WP6: Development of the FDI System

(UNAM, LBE, SPES)

November 2003 - November 2004

WP6: Objectives

- **O6.1** To develop an efficient FDI system for biological aerobic batch systems
- **O6.2** To test & validate such a system in simulation using the NL models developed within by WP2
- **O6.3** To integrate the FDS within a higher decision level (supervision system WP7)
- **O6.4** To test the global system at lab-scale in the presence of fault WP1
- **O6.5** To validate the monitoring system with a field-scale pilot plant WP1

WP6: Deliverables

- **D6.1** Diagnosis algorithms for robustly detecting and isolating of a number of sensors, actuators or/and process faults for SBR (T0+27)
- **D6.2** User guide of the FDI system which helps the operator of the reactor to reconfigure the process in abnormal conditions (T0+30)

WP6: Milestones & Expected Results

- **M6.1** Specifications of a diagnosis system for SBR considering practical situations:T0+16
- **M6.2** A set of validated (simulation) FDI routines which guaranty the protection of the biomass in the SBR: T0+16
- **M6.3** Validation of the diagnosis algorithms at field scale pilot plant and tuning of the system before integration: T0+27

Previous Works [11.03 – 04.04]

- Specification of devices and fault cases, M6.1
  - Sensor: Deterioration in the DO membrane
  - Actuator: Flow Valve
  - Process: Reduction in the nitratation capacity. POLIMI
- Proposition of a distribution system for FDI tasks, M6.2
  - Two levels in the diagnosis systems
- Starting the design of FD routines for the DO, M6.2
  - The parameters associated to the diffusion in the membrane is automatic identified

WP6: Activity Report

April 04- November 04

UNAM: C Verde, D Wimberger, J Mina & J Cuellar

Progress towards achieving objectives

- 90% Validation by simulation of the FD algorithm for the DO, D6.1 & M6.2

- 30% Methodology to design the FD for the servo-valve, D6.1 & M6.2

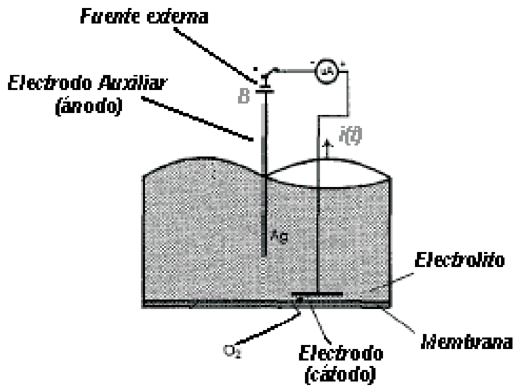
Progress towards achieving objectives

- Process Cases D6.1
  - 100% Analysis of the applicability of EM2a Model for FD task O6.1&O6.2
  - 60% Introduction of a reactor monitoring system using only DO data and specific short cycles for identification M6.2
  - 20% Develop of a descriptive model which can be used for PF tasks O6.1&O6.2

