COLLEGE OF ENGINEERING
LAMAR UNIVERSITY

Dr. Daniel H. Chen
Professor, Dan F. Smith Department of Chemical Engineering

Dr. Reza Barzegaran
Assistant Professor, Philip M. Drayer Department of Electrical Engineering

Abnormal Situation Management & Big Data

Objectives

- Early Detection of
  - Sticky or leaky Valves
  - Heat Exchanger Leakage (Cooling Tower HRVOC); Heat Exchanger Fouling
  - Hydrocarbon leaks from Pipelines and Storage Tanks
  - Rotating Equipment Failures (Electric/Magnetic/Acoustic Frequency Signatures)
  - Interacting Control Loops
- Advisory/Alert Info. for plant personnel generated based on proprietary schemes and DCS (Distributed Control System)/Non-intrusive Sensor Data.
- Development of software implementing detection schemes.

Methodology

- Primary Component Analysis (Latent Variables)
  - Use combination of multi-sensor results
  - Identify abnormal operations in 2-D plots
- Design of Experiment
  - To determine data sets to be collected
- Identify Potentially Interesting Outliers

Correlation Coefficient

$$\rho_{x,y} = \frac{Cov(X,Y)}{\sigma_x \cdot \sigma_y}$$

$where:$

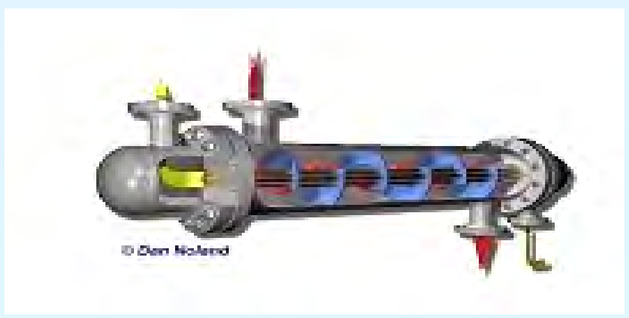
$$-1 \le \rho_{x,y} \le 1$$

$and:$

$$Cov(X,Y) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \mu_x)(y_i - \mu_y)$$

- A 45 degree phase angle between two cyclic time series would result in a correlation coefficient of about ±0.7.
- The correlation coefficient for the PV and OP data used in this example was 0.86.

