

# Statistical Techniques for Monitoring Industrial Processes

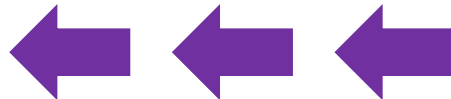


*Lecture* : PLS Modeling of LDPE Reactor

*Module* : PLS-based MSPM

# Course TOC

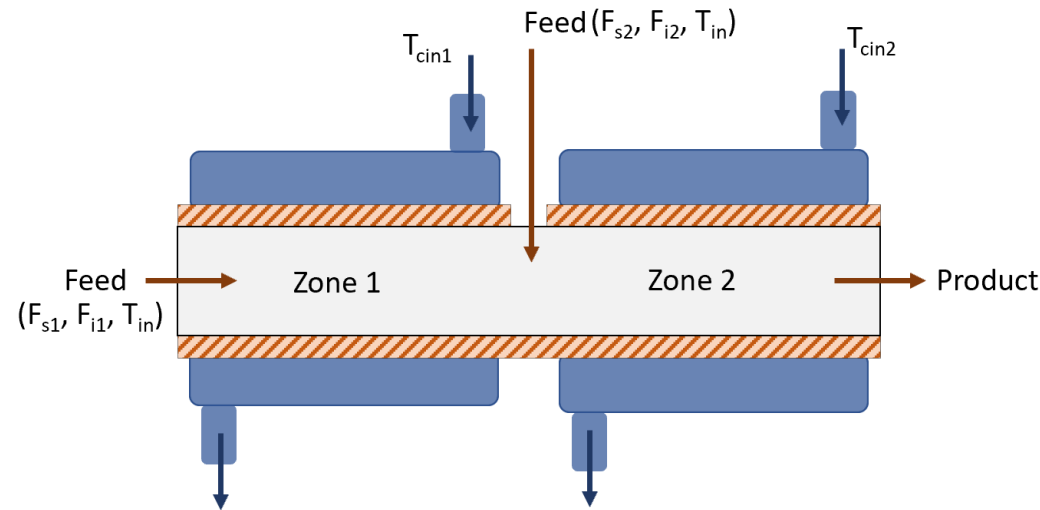
- ❑ Introduction to Statistical Process Monitoring (SPM)
- ❑ Python Installation and basics (optional)
- ❑ Univariate SPM & Control Charts
  - Shewhart Charts
  - CUSUM Charts
  - EWMA Charts
- ❑ Multivariate SPM
  - Principal Component Analysis (PCA)-based MSPM
  - Partial Least Squares (PLS) regression-based MSPM
    - Fault detection & diagnosis (FDD) using PLS
    - Application to a LDPE reactor monitoring
  - Strategies for handling nonlinear, dynamic, multimode systems
- ❑ Deploying SPM solutions



# LDPE (Low-Density Polyethylene) Production Dataset\*

## Process Signals

- Feed inlet temperature
- Max temperature of zone1
- Outlet temperature of zone1
- Max temperature of zone2
- Outlet temperature of zone2
- Coolant inlet temperature in zone1
- Coolant inlet temperature in zone2
- Reactor position where  $T_{max1}$  appears
- Reactor position where  $T_{max2}$  appears
- Inlet flow rate of initiators
- Intermediate flow rate of initiators
- Inlet flow of solvent
- Intermediate flow of solvent
- Reactor pressure



## Performance / Product quality measures

- Conversion per pass
- Number average molecular weight of product
- Molecular weight of polymer product
- Long-chain branching frequencies of product
- Short-chain branching frequencies of product

- Multi-zonal tubular reactor
- 54 samples of 14 process variables, 5 quality variables
- A process fault occurs sample 51 onwards

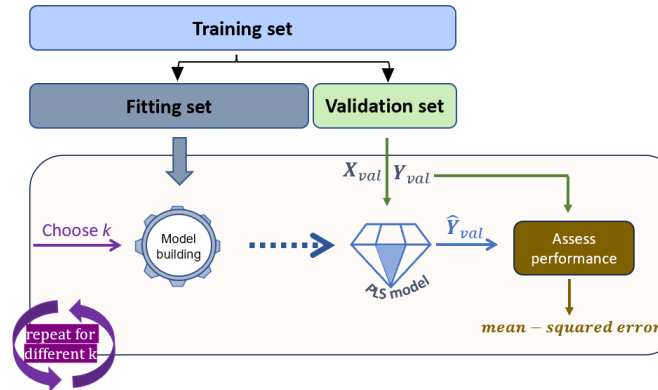
\*This dataset can be obtained from <https://openmv.net>

# PLS Modeling of LDPE Reactor

- Build a PLS model using the first 50 samples as the training dataset
- Explore the variances of different principal components and the correlations between them
- Explore the variances explained in X space and Y space by the principal components cumulatively

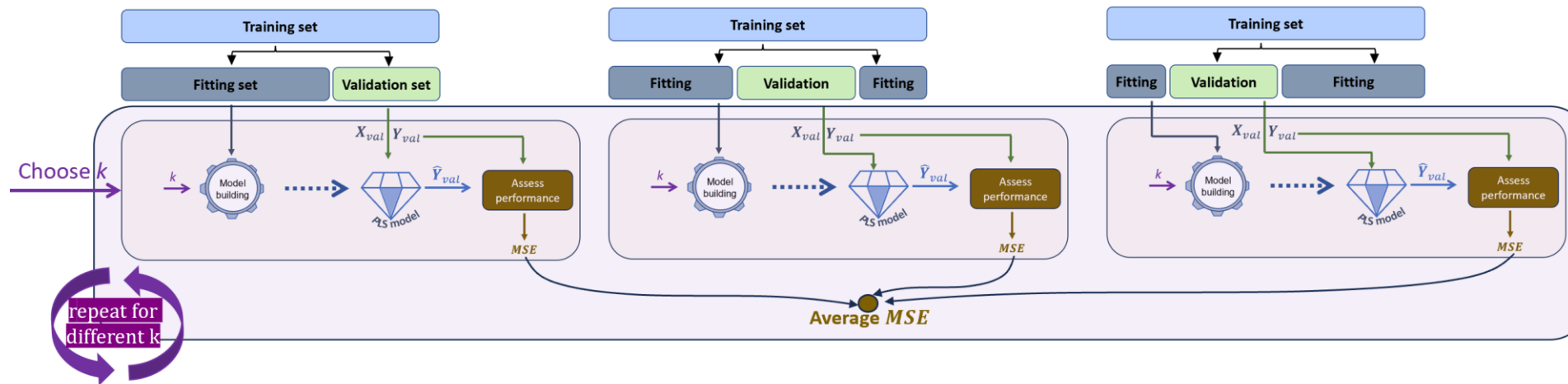
# PLS: Choosing Number of Principal Components via Cross-validation

## 2-way holdout cross-validation



*Select  $k$  that gives the minimum validation mean-squared error (MSE)*

## K-Fold cross-validation



*Select  $k$  that gives the minimum average MSE*



# Statistical Techniques for Monitoring Industrial Processes



*Next Lecture* : PLS – Fault Detection

*Module* : PLS-based MSPM

