

# Online Performance Monitoring of Industrial Compressors

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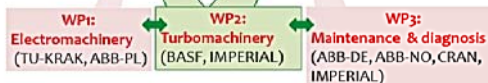
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## My project in Energy-SmartOps

- > Scalable and complete equipment monitoring systems
- o Example: Using electrical/mechanical interactions for diagnosis
- > Algorithms for overall performance monitoring and control
- o Example: Monitoring of compressors, enhanced surge control of compressors



## Problem statement

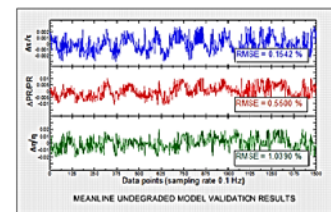
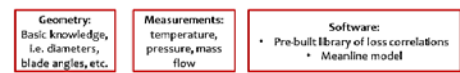
- The gas-path geometries of industrial turbomachinery are mechanical degraded with consequences on performances and availability.
- ✓ **OBJ1:** Assess the compressor operative range and its performances in undegraded health state
- ✓ **OBJ2:** Detect performance drops online (compressor running line)
- ✓ **OBJ3:** Assess the effect of degradation on operative range and performances (actual degraded state)
- o **OBJ4:** Correlate mechanical degradation dynamics to the compressor operative conditions



## Proposed solution

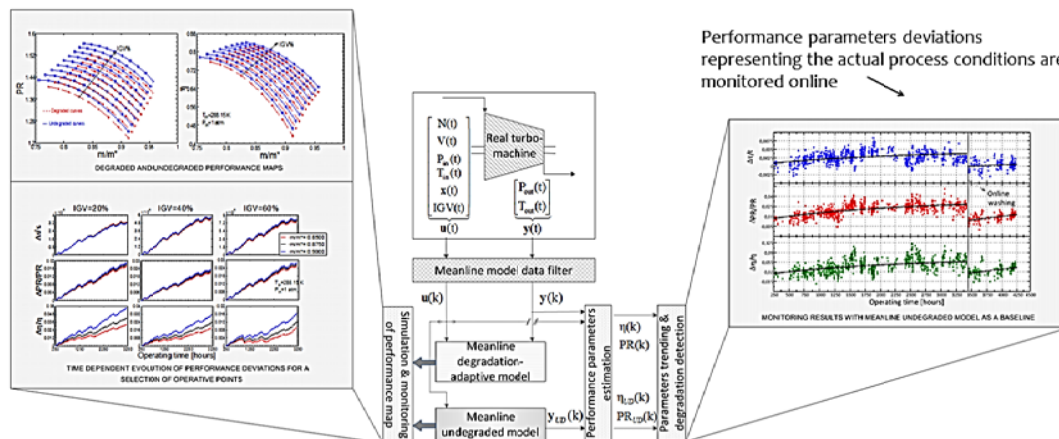
- **Offline meanline undegraded model development [1-2] (OBJ1):**

1. The model includes mass and energy balances, equation of state, 1D flow models and loss correlations
2. The model is calibrated and validated offline using historical data from the compressor running line



- **Online meanline degradation-adaptive modelling and performance monitoring [3] (OBJ2 & OBJ3):**

1. Undegraded model predicts outputs (analytical redundancy) for real-time degradation detection
2. The degradation-adaptive meanline model is updated using newly available data-sets
3. The adaptive and the undegraded models are simulated the actual and undegraded performance maps
4. The effect of degradation is assessed in the complete operative range



## Discussions

1. The meanline model accuracy is close to 99%
2. After 3250 operating hours the efficiency ( $\eta$ ) drops of circa 5.5% and the pressure ratio (PR) of circa 2%
3. For lower inlet guide vanes opening (IGV%) the PR drops of 2% and  $\eta$  drops of 6%
4. For higher IGV% the PR drops of 3% and  $\eta$  drops of 1.6%

## Conclusions and future works

1. The degradation dynamics are long and the magnitude of the effects on performance small
2. The effect of mechanical degradation on performances is a function of the operative conditions
3. The relationship between mechanical degradation dynamics and operative conditions is yet to be estimated (OBJ4)(possible collaboration with WP2: ESR-F for lab experimental studies)
4. The proposed solutions can be used for projective monitoring and performance-based optimization frameworks i.e. condition based maintenance (WP3: ESR-D and ESR-I), operation scheduling (WP2: ESR-G) and surge control (WP2: ESR-J)

[1] Ciccioiti, M., Martinez-Botas, R., Gozalbo, R., Geist, S., Schild A., Thornhill N. F., Khars O., Reiser W., "Assessment of meanline models for centrifugal compressors in the process plant industry". 5<sup>th</sup> International Symposium on Fluid Machinery and Fluids Engineering (ISFMFE), Jeju, Korea, October 24-27, 2012.

[2] Ciccioiti M., Martinez-Botas R. F., Romagnoli A., Thornhill N. F., Geist S., Schild A., "Systematic One Zone Meanline Modelling of Centrifugal Compressors for Industrial Online Applications". Proceedings of ASME Turbo Expo 2013, GT2013, San Antonio, Texas, USA, June 3-7, 2013.

[3] Ciccioiti M., Xenos D. P., Martinez-Botas R. F., Thornhill N. F., Bouaswaig A. E. F., "Online Performance Monitoring of industrial Compressors using Meanline Modelling". Proceedings of ASME Turbo Expo 2014, GT2014, Düsseldorf, Germany, June 16-20, 2014 (in preparation)