Future Activities

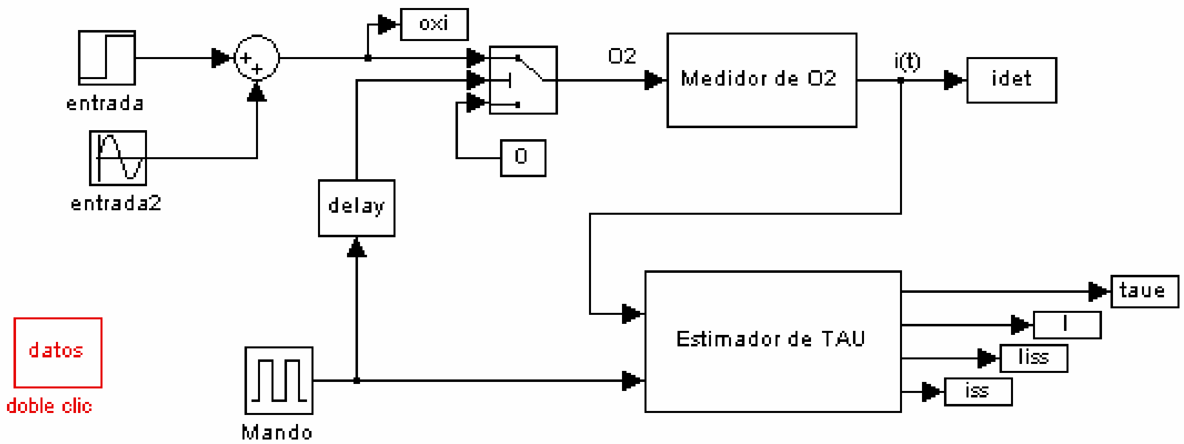
- **D6.1.** Develop of a descriptive model which can be tackled in the framework of FDI task
- **M6.2.** Develop of FDI algorithm for a Valve based on pattern recognition
- **M6.3.** Validation of the whole monitoring system
- **M6.2** a sensor FDI module is under development in conjunction with the extension of the SUS of WP7.

