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Phase Angle Measurement using PIC Microcontroller with Higher Accuracy

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***Abstract* — The importance of measuring phase angle between two sinusoidal waves of same frequency is useful for control system, robotics, communication, medical instruments, power system etc. The power is single/three phase system cannot be measured without measuring the phase angle between voltage and current using a microcontroller, a boon of very large scale integrated technology. This is a digital method of measuring phase angle and displaying lagging and leading state between the waves on a liquid crystal display. Development of programmes related to this phase angle measurement in high level language, C, converting into hex/binary level and integrated into the flash ROM of microcontroller has been tested in the laboratory.**

***Keywords*— Zero Crossing Detector; Phase Angle; PIC Microcontroller; Flash ROM; Liquid Crystal Display.**

I. INTRODUCTION

A sinusoidal instantaneous voltage wave (V_1) can be expressed as $V_1=V_{max} \sin \omega t$
(i)
$\omega=2\pi f$, f=50Hz

Where V_{max} = maximum/ peak voltage in volts.
ω= angular frequency in rad/sec.

Another sinusoidal voltage (V_2) can be expressed as $V_2=V_{max} (\sin \omega t+ Ø)$
(ii)
Where V_{max} = maximum/ peak voltage in volts.
ω= angular frequency in rad/sec.

The V_2 is lagging, shown in fig. 1(a) and that is leading shown in fig. 1(b).

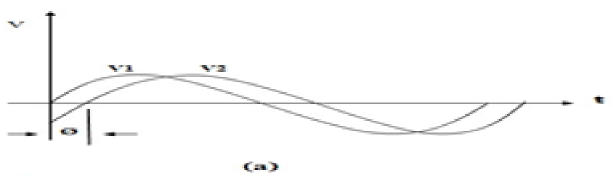

Fig. 1(a) Phase angle between V_1 and V_2; V_2 is lagging V_1 by an angle Ø

Fig. 1(b) Phase angle between V_1 and V_2; V_2 is leading V_1 by an angle Ø

To measure the phase angle digitally between V_1 and V_2, each wave is converted into square wave through Zero Crossing Detector, and then its level is restricted to 5V and passed through an XOR gate. The output of XOR gate will generate the ON period proportional to the phase angle between waves. The ON period is measured by the PIC microcontroller. The state of lagging and leading is detected and displayed on LCD using the software developed.

II. RELATED WORK

In the paper [1] very simple method is used in phase measurement error compensation technique for automation. The paper [2] deals with measurements of phase angle for fault tolerant systems using software methodology. Abdulrahaman K. Al-Ali et.al. [3] worked on microcontroller based phase angle measurement and correcting phase angle using voltage controlled capacitor. In paper [4] Weiguo Que et.al. measured phase angle between voltage and current for polymer insulators. The paper [5] has developed a simple algorithm for 16 bit microcontroller, its performance simulation and presentation of practical results. The paper [6] measured phase angle in electric power systems using the discrete Fourier Transformation algorithm.

An efficient electronic system based on a PIC microcontroller has been developed to measure the phase angle between two sinusoidal waves. The microcontroller through its hardware and software programmes determines the phase angle in degree and also shows lagging and leading with respect to the reference.

The system is also low cost and user friendly. The display system of lagging and leading is an additional attribute.

III. Proposed Work

The frequency sample is collected by a transformer connected to power supply of 50 Hz. and allowed to pass through a Zero Crossing Detector (ZCD), converted into a square wave signal say V_1. The square wave is supplied to a RC Phase Shift circuit for simulating Leading and lagging the signal V_2. Depending on the RC network value, the time duration will change accordingly. This change is actually the phase shift of the V_1 signal which is representing as V_2. Fig.2 (a) shows the reference signal V_1 and V_2 being the leading signal.

