Design and Implementation of Economical Power Factor Transducer

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Abstract- **The project consists of study and implementation of a proposed single phase fast response power factor transducer. It eliminates the disadvantages of conventional detectors, which can only measure the power factor of linear, sinusoidal loads. . In the designed circuit, the power factor is measured using PIC16F876. This project focuses to design the simple circuit and low-cost. The current and voltage signals of the load are measured at the same phase. Those signals are inserted into PIC16F876 by means of analog circuit. The power factor is calculated by the algorithm written on the PIC16F876. The measurement value of the power factor is displayed on the LCD screen. This power factor transducer also provides the information about the nature of the load. This transducer has a fast time response of one cycle of supply frequency. Also this transducer also has advantage of low cost over the conventional detectors.**

Keywords-* *power factor detector, Hall Effect sensor, PIC, Hardware, Optocoupler

I. INTRODUCTION

In general power is the capacity to do work. In electrical domain, electrical power is the amount of electrical energy that can be transferred to some other form (heat, light etc) per unit time. Mathematically it is the product of voltage drop across the element and current flowing through it. [3]

The power factor is defined as the cosine of the angle between the voltage and the current. It is an instantaneous value. Further the above is true only if both the signals, i.e. voltage and current are sinusoidal. In India, most of the load become non-linear when operated at voltages above the rated value. Additionally, all discharge lamps such as fluorescent tubes, sodium and mercury lamps, thyristor control devices, reconditioned motors, normal motors working at low loads, induction and arc furnaces, saturated reactors and weld-in loads are inherently non-linear loads. Non-linearity cause's harmonics and improvement of the power factor becomes a difficult task in the presence of harmonics. [1]

There are no methods available to measure power factor directly and substations use phase angle meters to measure the phase angle between v and I and with a power factor representing scale to display the power factor. Such meters are accurate only for sinusoidal balanced polyphase systems. [2]

In an analog electronic circuit based power factor detector, the magnitude of the power factor is detected while nothing has been mentioned about the nature of the power factor. Tutakne et al. proposes a new single phase fast response power factor transducer. In this method the dc output

Voltage proportional to power factor remains linear from almost zero power factor lagging through unity power factor and up to zero power factor leading. The power factor meter under consideration is developed to obtain accurate and fast measurement with a simple circuitry. The transducer has a fast time response of one cycle of supply frequency. The output of this transducer can directly be used in feedback control application for control of power quality and it can also be used for digital display of output. . In the designed circuit, the power factor is measured using PIC16F876. This project focuses to design the simple circuit and low-cost. The current and voltage signals of the load are measured at the same phase. Those signals are inserted into PIC16F876 by means of analog circuit. The voltage signal and current signals are first converted into voltage signals by sensing unit which consists of a Hall Effect sensor and Optocoupler. The power factor is calculated by the algorithm written on the PIC16F876. The measurement value of the power factor is displayed on the LCD screen. This power factor transducer also provides the information about the nature of the load. This transducer has a fast time response of one cycle of supply frequency.

II. EXISTNG METHEDOLOGY

1. Analog Type

General construction of any power factor meter circuit includes two coils pressure coil and current coil. Pressure coil is connected across the circuit while current coil is connected such it can carry circuit current or a definite fraction of current, by measuring the phase difference between the voltage and current the electrical power factor can be calculated on suitable calibrated scale.

In this types of methods since mechanical parts are involved hence accuracy is less and costly and require maintenance. Also due to presence of non-linearity in the load the measured values are not precise.

2. Method EmployedbBy Suppy Authorities

The supply authorities take the cumulative monthly readings of the kWh and kVAh meters. Let the kWh reading be X, the kVAh reading be H, and the kVArh reading be Y(if any). The power factor (taken over a month) is given by

$$PF = \frac{X2 - X1}{H2 - H1}$$

It is generally seen that

$$H2 \neq X^2 + Y^2$$

Thus it can be seen that although the method being straightforward and simple, it generates a considerable error. This in turn adds excess penalty on the consumer.

3. Digital Methods

These methods more or less use the same principle of time measurement. But most of the circuitry used in these methods is complex, costly and requires various compensations. Thus these meters become impractical to use because of cost. Also the line harmonics produce considerable error in these methods.