Heat Exchanger Diagnostics

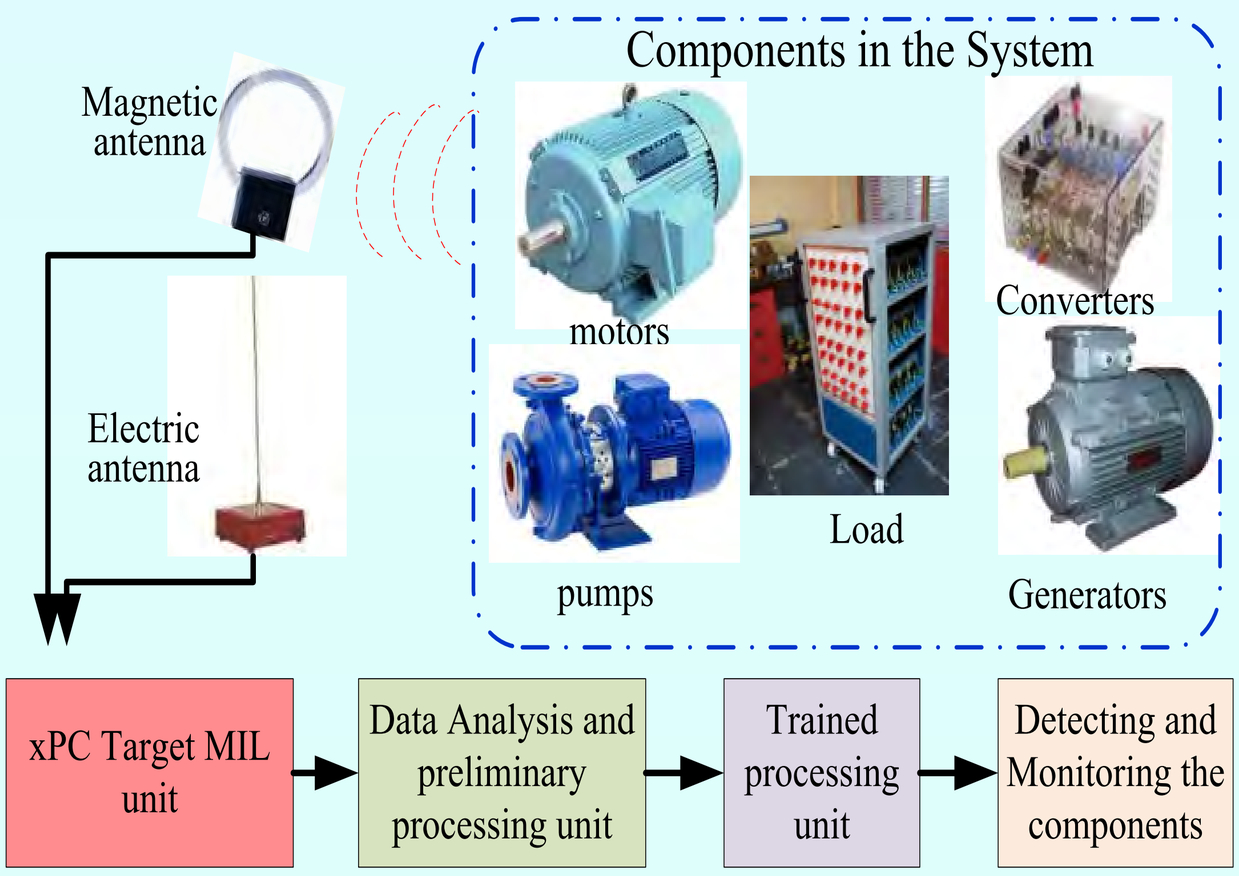


Heat exchangers leaks (externally and between the streams) can be detected through temperature/pressure relation changes and Heat/mass balances [Swan, 2006]

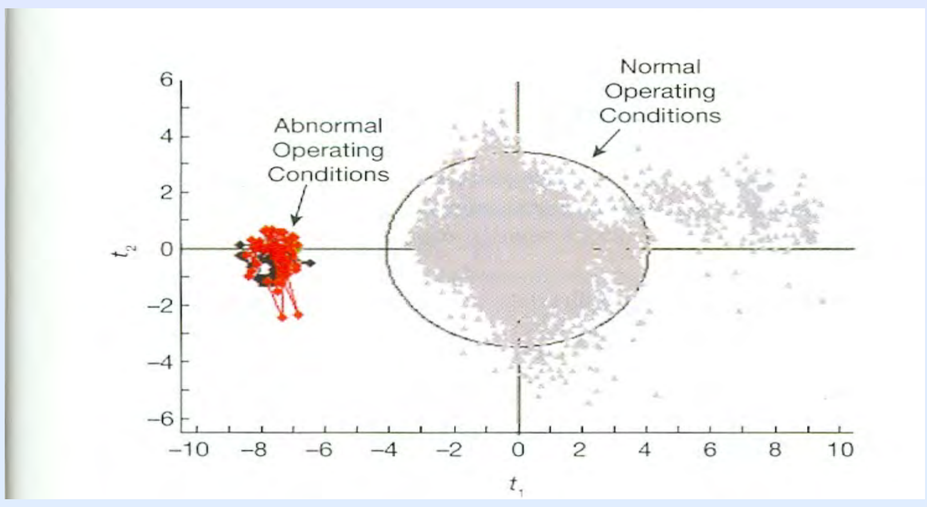
Nonintrusive Control and Condition Monitoring

The recognition is based on nonintrusive signature identification, without human intervention. The harmonic components of the radiated electric and magnetic fields will be measured as the sources of valuable information for signature identification. Then, a processing network is trained to identify the devices from which the harmonics radiated. The overall typical scheme of the studied system with the procedure of the recognition is shown in figure below.

