Exercises for Lecture Course on Modelling and System Identification (MSI)
Albert-Ludwigs-Universität Freiburg – Winter Term 2014

Exercise 10: Frequency response Estimation of a Heating System

(to be returned on Jan. 20., 2015, 8:15 in HS 26, or before in building 102, 1st floor, 'Anbau')

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Please remember to provide a solution on paper (written or typed) including all the necessary graphs from MATLAB. The MATLAB code (.m-files) should be sent to robin.verschueren@gmail.com and giovanni@ampyxpower.com

This exercise and Exercise Sheet 9b of previous week belong together and are dedicated to the modelling and identification of a heating system. This week we estimate the frequency response function of the system.

Exercise Tasks

At the end of this exercise, you will have an Estimated Transfer Function (ETF) of the heating system. A very practical input sequence to identify such a transfer function is a multisine signal. This is a signal composed of sines of different frequencies and phases.

Design of Input Sequence

The input $q_{\mathrm{h}}(t)$ should be periodic with a period N=2880 samples (which corresponds to 2 days). The disturbance$q_{\mathrm{d}}(t)$ should be white Gaussian noise (use the function wgn and set the power to 25).

1. At first, we want to create a periodic input sequence with all possible sines that fit entirely on one period (the 0th, 1st, 2nd, 3rd, ..., 1439th harmonic) with equal amplitudes and phase lag zero. Plot this periodic signal. What is the disadvantage of such a signal for identification purposes? (2 points)
2. Following from the previous point, the signal should be a multisine with constant amplitude in the frequency domain and random phase to avoid large peaks in the time domain. Scale the signal such that its value is contained in the interval $[0,\ 6000]$. To define the periodic part of $q_{\mathrm{h}}(t)$ you can use the following code:

```
% the DFT of q_h is initialized such that it contains N zeros
Q_h = zeros(N, 1);
% the amplitude of the frequency components are set to 1 and the phases
% are set to a random value
Q_h(2:N/2) = exp(i*2*pi*rand(N/2-1,1));
% Q_h is made conjugate symmetric
Q_h(end:-1:N/2+2) = conj(Q_h(2:N/2));
% q_h is defined using the inverse FFT
q_h = ifft(Q_h);
% q_h is rescaled in the interval [0, 6000]
q_h = 3000*(1+q_h/max(abs(q_h)));
% Q_h is updated
Q_h = fft(q_h);
```

(1 point)

Identification of the transfer function

Apply the input designed in question 2 of the previous section, periodically to the system. You should apply as many periods as needed for the transient behavior to disappear. To do this you can consider the following signal

```
y_diff = abs(y(1:(n_periods-1)*N)-y(N+1:end))
```

where y is the output signal resulting from the simulation and n_periods is the number of repetitions of the input signal (see Exercise 9b).

1. Calculate the Estimated Transfer Function using the output data corresponding to the last two days by considering

$$\frac{Y_k}{U_k} = G_k,$$

with Y, U, G the Fourier transforms of output, input and transfer function respectively. In this task you should consider only the input $q_{\mathrm{h}}(t)$. To calculate the ETF compute the DFT of the last part of the signal

```
Y = fft(y((n_periods-1)*N+1:end));
```

and use only the significant part of `Y` (which is `Y(2:N/2-1)`). (3 points)

2. Compare the Estimated Transfer Function with the one obtained from the system `sys(1)` (using `sys(1)` instead of `sys` will neglect the input used to simulate the disturbance $q_{\mathrm{d}}(t)$) . (2 points)

3. Repeat the previous four tasks but using a multisine where the amplitudes in the frequency interval $\left[\frac{800}{\mathtt{t\_s}\cdot\mathtt{N}}, \frac{1200}{\mathtt{t\_s}\cdot\mathtt{N}}\right]$ are 20 times bigger than the amplitudes outside this interval. What can you observe from the plots? (2 point)

This sheet gives in total 10 points.