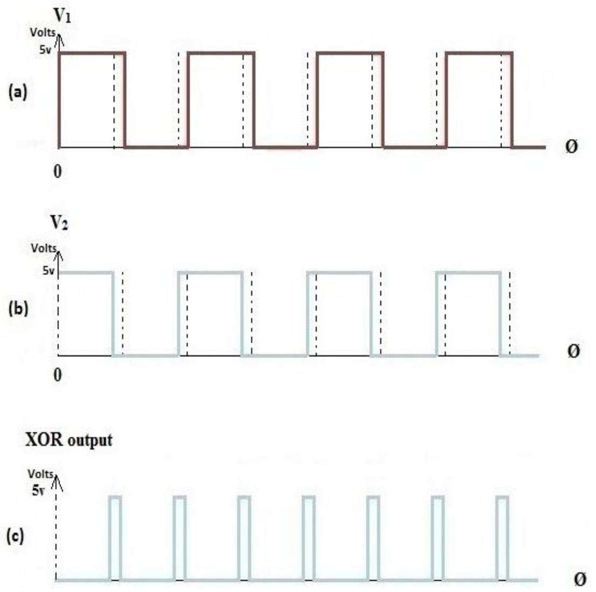

Fig.2 (a): shows the reference signal V_1 and V_2 being the leading signal.

Fig.2 (b): with respect to V_1 after converting it into square wave form of 5 volt.

Fig.2(c): shows the XOR output being the phase difference between the two signals.

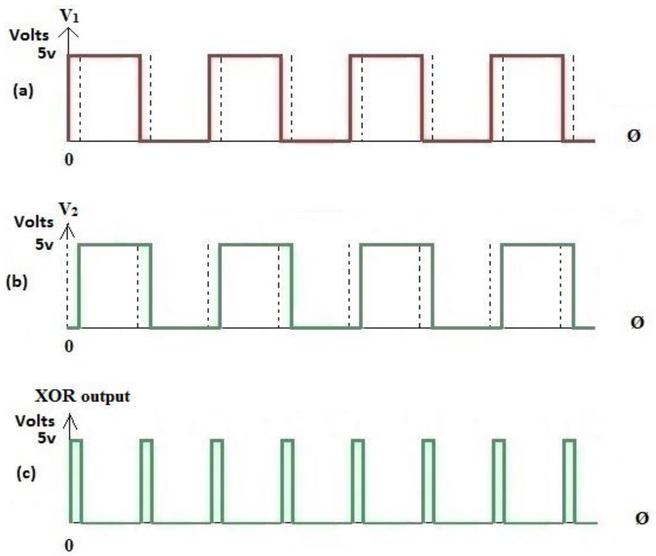

Fig.3 (a), Fig.3 (b) and Fig.3(c) show the case of lagging signals and its phase difference.

The XOR output is fed to bit 4 of port A (PA.4) to distinguish the lagging/ leading of V_2 and to measure the period for which it is lagging or leading. If the output at time t=0 is logical zero, the signal V_2 is leading else lagging. This will help to display lagging or leading condition of the signal.Fig:4 shows the data flow diagram of the system designed.

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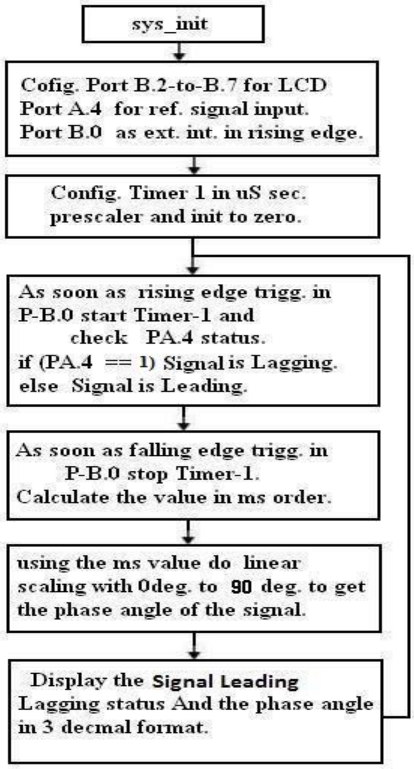

