Meter Data to Metrics Testing and Measurement Plan

The main task of our project is to create an intuitive product for our customer, Schneider Electric, which will interpret and analyze power quality data received from smart meters. We chose LabView to tackle this project because of its strong set of data analysis features and ease of use in creating intuitive and user friendly front-end interfaces. Using LabView, we will create a smooth, easy to understand user interface that will display industry accepted power quality metrics based on the data supplied from a smart meter. Specifically, the user interface will display four metrics: total harmonic distortion, individual harmonics, the presence of even harmonics, and voltage sag/swell characteristics both numerically and graphically. Additionally, the program will supply alarms if the power quality falls outside of industry accepted standards. Figure 1 describes a general flowchart for which our project will follow.

![Project flowchart](image)

Figure 1: Project flowchart

Harmonics are produced when non-linear loads are present in the grid, such as motors, fluorescent lighting, computers, and PLC’s. Harmonics distort the current and voltage waveforms, which when introduced back into the power grid, and can adversely affect capacitors, transformers, and motors present in the grid. Industry Standards are implemented to control the level of these harmonics, to insure a more stable and reliable grid. The Institute of Electrical and Electronics Engineers (IEEE) is one professional association that helps regulate these standards. Testing and design validations of three power quality metrics (individual harmonics, total harmonic distortion, and even harmonics) are to be discussed below.

**Individual Harmonics**

After taking a Fast Fourier Transform (FFT) of a current or voltage waveform, the individual harmonics are able to be extrapolated. These values can then cross referenced with the IEEE Standard 519 (Figure 2) to ensure each harmonic is within regulation. In our design, if any one of these individual harmonics are not within the standard an alarm with set. These alarms will be visible
via a smooth user friendly interface. We will use incremental testing to ensure that our product performs each of the following tasks individually, as well as regression validation to ensure that individual harmonics calculator is working properly with each other metrics calculations. Below is a list of inputs/tests that will be used to determine if our program has the correct output:

1) Use an ideal sine wave as an input. A nonzero output should only be visible at the fundamental frequency, 60 Hz.

2) Use two ideal sine waves with 120 degree shift as an input. A nonzero output should only be visible at the fundamental frequency, 60 Hz, and 2 times the fundamental frequency, 120 Hz.

3) Introduce random noise distortions into the input. These distortions will be based on different probability distributions. The output is then to be compared with hand calculations based on the probability distributions used.

4) Use asymmetric sinusoidal as inputs. Compare the maximum positive half cycle (in time domain) to the maximum negative half cycle (in time domain), and set the necessary alarm.

5) Measure the current drawn from a compact fluorescent light (CFL), and use that data as an input. Compare the output of our program with that of the power quality meter in the Engines and Energy Conversion Laboratory (EECL) at CSU.

### Maximum Harmonic Current Distortion

<table>
<thead>
<tr>
<th>Isc/load</th>
<th>&lt;11</th>
<th>11≤h&lt;17</th>
<th>17≤h&lt;23</th>
<th>23≤h&lt;35</th>
<th>35≤h TDD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>4</td>
<td>2.0</td>
<td>1.5</td>
<td>0.6</td>
<td>0.3 5%</td>
</tr>
<tr>
<td>20&lt;50</td>
<td>7</td>
<td>3.5</td>
<td>2.5</td>
<td>1.0</td>
<td>0.5 8%</td>
</tr>
<tr>
<td>50&lt;100</td>
<td>10</td>
<td>4.5</td>
<td>4.0</td>
<td>1.5</td>
<td>0.7 12%</td>
</tr>
<tr>
<td>100&lt;1,000</td>
<td>12</td>
<td>5.5</td>
<td>5.0</td>
<td>2.0</td>
<td>1.0 15%</td>
</tr>
<tr>
<td>&gt;1,000</td>
<td>15</td>
<td>7.0</td>
<td>6.0</td>
<td>2.5</td>
<td>1.4 20%</td>
</tr>
</tbody>
</table>

Even harmonics are limited to 25% of the odd harmonic limits above.

$\text{Isc} = \text{maximum short circuit current at PCC}$.

$\text{Iload} = \text{maximum demand load current (fundamental frequency component) at PCC}$.

Figure 2: IEEE Standard 519

After successful completion of all these test inputs, our Individual Harmonic Calculator is ready for data use from Schneider Electric.

