Data-Based Harmonic Source Identification Method

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1- Introduction

A noticeable trend in power systems nowadays is the emergence of harmonic-producing loads that increases the harmonic distortion levels in the system. Nowadays, in any given distribution or sub-transmission systems, there are many harmonic sources with comparable sizes distributed all over the network. In a case that a harmonic distortion problem occurs in the system, identifying customers that causes the problem is highly important for utility companies. ‘Harmonic Source Identification Package’ is based on a novel technique that enables utility companies to quantify the responsibilities of the customers and utility systems. This new technique is verified by extensive simulation studies and applied to the Alberta Power System.

Power system metering devices are increasingly deploying in the power systems. They include PMU/RTU at the transmission level, PQ monitors at the substation level and smart meters at the customer level. These sensor networks are an excellent platform for extracting power system information. Monitored harmonic voltage and currents are statistically analyzed to discover internal cause and effect relationships among them. Those customers that are real cause of the problem can be pinpointed and their responsibility can be quantified. The method is supported by rigorous circuit theory and characterized by extensive simulation analysis. There are two types of classical harmonic source identification problems, namely, Single-Point problem and Multi-Point problem. The proposed method covers both of them and implemented in an easy-to-use software.

2- Software

The method is implemented in software package. Continuous harmonic measurement at suspicious load sites should be collected. The data recorded shall include the fundamental frequency currents of the suspicious loads and harmonic voltage for the studied bus. They shall not be normalized with respect to the fundamental frequency component. Measurement device are installed at each site and measurements are performed simultaneously. By using measurement data, program estimates the harmonic impact of loads.

The harmonic responsibilities of a customer can be analyzed from a single-point approach. The schematic diagram of this approach is shown in Figure 1. In this approach, the responsibility of a customer to the harmonic distortion of its interface point to the system is quantified. Using this approach, a customer can be charged based on the amount of harmonic pollution that injects to the system.

Case Study:

In this case study, the new single-point technique is applied to the data measurement collected at Bow valley ski resorts. Fig. 2 and Fig. 3 shows self-harmonic impact of Sunshine substation using single-point method. As it can be seen the results achieved by the method is roughly close to the exact results.

3- Single-point applications

The harmonic impact of a load can be calculated by the following equation:

\[ HI = \frac{V_{harmonic}}{V_{fundamental}} \]

where \( HI \) is the harmonic impact of the load, \( V_{harmonic} \) is the harmonic voltage of the load, and \( V_{fundamental} \) is the fundamental voltage at the load terminals.

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4- Multi-point applications

Multi-Point problem can be considered as an extension of the single-point problem. It can be explained by an example shown in Figure 4. A harmonic problem is reported in bus X of a power distribution or transmission system. The system is known to contain, for example, three major harmonic-producing customers (A, B, and C). What need to be solved is to determine if these three suspicious loads cause the problem and, if yes, what is the responsibility of each load.

Case Study:

The IEEE 118 Bus test case is studied as a case study. This network represents a portion of the American Electric Power System in the Midwestern US as of December, 1962. The plant is fed from one utility slack bus (Bus 69) and fifty three local power plants (PV buses). Sixty four PQ loads are attached to the system. In our study, nine harmonic loads inject harmonic current to the system. The 5th order harmonic of voltages and currents are studied. In the study, we estimate harmonic impacts of loads to the specific points of the system by the proposed method. Estimated impacts are compared with their exact theoretical counterparts.

Table 1: Exact and PLS estimated harmonic impacts of loads on some selected buses

<table>
<thead>
<tr>
<th>Loads</th>
<th>Bus</th>
<th>7th</th>
<th>11th</th>
<th>13th</th>
<th>15th</th>
<th>17th</th>
<th>19th</th>
<th>21st</th>
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<tr>
<td>Exact</td>
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<td>12.18</td>
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<td>5.86</td>
<td>15.21</td>
<td>4.76</td>
<td>11.37</td>
<td>1.60</td>
<td>6.54</td>
</tr>
<tr>
<td>PLS</td>
<td></td>
<td>12.18</td>
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<tr>
<td>PLS</td>
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<td>10.9</td>
<td>1.73</td>
<td>6.62</td>
</tr>
</tbody>
</table>

Fig. 1: The schematic diagram of single-point problem

Fig. 2: The self-harmonic impact of sunshine substation for 5th harmonic order

Fig. 3: The self-harmonic impact of sunshine substation for 7th harmonic order

Fig. 4: The schematic diagram of multi-point problem

Fig. 5: IEEE 118-bus system

Fig. 6: The 5th order harmonic voltage (pu) in buses in the system

Fig. 7: Fundamental current drawn by PQ loads attached to the buses in the system