CHAPTER 14

# Time Series Analysis

The function of a process control system is to produce uniform end products in the face of varying raw materials and operating conditions. Tuning controllers, deals with optimizing the controllers tuning parameters based on the process dynamics, to provide stable robust control. In many cases, the job of the control loop is to minimize the impact of incoming variability on the downstream process and product. That is, for each control loop in the system to provide minimum variance control. If the load disturbances are cyclic, at frequencies near the frequency of the closed loop control system, variance will actually be increased. Achieving minimum variance control, therefore requires not only tuning the controllers, but knowledge about the sources, magnitude, and frequency of the disturbances to the process.

The time series analysis functions, in the Protuner$^{tm}$ software, are powerful tools that can be used as an integral part of a testing program to improve product quality by identifying and reducing process variation. Time series analysis refers to techniques dealing with the analysis of a series of values, collected over time at successive, equally spaced intervals. The analysis functions generated by the time series analysis are summarized in **Table 14.1**. The Protuner$^{tm}$ System Analysis software incorporates both univariate (one variable) and bivariate (two variable) analysis capabilities.

| *Function* | *Number Of Process Variables* | *Domain* | *Information Provided* |
|---|---|---|---|
| **Power-Spectrum** | One | Frequency | • Separates the variation into its frequency components<br>• Characterizes variation as either high or low frequency<br>• Identifies cyclic variation<br>• Evaluation of control loop performance<br>• Information regarding potential improvement from process control |
| **Auto-correlation** | One | Time | • Characterizes variation as either long or short term<br>• Identifies cyclic variation<br>• Evaluation of control loop performance |
| **Cross-correlation** | Two | Time | • Indicates the similarity between two variables |
| **Convo-lution** | Two | Time | • The mirror image of Crosscorrelation |

**Table 14.1 - Time Series Analysis Functions**

# Feedback Controls With Cyclic Disturbances

To help understand the value of the time series analysis functions in achieving minimum variance control, it is important to understand, that a well tuned feedback control loop, can actually increase variability. This may sound like a contradiction, using the term well tuned with increased variability, but the following example will assist you in understanding the concept.

A control loop analysis test was conducted on a control loop to determine the tuning parameters and the ultimate period of the process.

A load disturbance of a constant amplitude at various frequencies was then introduced. The open loop variance and the closed loop variance was then compared at each frequency to determine the effects of the closed loop controller on the variance. Equivalent tests were conducted using the Protuner$^{tm}$ calculated tuning parameters for slow, medium and fast control. **Figure 14.1** illustrates the results of these tests.

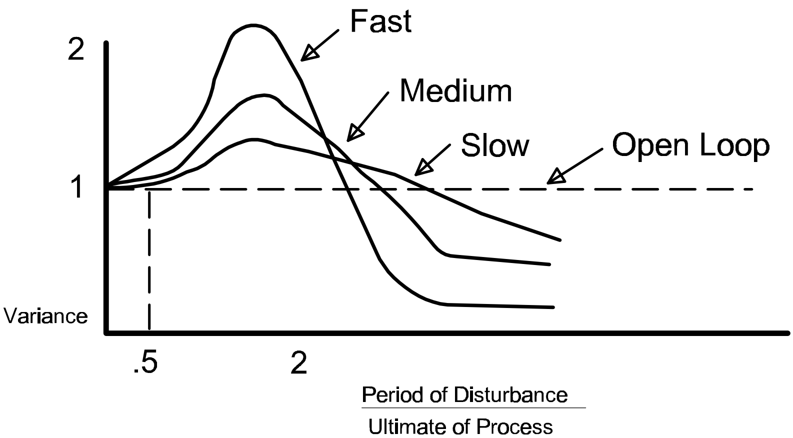


**Figure 14.1 - Closed Loop Variance Attenuation as a Function of the Disturbance Frequency**

As the graph illustrates, when the period of the disturbance is less than .5 times the ultimate period of the process, the controller in closed loop neither amplifies or decreases the variance. Therefore, disturbances with periods less than .5 times the process period, can be considered noise.

**NOTE**

*The controller output will cycle trying to correct the error caused by these fast disturbances, but will have no effect on the magnitude of the measured variance.*

With fast tuning parameters on the controller, disturbances with cyclic periods between 0.5 and 3.5 times the ultimate period of the process are amplified by the control loop. In this example, the variance in closed loop was twice as large as the variance in open loop, when the period of the disturbance variable was between 1.5 and 2 times that of the ultimate period of the process.

