnormality such that it can be removed from the network automatically avoiding major accident and heavy damage to all other appliances. The designed circuit is further advantageous than the other circuit because the designed circuit can be employed code protection and programme development facility for any future change.

Further the development in smart grid technologies and demand response schemes require the information of smart appliances in order to schedule them automatically according to the demand being raised. The smart socket will provide a single line solution for those requirements.

REFFERENCE

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