**Even Harmonic Distortion**
Even harmonics are, in theory, supposed to non-existent and cancel out due to the Fourier Series, but in practice this is not the case. Because the THD calculations are a sum of all the harmonics, the even harmonics still play a role especially when dealing with half-wave rectifiers and arc furnaces. However, even harmonics are subject to a smaller tolerance than the odd harmonics. Individual Even Harmonics are subject to 25% of the odd harmonic tolerance levels in Figure 2. These harmonics will be tested and validated just as the odd harmonics will.

**Total Harmonic Distortion**

The total harmonic distortion (THD) is another power quality metric that is to be calculated. This is a superposition of all the individual (both odd and even) harmonics which is normalized based on the fundamental frequency. The THD or TDD (Total Demand Distortion when looking at the load) can be calculated through the equation in Figure 3. This value is then converted into a percent and then compared to the IEEE Standard 519. This metric will go through the same set of inputs/test as the Individual Harmonic Calculator to ensure that our results are verified with known outputs. After all tests are successful, the Total Harmonic Distortion Calculator is ready for real data from Schneider Electric.

\[
THD = \sqrt{\frac{\sum_{h=1}^{h_{\text{max}}} I_h^2}{I_1}}
\]

Figure 3: Total Harmonic Distortion Formula

**Voltage Sag/Swell**

Voltage sag/swell is when the voltage is reduced/increased from the nominal value for certain durations of time. These magnitudes and durations are again monitored by the IEEE, through the CBEMA curve shown in figure 4. In order to test and validate our instantaneous voltage levels over time, we will go through the same procedure as indicated for the harmonic evaluation. The only difference for this portion is we will test each of the following functions individually before we interconnect all of them.

1) Overall Duration: This function indicates how long a particular voltage or current waveform is being sampled for. This would be based on discrete data points given at a
certain sampling rate.

2) **Max/Min Values:** This function indicates if the voltage is above or below the CBEMA curve and records how long it is.

![CBEMA curve](image)

**Figure 4:** CBEMA curve

After these tests have been performed for each of the inputs/tests listed for the harmonic calculations, we will be ready to interpret data from Schneider Electric and display all of these metrics via a LabView interface.
Group Members: Keaton Andersen, Jeremy Eldridge, Chad Brotherton

Project Leader: Jeremy Eldridge (jre@rams.colostate.edu)

Faculty Adviser: Dr. Siddharth Suryanarayanan

Appendix A: Project Timeline

<table>
<thead>
<tr>
<th>Task</th>
<th>Start</th>
<th>End</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begin preliminary research and deliver project outline rough draft</td>
<td>August 28, 2013</td>
<td>September 11, 2013</td>
<td>Keaton, Jeremy, Chad</td>
</tr>
<tr>
<td>Work on project website</td>
<td>September 12, 2013</td>
<td>September 18, 2013</td>
<td>Jeremy</td>
</tr>
<tr>
<td>Update project outline</td>
<td>September 12, 2013</td>
<td>September 23, 2013</td>
<td>Keaton, Jeremy</td>
</tr>
<tr>
<td>Testing and Measurement plan</td>
<td>October 10, 2013</td>
<td>October 25, 2013</td>
<td>Chad</td>
</tr>
<tr>
<td>Review and update project timeline; assess progress</td>
<td>October 25, 2013</td>
<td>October 26, 2013</td>
<td>Keaton</td>
</tr>
<tr>
<td>Update project website with progress</td>
<td>October 26, 2013</td>
<td>November 1, 2013</td>
<td>Jeremy</td>
</tr>
<tr>
<td>Oral Presentation and Written Report</td>
<td>November 16, 2013</td>
<td>December 7, 2013</td>
<td>Keaton, Jeremy, Chad</td>
</tr>
<tr>
<td>Update timeline for second semester</td>
<td>December 3, 2013</td>
<td>December 9, 2013</td>
<td>Keaton, Jeremy, Chad</td>
</tr>
<tr>
<td>Front-End complete with all Metrics displayed using synthetic data</td>
<td>December 3, 2013</td>
<td>December 6, 2013</td>
<td>Keaton, Jeremy, Chad</td>
</tr>
</tbody>
</table>
Images Used:


http://2.bp.blogspot.com/-ssYvxYBuzjs/TZljsmIxEI/AAAAAAAAAEk/aiSZZ5hwqlg/s400/CBEMA+Curve.jpg