Plug-and-Play Monitoring and Performance Optimization for Industrial Automation Processes

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To my parents:
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Nomenclature

The main abbreviations and symbols used in this work are summarized in the following nomenclature. Here, the chosen declaration is based on DIN 1338. All scalar values, physical constants and functions are in italics. Standard mathematical functions and constants are described by letters in normal font. Matrices and vectors are written in bold letters, while vectors are of lowercase letters and matrices are of uppercase letters.

Abbreviations

Abbreviation	**Description**
AGC	Automatic Gauge Control
ALB	Acceptable Lower Bound
AUB	Acceptable Upper Bound
BLDC	Brushless Direct Current
CAN	Controller Area Network
CL	Component Level
DC	Direct Current
DO	Diagnostic Observer
ECU	Electronic Control Unit
FD	Fault Detection
FDA	Fisher Discriminant Analysis
FDF	Fault Detection Filter
FDI	Fault Detection and Isolation
FDIA	Fault Detection, Isolation and Identification
FFT	Fast Fourier Transform
FTC	Fault-Tolerant Control
FTCA	Fault-Tolerant Control Architecture
GIMC	Generalized Internal Model Control
GM-AGC	Gauge Meter Automatic Gauge Control
HIL	Hardware-in-the-loop
I/O	Input/Output
ICA	Independent Component Analysis
IMC	Internal Model Control
KPI	Key Performance Indicator
LAN	Local Area Network
LB	Lower Bound
LCF	Left Coprime Factorization
LTI	Linear Time-Invariant
MIMO	Multi-Input Multi-Output
MISO	Multi-Input Single-Output
PCA	Principle Component Analysis

Abbreviation	**Description**
PI	Proportional-Integral
PID	Proportional-Integral-Derivative
PLS	Partial Least Squares
PS	Parity Space
PnP	Plug-and-Play
PnP-PMCA	Plug-and-Play Process Monitoring and Control Architecture
RCF	Right Coprime Factorization
RMS	Root Mean Square
SCADA	Supervisory Control And Data Acquisition
SIM	Subspace Identification Method
SIMO	Single-Input Multi-Output
SIR	Stable Image Representation
SISO	Single-Input Single-Output
SKR	Stable Kernel Representation
SL	System Level
SSL	Subsystem Level
SVD	Singular Value Decomposition
SVM	Support Vector Machine
UB	Upper Bound
w.r.t.	with respect to

Mathematical symbols

Symbol	**Description**
$\in$	belong to
$\approx$	approximately equal
$\neq$	not equal
$:=$	defined as
$\Rightarrow$	imply
$\|\cdot\|_2$	$\mathcal{L}_2$-norm of a signal
$\mathbf{I_n}$	an n by n identity matrix
$\mathbf{0_n}$	an n by n zero matrix
$\mathcal{R}^n$	space of real n-dimensional vectors
$\mathbf{A}^T$	transpose of $\mathbf{A}$
trace($\mathbf{A}$)	trace of $\mathbf{A}$
eig($\mathbf{A}$)	eigenvalues of $\mathbf{A}$
sup	supremum
max (min)	maximum (minimum)
vec	vectorization of a given matrix
$\otimes$	the Kronecker product

Control theoretical symbols

Symbol	Description
k	discrete-time sample
n	system order
l	number of inputs
m	number of outputs
k_d	number of disturbances
k_f	number of additive faults
$\mathbf{u}$	input vector
$\mathbf{y}$	output vector
$\boldsymbol{\omega}$	reference vector
$\mathbf{x}$	state variable vector
$\mathbf{d}$	unknown disturbance vector
$\mathbf{f}$	additive fault vector
$\boldsymbol{\xi}$	process noise vector
$\mathbf{v}$	measurement noise vector
$\mathbf{A}$	system matrix
$\mathbf{B}$	input matrix
$\mathbf{C}$	output matrix
$\mathbf{D}$	feed-through matrix
$\mathbf{E_d}$	disturbance distribution matrix
$\mathbf{F_d}$	disturbance distribution matrix
$\mathbf{E_f}$	fault distribution matrix
$\mathbf{F_f}$	fault distribution matrix
$\mathbf{A_f}$	faults on system matrix
$\mathbf{B_f}$	faults on input matrix
$\mathbf{C_f}$	faults on output matrix
$\mathbf{D_f}$	faults on feed-through matrix
$\mathbf{G_{yu}}(z)$	discrete-time transfer function matrix from u to y
$\mathcal{RH}_\infty$	set of all proper and real-rational stable transfer matrices
$\boldsymbol{\Delta}$	model uncertainty