Harmonic Analysis – A Tool for Troubleshooting Plant-wide Disturbances.

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Extended Abstract:

Large process plants, such as oil refineries, power plants and pulp mills, are complex integrated systems, containing thousands of measurements, hundreds or thousands of controllers and many recycle streams. This integration of energy and material flow, required for efficiency, means that the smallest upset in the process will quickly propagate throughout the plant. These fluctuations force the plant to operate farther from the economic optimum, and so cause decreased efficiency, lost production and often increased safety concerns. Because of the scale of operation of process plants, a small percentage decrease in productivity has large financial consequences.

It is a non-trivial task to pinpoint the exact cause of such fluctuations. In the most difficult case, the fluctuations are in the form of oscillations. The problem is that oscillations have no defined beginning and end, and so the cause cannot be isolated by standard techniques. Finding the cause of oscillations is a tedious, labour-intensive, often fruitless task. Once the cause or diagnosis is understood, removal of the oscillations is usually straightforward.

Figure 1 shows time trajectories of 20 refinery variables in the left panel, with the corresponding power spectra in the middle panel. An oscillation in the time trajectory shows up as a spike in the power spectrum. From the power spectra of 20 process variables it is clear that several measurements oscillate at a common frequency of 0.06 (17 samples per cycle). The questions that process engineers are routinely faced with is: 1) What is the source of these oscillations? 2) Can it be removed so that the process can be run in a productive and efficient manner?

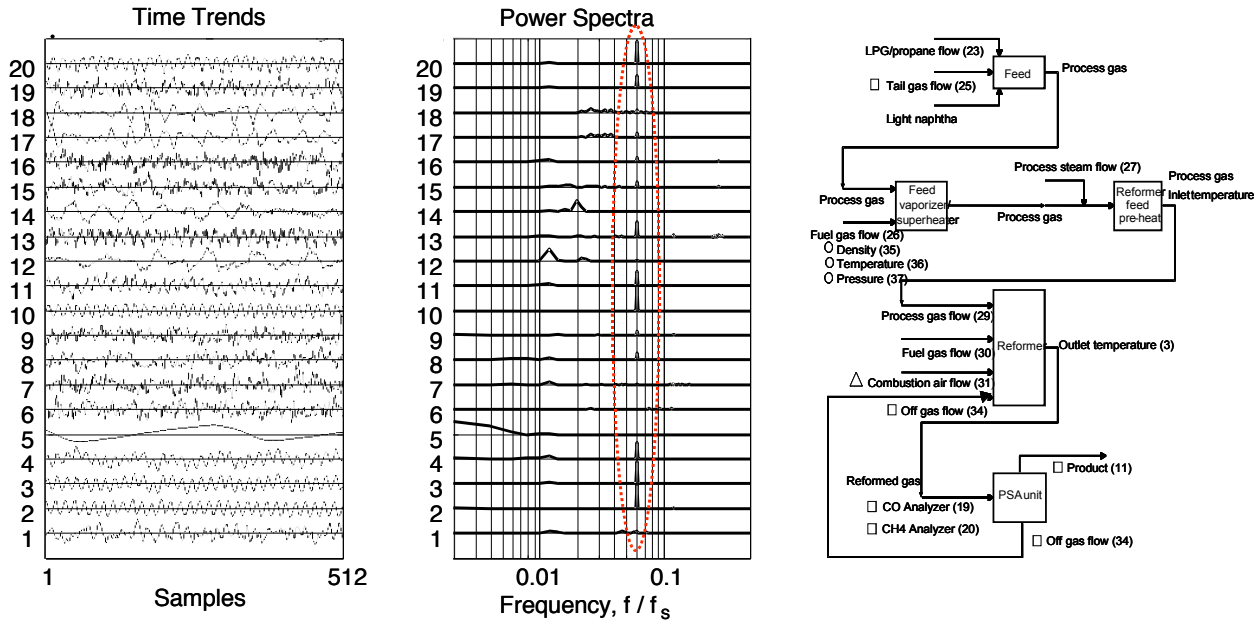

Figure 1: Illustration of plant wide oscillations in an industrial process. Temporal trends (left), Spectral trends (middle), and process schematic (right)

The objective of this presentation is to identify the root cause of such common oscillations in a plant. Once the root cause is known, the offending oscillations can be eliminated, and the process can then be run more efficiently.

Oscillations commonly originate in process plants for reasons such as sensor faults, valve faults, process faults, etc. Many of these faults manifest themselves as nonlinear elements in an otherwise locally linear control loop. Faults in the form of nonlinearity may produce oscillations with a fundamental frequency and corresponding higher order harmonics. Such faults in a control loop of a process unit can easily propagate to the adjacent units due to the material and energy flow paths or the interactions due to the multivariate nature of the process. It is well known that chemical processes are low-pass filters in nature. Therefore, when a fault propagates away from its origin or source, the higher order harmonics generally get filtered out. This presentation will present a method to estimate the amplitudes and phases of the fundamental oscillation and their harmonics and use this information to troubleshoot or pinpoint the root-cause of plantwide or unit-wide oscillations. The successful application of the method will be demonstrated on simulated and industrial data sets.