FD algorithm for DO

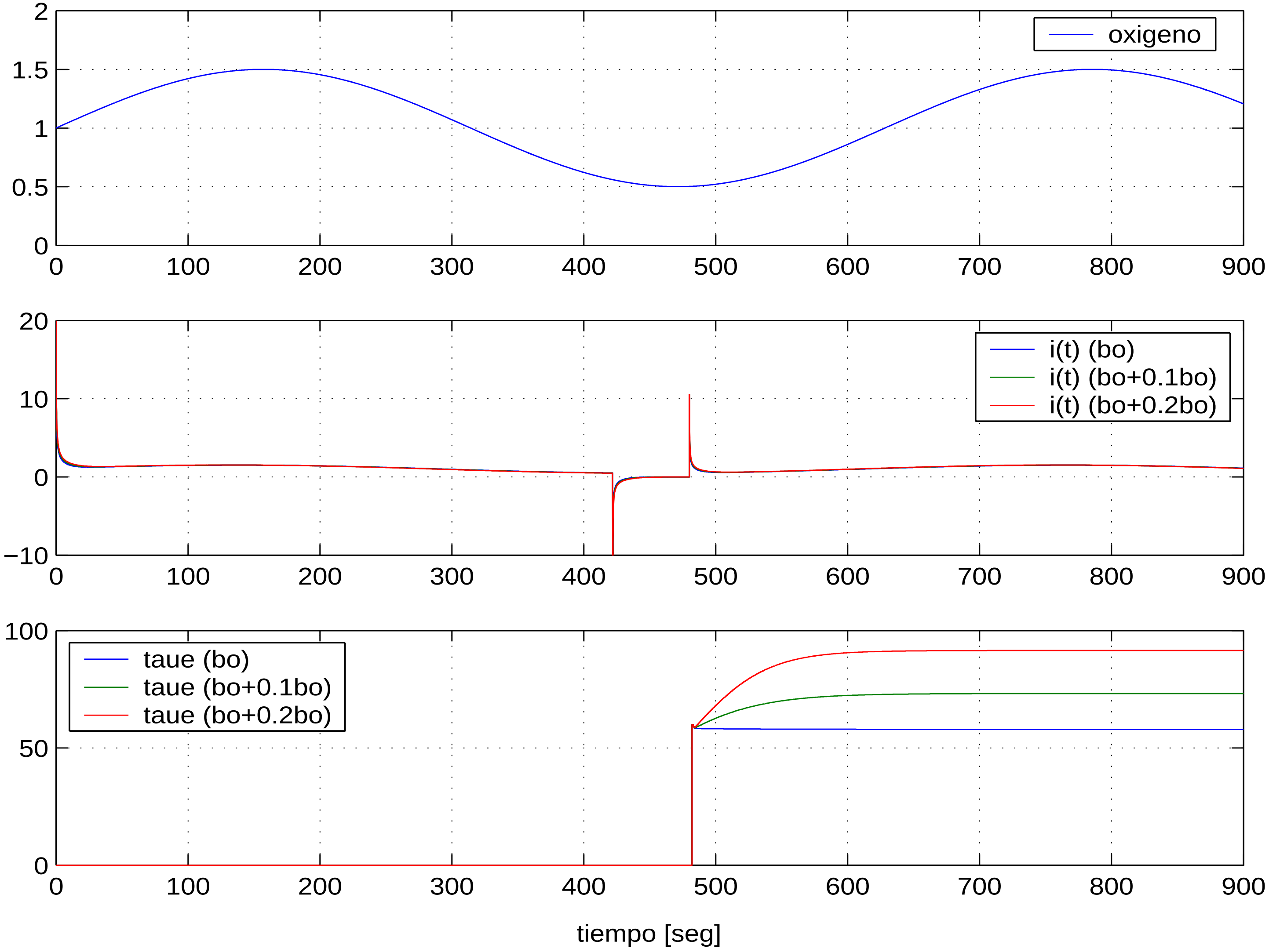


$$i(t) = i_{\infty}\left(1 + 2\sum_{n=1}^{\infty}\exp\left(-\frac{(n\pi)^2 D_m t}{b^2}\right)\right)$$

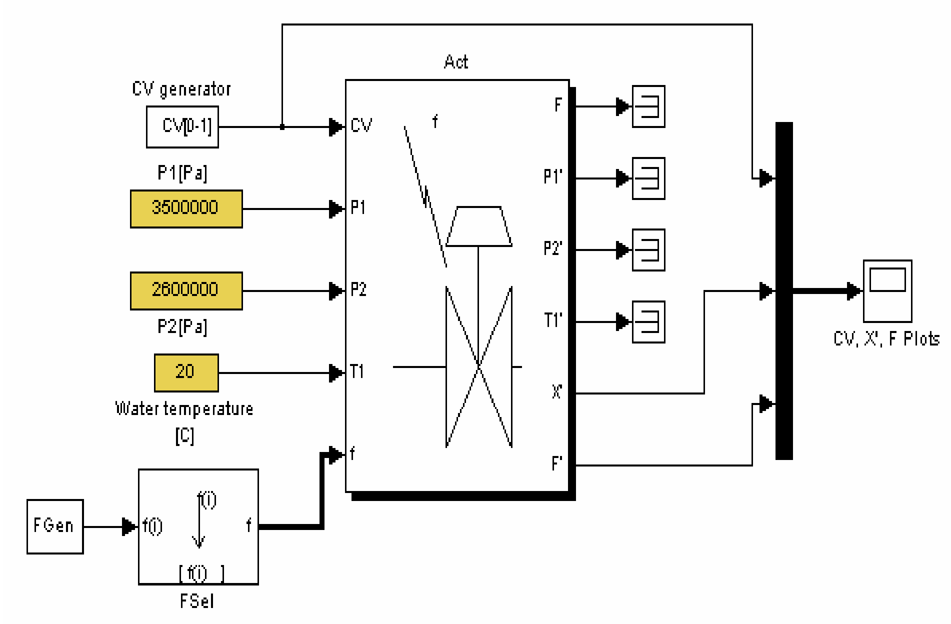
$$D_m = \qquad\qquad b =$$



Detection Results for DO



Valve Model



Simulation Conditions

- **Normal Condition**
- **F1: Valve Clogging**
- **F2: Valve Plug or Seat Sedimentation**
- **F3: Valve Plug or Seat Erosion**