As shown, the components consist of the power converter and typical rotating machines such as DC motor, induction motor and synchronous generator which are preliminary components of a grid



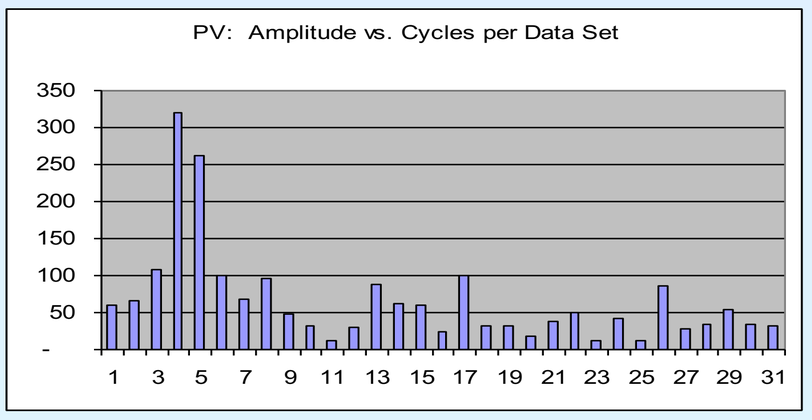
2-D Plot in terms of Latent variables



2-D plot in terms of latent variables reveals abnormal operations [Garcia Mundoz, S. and D. Settell, Computers and Chemical Engineering, 33(12)2106-2110 (2009).]

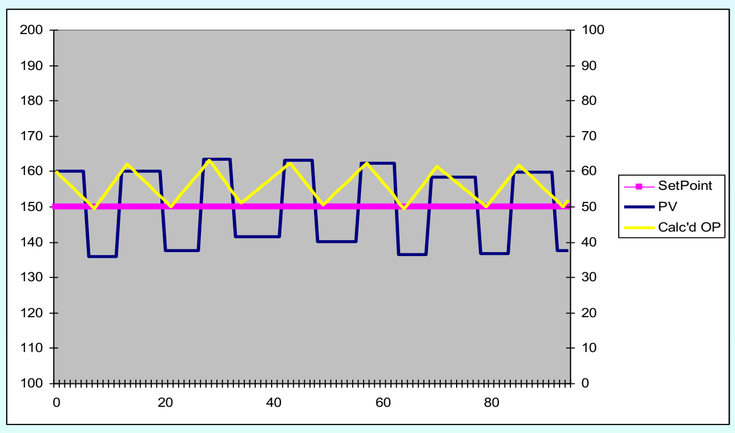
Results

Fourier Analysis of Control Valve Data



- Same Frequency: 4-5 Cycles per Data Set
- Phase Angles of 50 and 55 degrees between Predominant Peaks

Sticky Valve Characteristics



Controller output (CO) and process variable (PV) curves are out of phase and display a saw tooth pattern for sticky control valves [Swan, 2006]

Co-PIs

Xiangchang Li, Peyton Richmond

Students

Dan Fernandes (PhD, Spring 2016), Aniket Khade (Ph.D., Spring 2016), Napoli Rosario (DE, Sp. 2016)

Funding

Lamar Visionary Initiatives, Lamar Distinguished Research Fellow Award

Selected Publications

P. Lo, W. Swan, D. Chen, P. Wetuski, S. Stout, "Detection of Interacting Controllers Using Fast Fourier Transform and Correlation Coefficient," Hydrocarbon Processing, April 2006.
W. Swan, "Selected Topics in Process Diagnostics and Advisories", D. E. Dissertation, Lamar University, Beaumont, TX, 2006.