Fig. 4: Data Flow Diagram

A counter initialized is started at the instant XOR output is logic one, incremented by 400 ns pulse and stopped when XOR output is logic zero. The count value incremented multiplied by 400 ns presents the ON time period of XOR output signal. This time period calibrated in terms of phase angle will provide phase difference between the two signals. For a 50 Hz signal, time taken for 90 degree phase difference is 5 milli-seconds. With this reference, the time period measured is calibrated in degrees. The microcontroller will calculate this angle or phase difference and display both degree and leading/lagging condition on 16X2 Liquid Crystal Display (LCD). The overall system overview of the instrument designed is shown in Fig.5.

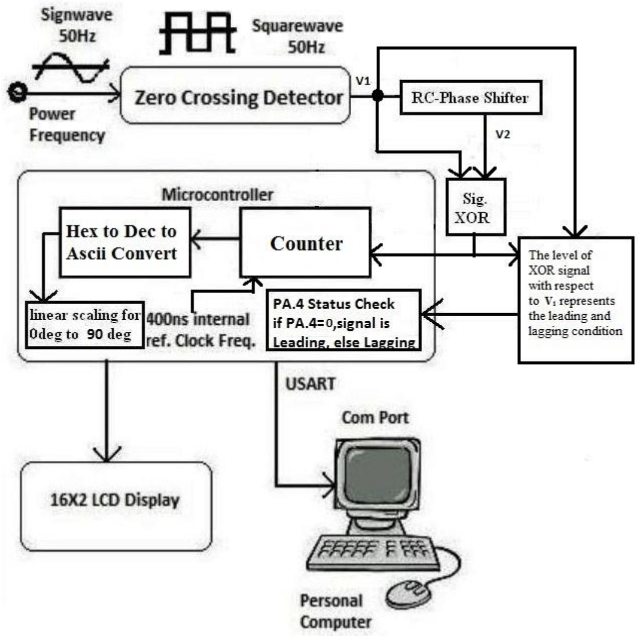

Fig.5: System Overview

In order to display, the decimal value on LCD, the difference count value in hex is converted into decimal value, and then corresponding to each decimal digit is converted into ascii and send it to Liquid Crystal Display (LCD).Fig. 5 shows the block diagram of the controller used for the purpose along with the personal computer connected through universal synchronous asynchronous receiver transmitter (USART) and serial communication port for displaying the result in computer terminal as well.

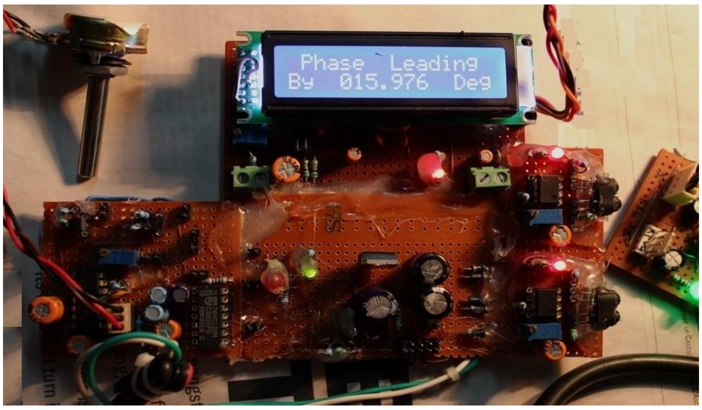

Fig. 6: The setup of Phase Angle measuring system showing the leading phase angle