CV: Process Control Value

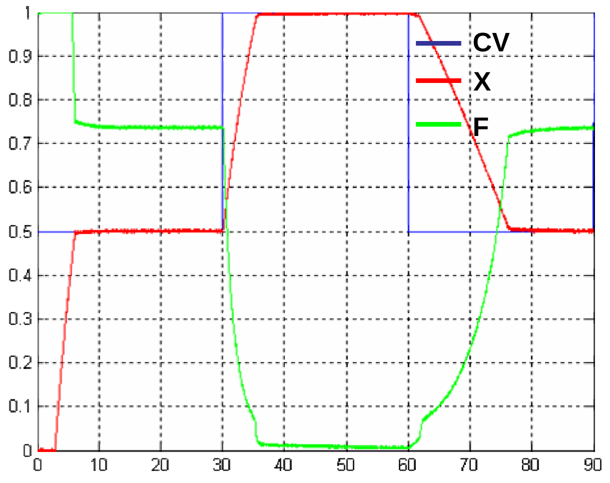
X: Valve Plug Displacement

F: Flow Rate

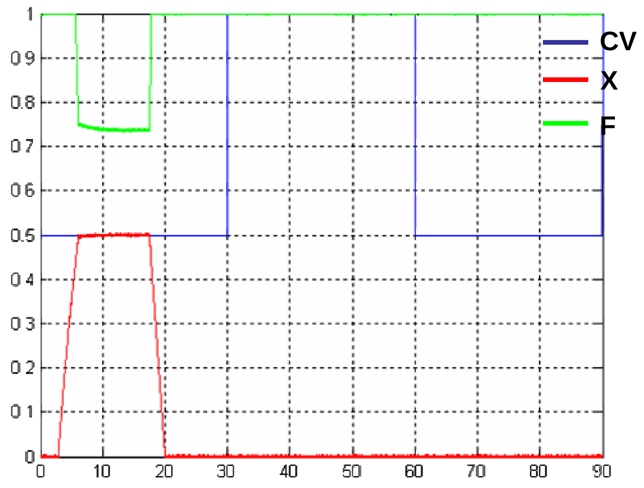
P1, P2: Pressures on Valve: Inlet and Outlet

