Predictive Control Library V3.0

a SoCollaborative library

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Table of Contents

	Safety Information	**5**
	About the Book	**7**
Part I	**General Information**	**9**
Chapter 1	**Using the Predictive Control Library with Unity Pro or Concept**	**11**
	Using the Predictive Control Library with Unity Pro or Concept	12
	Unity Pro: Block Availability on the Various Hardware Platforms	13
	Concept: Block Availability on the Various Hardware Platforms	14
Chapter 2	**Predictive Control**	**15**
	General Principles of Model Based Predictive Control	16
	Predictive Control Description	18
Part II	**EFB Descriptions**	**21**
Chapter 3	**PCR_SF1: Simple Predictive Controller for First Order Process**	**23**
	Brief Description	24
	Detailed Description	27
Chapter 4	**PCR_EF1: Enhanced Controller: First Order with Feed-Forward, Cascade, Split Range, Self Compensation**	**29**
	Brief Description	30
	Detailed Description	35
Chapter 5	**PCR_IF1: Controller for Integrative First Order Process**	**37**
	Brief Description	37
Chapter 6	**PCR_EIF1: Enhanced Controller: Integrative First Order Process with Feed-Forward, Cascade, Ramp Set Point**	**41**
	Brief Description	42
	Detailed Description	46
Chapter 7	**PCR_RD1: Ramp and Docking Set Point Controller for First Order Process**	**47**
	Brief Description	48
	Detailed Description	53

Chapter 8 PCR_DC3: Dedicated Controller for Third Order Process 55
Brief Description. 55
Chapter 9 PCR_ZTR: Zone Control with Non-Linear Time Response 59
Brief Description. 60
Detailed Description. 62
Chapter 10 PCR_FIL: Rate Limiter Filter 65
Brief Description. 66
Detailed Description. 68
Chapter 11 PCR_RSP: Ramp and Docking Set Point Generator . . . 71
Brief Description. 71
Chapter 12 PCR_FF1: Model for First Order Feed-Forward Compensation 77
Brief Description. 78
Detailed Description. 81
Chapter 13 PCR_IFF1: Model for Feed-Forward Compensation Used with Integrative First Order System 83
Brief Description. 84
Detailed Description. 87
Chapter 14 PCR_SR1: Supervisor for 2 Controllers in Split Range Configuration 89
Brief Description. 90
Detailed Description. 92
Chapter 15 PCR_ESR1: Enhanced Split Range Supervisor with Min Constraints Different from Zero 95
Brief Description. 96
Detailed Description. 100
Index 101

Safety Information

Important Information

NOTICE

Read these instructions carefully, and look at the equipment to become familiar with the device before trying to install, operate, or maintain it. The following special messages may appear throughout this documentation or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of this symbol to a Danger or Warning safety label indicates that an electrical hazard exists, which will result in personal injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

DANGER

DANGER indicates an imminently hazardous situation which, if not avoided, **will result in** death or serious injury.

WARNING

WARNING indicates a potentially hazardous situation which, if not avoided, **can result in** death or serious injury.

⚠ CAUTION

CAUTION indicates a potentially hazardous situation which, if not avoided, **can result in** minor or moderate injury.

CAUTION

CAUTION, used without the safety alert symbol, indicates a potentially hazardous situation which, if not avoided, **can result in** equipment damage.

PLEASE NOTE

Electrical equipment should be installed, operated, serviced, and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

About the Book

At a Glance

Document Scope

This document describes the function blocks of the Predictive Control library.

This document is valid for the Predictive Control library version 3.0.

Validity Note

This documentation applies to Unity Pro 2.3 and later.

The data and illustrations found in this document are not binding. We reserve the right to modify our products in line with our policy of continuous product development. The information in this document is subject to change without notice and should not be construed as a commitment by Schneider Electric.

Related Documents

Title of Documentation	Reference Number
Unity Pro, Program Languages and Structure, Reference Manual	-

You can download these technical publications and other technical information from our website at www.schneider-electric.com.

Product Related Information

Schneider Electric assumes no responsibility for any errors that may appear in this document. If you have any suggestions for improvements or amendments or have found errors in this publication, please notify us.

All pertinent state, regional, and local safety regulations must be observed when installing and using this product. For reasons of safety and to ensure compliance with documented system data, only the manufacturer should perform repairs to components.

When controllers are used for applications with technical safety requirements, please follow the relevant instructions.

Failure to use Schneider Electric software or approved software with our hardware products may result in injury, harm, or improper operating results.

Failure to observe this product related warning can result in injury or equipment damage.

User Comments

We welcome your comments about this document. You can reach us by e-mail at techcomm@schneider-electric.com.

General Information

I

Introduction

This part contains general information about the Predictive Control library.

What's in this Part?

This part contains the following chapters:

Chapter	Chapter Name	Page
1	Using the Predictive Control Library with Unity Pro or Concept	11
2	Predictive Control	15

Using the Predictive Control Library with Unity Pro or Concept

1

Introduction

You can use the Predictive Control library with Unity Pro or with Concept.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Using the Predictive Control Library with Unity Pro or Concept	12
Unity Pro: Block Availability on the Various Hardware Platforms	13
Concept: Block Availability on the Various Hardware Platforms	14

Using the Predictive Control Library with Unity Pro or Concept

Introduction

You can use the Predictive Control library with Unity Pro or with Concept.