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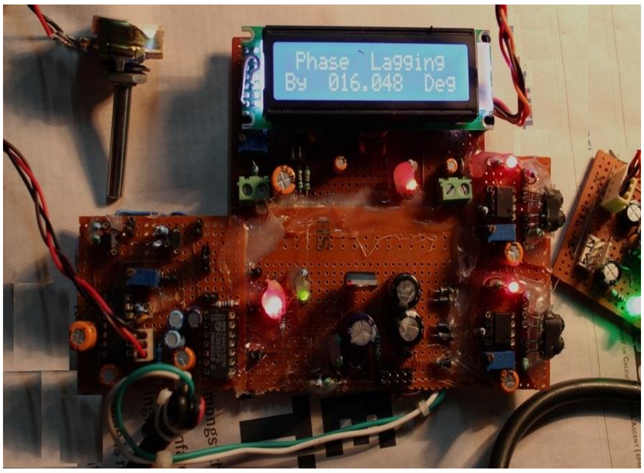

Fig. 7: The setup of Phase Angle measuring system showing the lagging phase angle

IV. RESULTS

Table.1
Results of Phase Angle measurement and Error percentage

R in KΩ	C in µF	Time in Sec.	Simulated Time Delay t=1.1RC(ms)	Degree *Simulated*	Measured Time Delay (ms)	Degree Measured	% Error *(Degree)*
1	0.1	0.00011	0.11	1.98	0.109	1.962	-0.02
4.7	0.1	0.000517	0.517	9.306	0.512	9.216	-0.081
10	0.1	0.0011	1.1	19.8	1.109	19.962	0.1458
14	0.1	0.00154	1.54	27.72	1.525	27.45	-0.243
22	0.1	0.00242	2,42	43.56	2.41	43.38	-0.162
30	0.1	0.0033	3.3	59.4	3.32	59.76	0.324
33	0.1	0.00363	3.63	65.34	3.6	64.8	-0.486
42	0.1	0.00462	4.62	83.16	4.6	82.8	-0.324
43	0.1	0.00473	4.73	85.14	4.7	84.6	-0.486

In order to verify the accuracy level of the instrument, measuring phase angle, the simulated phase angle is measured using our developed instrument and calculated the difference between the measured value and calculated value used for simulation. The result is given in the Table 1. And the percentage error versus phase angle is shown in Fig: 8.

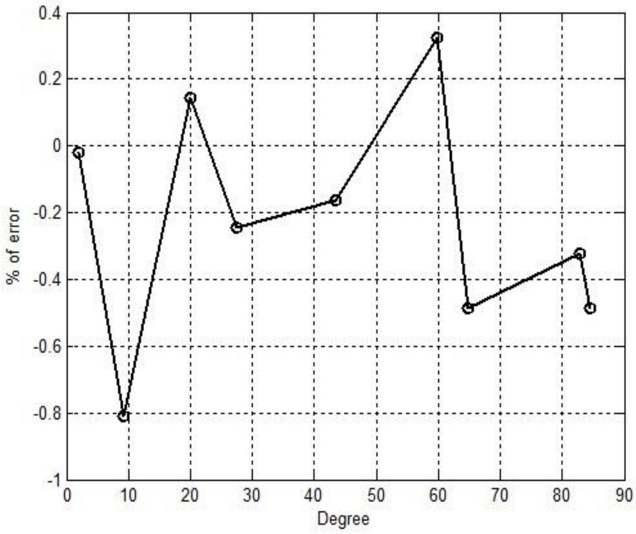

Fig.8: Percentage error versus phase angle graph

It shows that the maximum percentage of error from the graph is -0.8%. The accuracy level belongs to Class 0.5. In the programmer, the 400 ns interval sample pulse is used. The 100 ns interval sample pulse can easily be used. This will definitely improve the accuracy class with this same hardware system.

V. CONCLUSION

The contribution to this field of measurement is the implementation of the concept available using the latest development of programmable devices (PIC microcontroller). The developed microcontroller based advance system has been implemented on a printed circuit board with a microcontroller, LCD display system and some other interfacing components. Its cost is about Rs.2000.00 only, which shows very cost effective and efficient displaying system. This system will be very useful in power system when the phase-angle needs to be measured and monitored.

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