T1: Medium Temperature

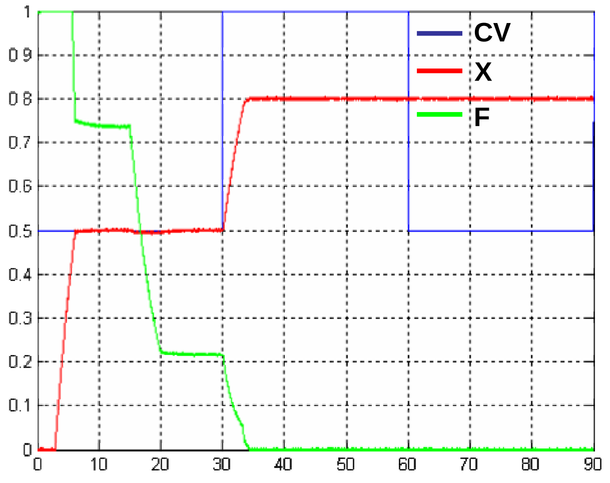
Valve Response



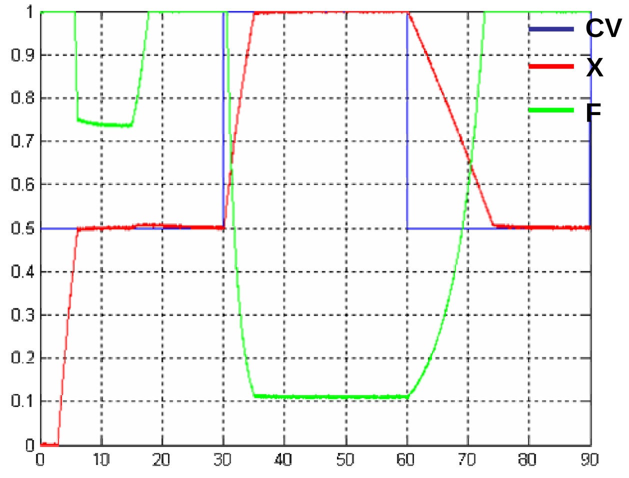
Normal Condition



F1 – Valve Clogging



F2 – Valve Plug or Seat Sedimentation

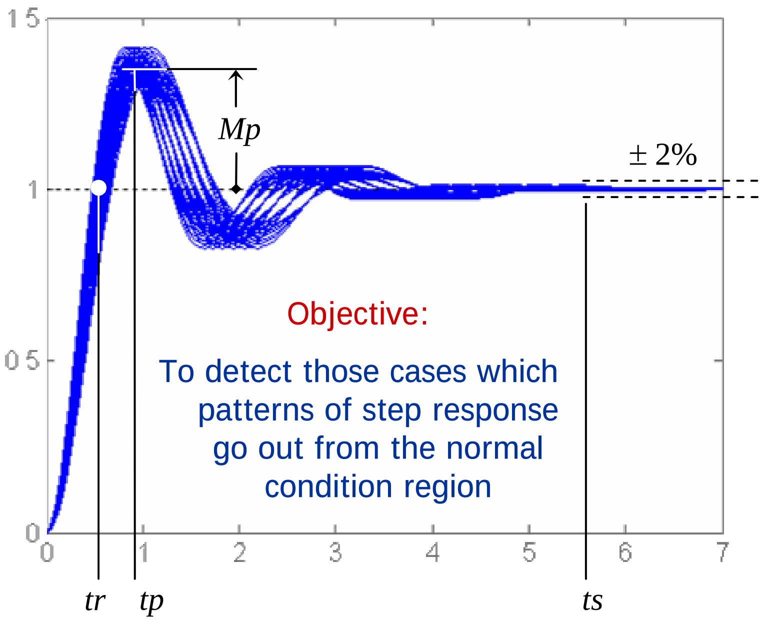


F3 – Valve Plug or Seat Erosion

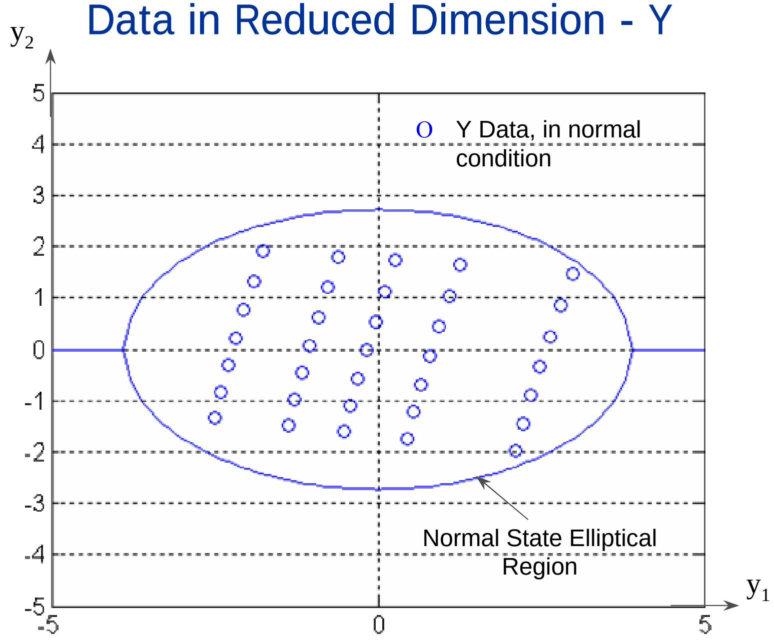
Case of Study: Second Order System

$$\frac{C(s)}{U(s)} = \frac{\omega_n^{\ 2}}{s^2 + 2\zeta\omega_n + \omega_n^{\ 2}} \quad , \quad 0.27 \le \zeta \le 0.33 \quad y \quad 3 \le \omega_n \le 4$$

