# 1 PdM using a Simulation Model

## 1.1 Differences between Model-Based PdM and PdM using Digital Twin

There is a difference between using Model-Based PdM and using Simulation Model as a Digital Twin.

## 1.2 Model-Based Condition Indicators

Model-Based approach is suitable when it's difficult to identify condition indicators using only signals. In some cases it's useful to fit some model from data and extract condition indicators as some system parameter.

### 1.2.1 Static and Dynamic Models

If the system behavior can be fit from the data as a static model, than we can extract condition variables from this model. For example, if model was fitting to a polynomial model, than polynomial coefficients can be use as condition indicators.

Signals showing dynamic behavior can be fitted to dynamic models such as State-Space or AR, ARX, NLARX (Nonlinear auto recursive model) and so on. Then condition indicators can be extracted as poles, zeros damping coefficients from estimated model.

## 1.3 Using Simulation Model for Residuals Estimation

Another option is using the Simulink model with **prediction error minimization function** to compute difference between Simulink model and measured data. From this difference we can separate fault condition and healthy operation.

### 1.3.1 Comparison with Nominal System Model

Same thing as section **??**

Compare actual system behavior with system model. This will generate some error $e(t) = y(t) - \hat{y}(t)$. From this error residual can be generated in form $r(t) = \Phi(u_t, y_t, \varepsilon_t, v_t, d)$ and after some decision.

## 1.4 Using Digital Twin to Generate Fault Data

## 1.5 Using Digital Twin to Generate Prognostic Data

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