III. PROPOSED METHOD

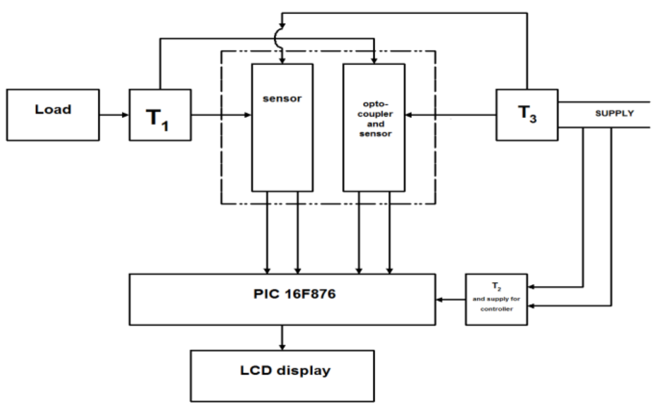

Fig 1:- Proposed block diagram

Where TI, T2 and T3 are step down transformers. The basic block diagram of the proposed power factor meter is as shown in the above figure. As it can be seen from the figure, the load is connected to a step down transformer which steps down the voltage to the level of the electronic circuitry. Voltage from the supply will be fed to microcontroller power circuit by first stepping it down by a transformer. Similarly it is given to sensing block which consists of a sensor and an Optocoupler. Current from the supply is obtained by a Hall Effect sensor configured as a current sensor. Voltage and current from the load are also stepped down and fed to the sensing unit. V & I thus obtained will be given to the interrupts of microcontroller. Here we take the value of count1 and value of count2 then take the ratio of count2 to count1. This will give the ratio between time lag and time period. Now the angle is calculated as-

Angle φ = (count 2/ count 1) * 360.

And then Power factor = cos (angle)

The nature of the load is obtained by calculating the ratio of the time lag and the time of a complete cycle. If this ratio is less than ½ then the power factor is leading. If this ratio is greater than ½ then power factors lagging

IV. CIRCUIT DESIGN AND ANALYSIS

A. Optocoupler:

An Optocoupler is a device, which transfer electrical signals between two isolated circuits using light. It prevents the system receiving the signal from high voltages.

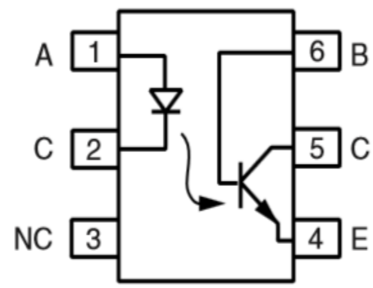

Fig 2:- pin configuration of 4N35

It consists of LED and a phototransistor in the same opaque package. LED convert electrical input signal into light and a phototransistor as a sensor receive that light into electrical signal. Optocoupler or Opt-isolator is a safety component that transfers electrical signals between two isolated circuits by using light signal. Optocoupler are mainly used in delicate system like between sensor and PLC.

An opt-isolator connects input and output sides with a beam of light modulated by input current. It transforms useful input signal into light, sends it across the dielectric channel, captures light on the output side and transforms it back into electric signal.

In the proposed method, the Optocoupler is used for logic ground isolation for microcontroller and step down transformer. It also provides the square wave which is to be given to the interrupts of the microcontroller. The isolation test voltage for this IC is 5 kV RMS. Also it easily interfaces with common logic families. Input-output coupling capacitance < 0.5 pF. Industry standard dual-in-line 6 pin package is available for this IC.

B. Hall Effect sensor

The Hall Effect is an ideal sensing technology. The Hall element is constructed from a thin sheet of conductive material with output connections perpendicular to the direction of current flow. When subjected to a magnetic field, it responds with an output voltage proportional to the magnetic field strength.

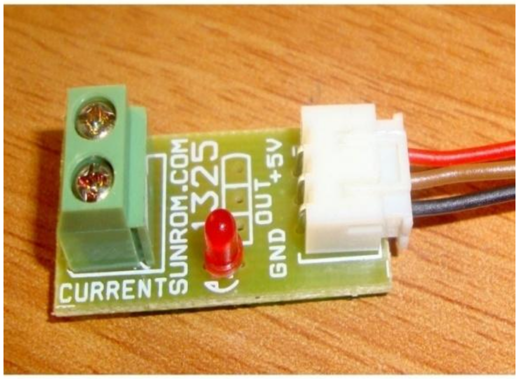

Fig 3:-Hall Effect sensor

The voltage output is very small (μV) and requires additional electronics to achieve useful voltage levels. When the Hall element is combined with the associated electronics, it forms a Hall Effect sensor. [4]
The aforementioned sensor is configured as a current sensor for obtaining the current waveform, which is given to the interrupt of the microcontroller.