Normal Behavior of Step Response



Data in Reduced Dimension - Y



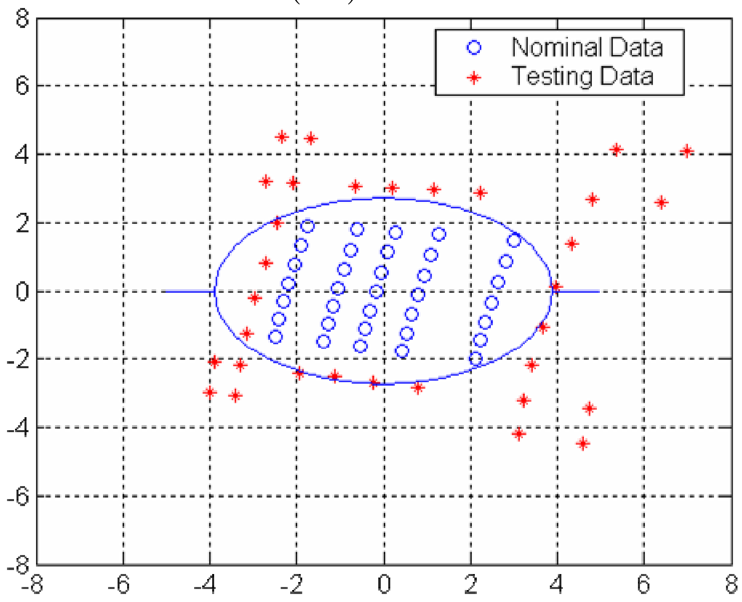
$$X = [tr \quad tp \quad Mp \quad ts]_{(35\times4)}$$

$$Y_{(35\times2)} = \breve{X}V_T$$

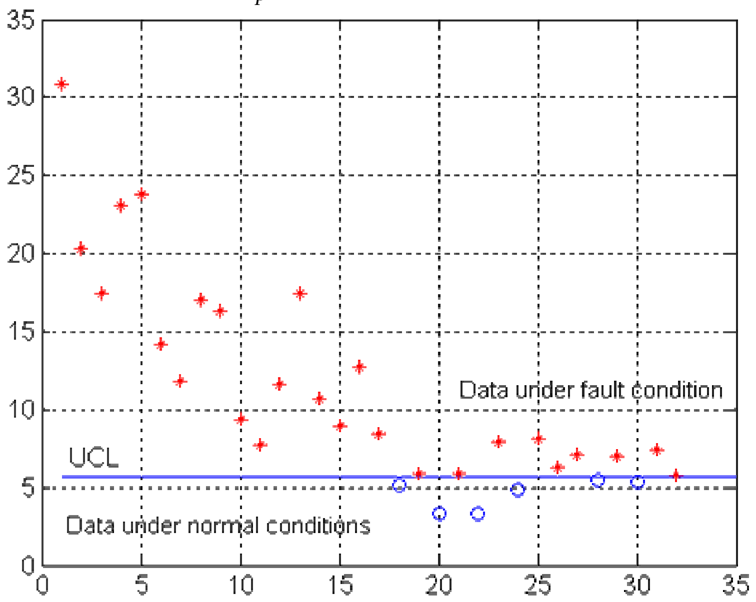
Normal and Fault Region

Testing Data: $X_p = [tr_p \; tp_p \; Mp_p \; ts_p]_{(32x4)}$

$$y_{p(1\times 2)} = \breve{x}_p V_T \qquad T_{y_p}^{\;2} = y_p S_Y^{-1} y_p{}'$$



