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, $\omega$= angular frequency in rad/sec.

Another sinusoidal voltage (V_2) can be expressed as $V_2 = V_{max} \sin (\omega t + \Phi)$

(ii)

Where $V_{max}$ = maximum/peak voltage in volts, $\omega$= angular frequency in rad/sec.

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

II. RELATED WORK


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.

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.

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

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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).

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

Table 1
Results of Phase Angle measurement and Error percentage

<table>
<thead>
<tr>
<th>R in kΩ</th>
<th>C in µF</th>
<th>Time in Sec.</th>
<th>Simulated Time Delay (ns)</th>
<th>Degree Simulated</th>
<th>Measured Time Delay (ms)</th>
<th>Degree Measured</th>
<th>% Error (Degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1</td>
<td>0.00011</td>
<td>0.11</td>
<td>1.98</td>
<td>0.109</td>
<td>1.962</td>
<td>-0.02</td>
</tr>
<tr>
<td>4.7</td>
<td>0.1</td>
<td>0.00017</td>
<td>0.517</td>
<td>9.306</td>
<td>0.512</td>
<td>9.216</td>
<td>-0.081</td>
</tr>
<tr>
<td>10</td>
<td>0.1</td>
<td>0.0011</td>
<td>1.1</td>
<td>19.8</td>
<td>1.109</td>
<td>19.962</td>
<td>0.1458</td>
</tr>
<tr>
<td>14</td>
<td>0.1</td>
<td>0.00154</td>
<td>1.54</td>
<td>27.72</td>
<td>1.525</td>
<td>27.45</td>
<td>-0.243</td>
</tr>
<tr>
<td>22</td>
<td>0.1</td>
<td>0.00242</td>
<td>2.42</td>
<td>43.56</td>
<td>2.41</td>
<td>43.38</td>
<td>-0.162</td>
</tr>
<tr>
<td>30</td>
<td>0.1</td>
<td>0.0033</td>
<td>3.3</td>
<td>59.4</td>
<td>3.32</td>
<td>59.76</td>
<td>0.324</td>
</tr>
<tr>
<td>33</td>
<td>0.1</td>
<td>0.00363</td>
<td>3.63</td>
<td>65.34</td>
<td>3.6</td>
<td>64.8</td>
<td>-0.486</td>
</tr>
<tr>
<td>42</td>
<td>0.1</td>
<td>0.00462</td>
<td>4.62</td>
<td>83.16</td>
<td>4.6</td>
<td>82.8</td>
<td>-0.243</td>
</tr>
<tr>
<td>43</td>
<td>0.1</td>
<td>0.00473</td>
<td>4.73</td>
<td>85.14</td>
<td>4.7</td>
<td>84.6</td>
<td>-0.486</td>
</tr>
</tbody>
</table>

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

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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