Benchmark on Adaptive Regulation - Rejection of unknown/time-varying multiple narrow band disturbances

I. Measurements for Performance Analysis

In order to assess the performance of the proposed approaches used in this benchmark, measurement procedures have been defined. These measurements will give information both for *steady state* and *transient* behavior.

A. Measurements for Simple Step test

For step application of the disturbance, measurements for the transient behavior and steady state behavior (tuning capabilities) have been defined. The benchmark protocol for the *Simple Step* test defines the time period for the disturbance application. The disturbance is applied at $t = 5$ seconds, while the entire experiment duration is 30 seconds. In this context, the *transient* behavior will be considered in the first 3 seconds after the disturbance is applied. For measuring the *steady state* behavior the last 3 seconds of the test (before the disturbance is removed), will be used since it is expected that the algorithm has converged at this time.

The measurements considered in the time domain are:

- The *square of the truncated two norm* of the residual force defined by

$$N^2T = \sum_{i=1}^{m} y(i)^2,$$

  where $y(i)$ is a sample of the discrete-time signal to evaluate. This quantity indicates the *energy* contained in the measured signal.
- The *maximum value* measured in millivolts and defined by

$$MV = \max_m |y(i)|.$$

- The *transient duration* (TD) expressed as the ratio (α) between the square of the truncated two norm of the intervals $7 \rightarrow 10$ sec and $17 \rightarrow 20$ sec.

$$\alpha = \frac{N^2T(7:10)}{N^2T(17:20)}.$$

  The idea is take the residual force after 2 sec of the application of the disturbance and compared it with the steady state value, considered in the last three seconds of the test.

The measurements in the frequency domain (steady state behaviour) are:

- *Global Attenuation* (GA) measured in dB and defined by

$$GA = 20\log_{10}\frac{N^2Y_{ol}}{N^2Y_{cl}},$$

  where N^2Y_{ol} and N^2Y_{cl} correspond to the square of the truncated two norm of the measured residual force in open and closed loop, respectively, evaluated during the last 3 seconds of the experiment.

- *Disturbance Attenuation* (*DA*) measured in dB and defined as the minimum value of the difference between the estimated PSD[1] of the residual force in closed loop and in open loop:

$$DA = \min\left(\mathrm{PSD}_{cl} - \mathrm{PSD}_{ol}\right).$$

- *Maximum Amplification* (*MA*) measured in dB, is defined as the maximum value of the difference between the estimated PSD of the residual force in closed and open loop:

$$MA = \max\left(\mathrm{PSD}_{cl} - \mathrm{PSD}_{ol}\right).$$

For all the frequency domain measurements, only the last 3 seconds of the test are considered.

B. Measurements for Step Frequency Changes

For the *Step Frequencies Changes* only time domain measurements were considered. Based on the protocol for this test, a frequency step change occurs every 3 seconds. During this time period the following measurements are considered:

- Square of the truncated two norm of the transient N^2T.
- Maximum value of the transient MV.

C. Chirp Frequency Change

For the *Chirp* Test only time domain measurements were considered. The measurements are:

- Mean Square of the residual force defined as

$$MSE = \frac{1}{m}\sum_{i=1}^{m} y(i)^2 = \frac{1}{m}N^2T,$$

  where m correspond to the number of output samples evaluated.
- Maximum value MV measured in millivolts.

[1]Power Spectral Density. The PSD is calculate using the function: spectre_psd_rms.m, provided in the website.