Nominal and testing data in the k-dimensional plane



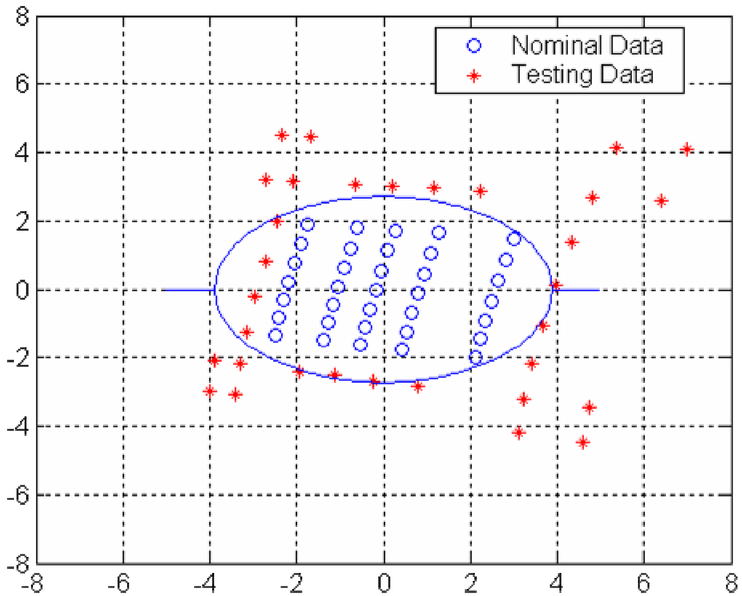
$T_{y_p}^{\;2}$ parameters and UCL limit

$$T_{y_p}^{\;2} = f\left(tr_p, tp_p, Mp_p, ts_p, V_T, S_Y\right)$$

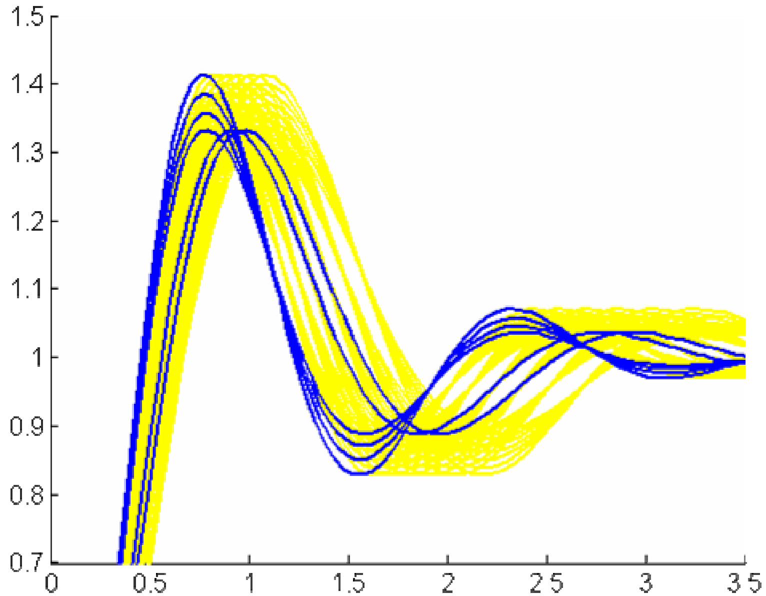
Results

Testing Data: $X_p=[tr_p\ tp_p\ Mp_p\ ts_p]_{(32x4)}$

$$y_{p(1\times 2)} = \breve{x}_p V_T$$



Nominal and testing data in the k-dimensional plane



Step responses of the six cases which are inside the nominal region

EOLI Project

- Given a set of observations: $X_{(n\times m)} = \left[X_1 \quad X_2 \quad \ldots \quad X_m \right]$, PCA expresses the m-variables in a reduced dimension through the transformation, $Y_{(n\times k)} = \breve{X} V_T$; keeping the most of the variability (information) of the original data
- It is possible to make a selection of those variables which are more descriptive of the interest phenomena

From: $$Y_{(j)} = v_{(j)1}\breve{X}_1 + \ldots + v_{(j)m}\breve{X}_m \quad para \quad j = 1,2,\ldots k$$

The *Load Factors* are defined as: $$L_{ji} = v_{ji}\sqrt{\lambda_j} \in [0,1] \quad para \quad i = 1,2,\ldots,m$$

The most influential variables are those with the highest load factors

Objective:

Get a low dimension 'external model' as reference, from measured data, only considering deviations due to common causes