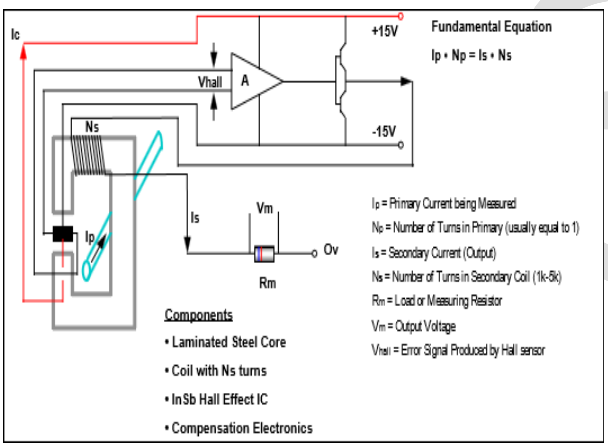

Fig 4:- current sensor using Hall Effect

The primary current being measured (Ip) creates a magnetic flux in the core just as in the open loop linear sensor. The core is made up of thin pieces of steel stacked together to give high frequency response. The Hall Effect sensor in the core gap measures the amount of flux in the core. As with the open loop sensor, the voltage output of the Hall Effect sensor is proportional to the current Ip. The output of the Hall sensor is amplified in the compensation electronics.

C. PIC 16F876 Microcontroller

Microcontrollers are embedded devices having a central processing unit, interrupts, counters, timers, I/O ports, RAM, ROM/EPROM which are used to control other systems [11]. The circuit used in this work operates at 20MHz clock frequency and runs each instruction as fast as 200 ns. The microcontroller used has thre timers, two 8-bit and one 16-bit, which are essential for measurement of time period. This microcontroller has Fully static design, Low power, high speed Flash/ EEPROM technology with a wide operating voltage range (2.0V to 5.5V).

This microcontroller has three I/O ports. Port A (pin 2-7), port B (pin 21-28) and port C (pin 11-18). The pin configuration for mesurement of power factor is as shown in the figure

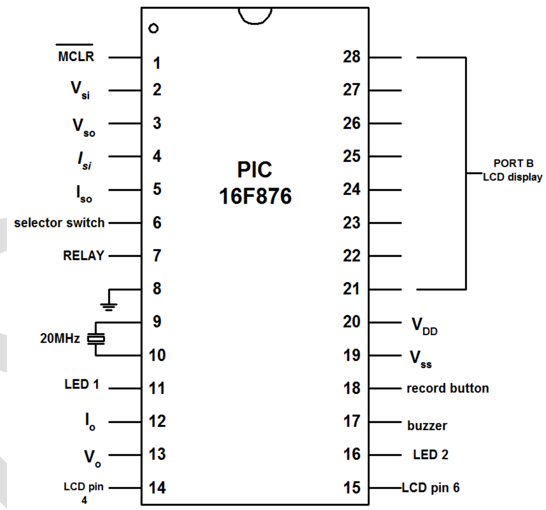

Fig 5:- pin connection for PIC 16F876

V. HARDWARE IMPLEMENTATION

Basically the whole system is divided into 3 parts. One is the power supply, second is the microcontroller PIC and third being the sensing unit consisting of Optocoupler and Hall Effect sensor. First stage is concerned with the step down arrangement of the incoming voltage and current signals into the PIC voltage level (e.g. 5V). Here we have used the step down arrangement of the transformer. The supply is first stepped down and then given to the power supply circuit of the micro controller which consists of a bridge rectifier and a regulator IC 7805 to maintain the voltage level to 5 volts.

Second stage is concerned with zero crossing level detection by using a sensing block for voltage and current, the incoming signals. Voltage signal can be acquired by using Optocoupler (TC 4N25) at the output of Potential Transformer for detection. Current Signal can be acquired by using Current Transformer connected at main AC line. In third stage block diagram represents the automatic power factor measurement with the help of microcontroller PIC. The microcontroller uses a clock of frequency 20MHz. The output of the sensing block is given to the interrupts of the microcontroller which in turn gives the power factor in terms of digital output.