Using medium tuning parameters, disturbances with cyclic periods between 0.5 and 4.5 times the ultimate period of the process increased the variance in the controlled variable. The peak being an increase in variance of 1.55 times the open loop variance at a disturbance period of two times the ultimate period of the process. With slow tuning parameters on the controller, disturbances with cyclic periods between 0.5 and 5.5 times the open loop variance were amplified by the control loop. The maximum amplification being 1.3 times the open loop variance.

The graphs illustrate, that the faster the tuning parameters, the greater the amplification of cyclic variances with periods near the ultimate period of the process, but afford greater attenuation of disturbances with longer periods.

In conclusion, load disturbances, measured in an open loop process variable measurement signal, with cyclic periods between 0.5 and 6 times the ultimate period of the process, are likely to be amplified, not reduced, by the control loop in automatic. It is therefore, very important, as part of your control system analysis procedures, to identify such disturbances and to engineer the appropriate solutions to achieve minimum variance control. The following examples illustrate how the Protuner^tm Spectral Analysis functions can be applied to do just that.

## Time Analysis Test Procedure

The first step, in the analysis of cyclic load disturbances, is to perform the Protuner^tm Loop Analysis test to determine the optimum tuning parameters and the ultimate period of the process being controlled.

The second step, is to connect the Protuner^tm to measure the PV and the PD signal of the loop being tested, along with other PV measurements both upstream and downstream of the loop, that maybe a source of the cyclic variation. Place the control loop under test in manual, with the other loops in the control system in automatic, and record the normal control system operation.

## Time Series Analysis Of The Test Data

Window the test data to be analyzed. The time series analysis functions can be run on a maximum of 4096 data points. If the data set you want to analyze exceeds 4096 data points, use the Convert function to create a duplicate file at the appropriate scan rate for the analysis.

The Power Spectrum of the data is used to determine the frequencies associated with the cyclic load disturbance on the measurement. This is done using the *cursor* to determine the peak frequencies on the Power Spectrum plot. If the period of the load disturbance is between .5 and 6 times the loop period, the variance will be greater in closed loop than in manual. If you find this situation, it will be necessary to determine the source of the disturbance and eliminate it at its source.

The Power Spectrum analysis can be run on each of the other measured variables to determine if any of them are cycling at the same frequency as the variable being controlled. The recorded variable, cycling at the same frequencies as the controlled variable, is very likely the source of the disturbance.

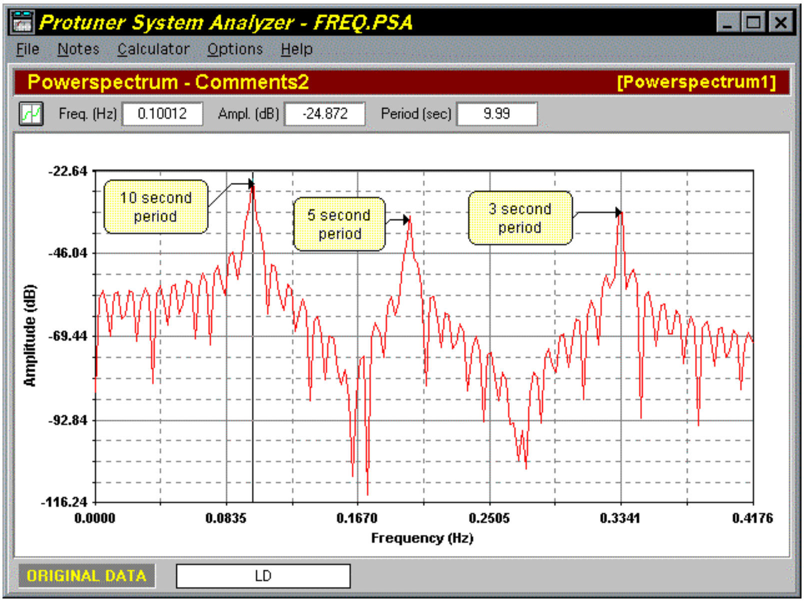


**Figure 14.2 - Power Spectrum**

**Figure 14.2** illustrates the Power Spectrum performed on cyclic data. Use the Window, Zoom and Cursor functions to identify and document the peak frequencies. Use the Comment function to document the peak frequencies found.

If you determine that the cyclic load disturbance contains frequencies that cannot be controlled by the controller, run the Power Spectrum analysis on the other interactive variables to determine which variables are the source of the disturbance.