Experiment 10

Dynamic studies of a nonlinear mechanical system on Simulink.

Background:

We have studied the following system as linearised approximations in Expt #8. The details are presented once again just to complete this problem.

$$[m_L + m_C] \cdot \ddot{x}_1(t) + m_L l \cdot [\ddot{x}_3(t) \cdot \cos x_3(t) - \dot{x}_3^2(t) \cdot \sin x_3(t)] = u(t)$$

$$m_L \cdot [\ddot{x}_1(t) \cdot \cos x_3(t) + l \cdot \ddot{x}_3(t)] = -m_L g \cdot \sin x_3(t)$$

where:

m_C: Mass of trolley; 10 kg.
m_L: Mass of hook and load; the hook is again 10 kg, but the load can be zero to several hundred kg's, but constant for a particular crane operation..
l: Rope length; 1m or higher, but constant for a particular crane operation.
g: Acceleration due to gravity, 9.8 ms^{-2}.

Variables for the problem include:

Input:
u: Force in Newtons, applied to the trolley.

Output:
y: Position of load in metres, $y(t) = x_1(t) + l \cdot \sin x_3(t)$.

States:
x_1: Position of trolley in metres.
x_2: Speed of trolley in m/s.
x_3: Rope angle in rads.
x_4: Angular speed of rope in rad/s

Objective:

Dynamic studies of the given crane trolley system on Simulink, using a detailed nonlinear state space system simulation in four state variables..

Tutorial:

Check out the various function libraries available on Simulink through icon-select menu's, and study their properties.

Further, study the outcomes of Expt #8 very thoroughly, as the same will be useful for the present work.

Project:

By a careful selection of nonlinear simulation blocks, together with judicious patch diagram on the main visual screen of Simulink, create a complete four-state, single output simulation model for the crane.

Check how each parameter can be programmed for individual dynamic studies.

Please note that the simulation evolved should be for the ***complete nonlinear set of equations***, and should not be confused with the linearised studies that we undertook in Expt #8.

For observations and discussions:

Using step, impulse, and ramp inputs for $u(t)$, study the dynamics of the crane from one steady-state to another, using traces of all four state variables as well as the single output variable.

Accordingly, conclude the best input for the nonlinear system to work with.

Repeat the studies for different values of load mass that the crane is lifting. Discuss thoroughly if the load mass makes any difference to system dynamics.

Your discussions should refer to your results from Expt. #8, and as and when useful, may be discussed in view of the earlier studies.

*Make sure your submission includes the **detailed patched block diagram** for the overall system from the Simulink main screen. A brief write-up on the simulation, involving notes and comments, could add credit to your work.*