A. Algorithm

Step 1- Switch on the supply for microcontroller
Step 2- Select the load using relay
Step 3- Check for voltage cross zero from negative to positive.
Step 4- Timer T1/count 1 starts (T).
Step 5- Timer T2/count 2 starts (ΔT).
Step 6- Check for current cross zero from negative to positive.
Step 7- Timer ΔT stops.
Step 8- Check again for voltage cross zero from negative to positive.
Step 9- Timer T stops.
Step 10- angle φ = (count 2/ count 1) * 360.
Step 11- Get cos φ from look up table.
Step 12- Tp= ΔT/T
Step 13- If Tp > ½ power factor is lagging
Step 14 – If Tp < ½ power factor is leading
Step 15- Check the value of power factor on LCD display

VI. RESULT AND ANALYSIS

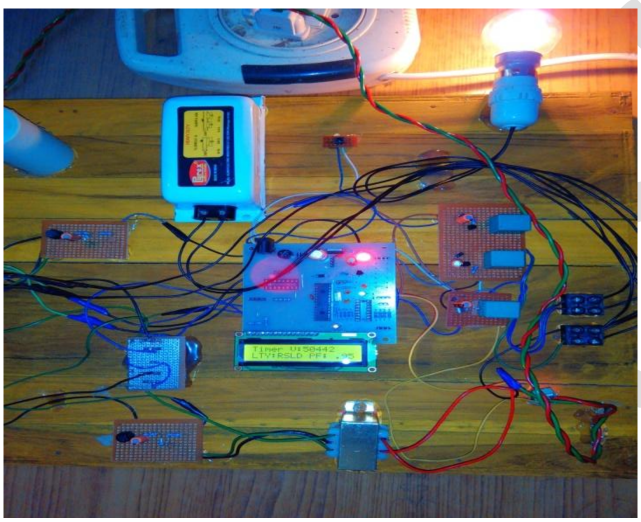

Fig 6:- Hardware implementation of circuit with

A. Resistive Load
B. Inductive Load
C. Capacitive Load

A) With Resistive Load

When resistive load is ON, as shown in Fig. 6-A There is no phase difference between current and voltage signals and they are in phase. In this case the power factor was found out be 0.9, same as analog valueHere as it can be seen from the figure 6-A resistive load (incandescent bulb) has been switched ON with the selector switch of relay
The count was found out to be 50442 with a variation of ± 6 counts.
The power factor denoted on the LCD meter was found to be 0.97 with ±.02 variation.

B) With Inductive Load

For testing of transducer on lagging load, an inductor choke (40W, 0.4A) was used. First the value of the power factor was calculated by using analog power factor meter. The power factor by this method was found to be near to 0.68 lagging with a variation of 0.02 units.
The power factor for the choke was found by using the arrangement as in figure 6-B to be -0.70 with a variation of 0.02. The count obtained was 50399 with variation of ±5. The negative sign indicates that the load is lagging

C) For Capacitive Load

The load used for testing the leading power factor was a capacitor (250V, 30 µF). The power factor of the load was found out to be 0.4 from the power factor meter.
The value of power factor displayed by LCD was +0.37 with a variation of 0.02. The count obtained from the meter was 50339. Even though a condenser was used as a capacitive load, the power factor obtained was not unity as the capacitor used was not pure and had some loss factor. The error which is present while measuring the capacitive power factor is due to distortions in the waveform. Thus the distortions in capacitive waveforms due to alternate charging and discharging of the capacitor has caused a considerable error in measurement
Thus the filtering circuit for the waves needs to be employed.

Thus the observations for different types of loads can be summarised in tabular form as

Sr. No.	Load	Power Factor (By Analog Meter)	Power Factor (By proposed transducer)
1.	No Load	-	-
2.	Resistive Load (Bulb)	0.98	0.97±0.02
3.	R-L Load (Choke)	0.68	-0.7±0.02
4.	Capacitive load	0.4	+.37±0.02

Table 1:- output summary

VII. CONCLUSION

Thus from above three results we can see that the value of power factor is directly proportional to the count of the meter. Also the nature of the power factor is indicated by the + and – sign which indicates leading and lagging power factors respectively. The error which is present while measuring the capacitive power factor is due to distortions in the waveform
But in case of resistive and inductive load the operation of the transducer is satisfactory and the error produced is also negligible.

In this study, the power factor measurement circuit is designed to display the power factor of the load connected the network. The conversion process of difference between the current and voltage signals of the load to degree and time, and calculation process are achieved by PIC16F876 and designed analog-digital integrated circuit. The designed circuit is further advantageous than the other power factor circuit because the designed power factor circuit has a lower cost, fast response and accuracy.

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