Related Documents

For further details on how to use EFBs with Unity Pro or Concept (for example `EN` and `ENO`), please refer to the respective documentation.

- For Unity Pro please refer to *Unity Pro, Program Languages and Structure, Reference Manual*.
- For Concept please refer to *Concept User Manual*.

Unity Pro: Block Availability on the Various Hardware Platforms

Introduction

Block availability by hardware platform can be found in the following table.

Block Availability

Group	Block Name	Block Type	M340	Premium	Quantum
Controller	PCR_SF1	EFB	+	+	+
	PCR_EF1	EFB	+	+	+
	PCR_IF1	EFB	+	+	+
	PCR_EIF1	EFB	+	+	+
	PCR_RD1	EFB	+	+	+
	PCR_DC3	EFB	+	+	+
Generator	PCR_ZTR	EFB	+	+	+
	PCR_FIL	EFB	+	+	+
	PCR_RSP	EFB	+	+	+
Model	PCR_FF1	EFB	+	+	+
	PCR_IFF1	EFB	+	+	+
Supervisor	PCR_SR1	EFB	+	+	+
	PCR_ESR1	EFB	+	+	+
Legend:					
+	yes				
-	no				

Concept: Block Availability on the Various Hardware Platforms

Introduction

Block availability by hardware platform can be found in the following table.

Block Availability

Group	Block Name	Block Type	Atrium	Quantum	Momentum	Compact
Controller	PCR_SF1	EFB	+	+	+	+
	PCR_EF1	EFB	+	+	+	+
	PCR_IF1	EFB	+	+	+	+
	PCR_EIF1	EFB	+	+	+	+
	PCR_RD1	EFB	+	+	+	+
	PCR_DC3	EFB	+	+	+	+
Generator	PCR_ZTR	EFB	+	+	+	+
	PCR_FIL	EFB	+	+	+	+
	PCR_RSP	EFB	+	+	+	+
Model	PCR_FF1	EFB	+	+	+	+
	PCR_IFF1	EFB	+	+	+	+
Supervisor	PCR_SR1	EFB	+	+	+	+
	PCR_ESR1	EFB	+	+	+	+
Legend:						
+	yes					
-	no					

Predictive Control

2

Introduction

This chapter provides information about the general principles of predictive control and general information about Predictive Control.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
General Principles of Model Based Predictive Control	16
Predictive Control Description	18

General Principles of Model Based Predictive Control

Introduction

A model based predictive controller is a controller that uses a model in real time for the computation of the control action to be applied. The main aspects of this controller are given below.

Model

The model which is embedded in the controller is a mathematical equation that computes a 'model' output which is comparable to the process output PV (Process Variable).

The model represents the relationship linking the process input(s) to the process output.

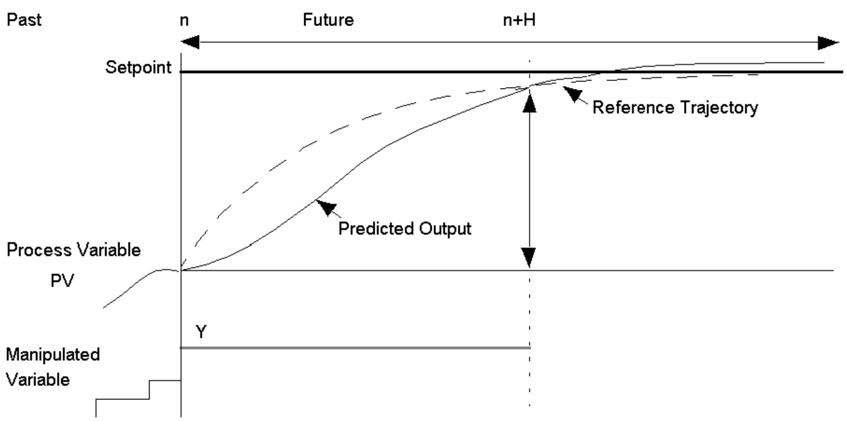
This model must be identified: the parameters of the model are to be estimated from recorded plant tests.

The model is used to predict the process output and to compute the control action in order to satisfy a given target specified on the PV.

Future Desired Trajectory

At present time (n), the process output is `PV(n)` and the set point value is `SP(n)`.

The future desired trajectory (so-called reference trajectory) is the desired behavior of the process output to move from its present value `PV(n)` to `SP(n)` in the future.



The reference trajectory is computed by a first order system (see above) and the response time of this trajectory is the closed loop response time: the PV will respond to a set point step change with the response time given by the user.

The closed loop response time (TRBF) is a specification which defines the strength or the smoothness of the controller. There is a trade-off between dynamic performance and robustness. The controller is more robust when the specified TRBF is longer.

An intermediate target is selected along that trajectory at a future time `(n+H)`, where H is called the coincidence point. A simple rule for the coincidence point is to set it to the third of the 95% response time: H=TRBF/3.

Solver

The solver is the part of the controller which computes the control action to be applied in such a way the predicted output at time `(n+H)` is equal to the reference trajectory at the same future instant.

The computed control action takes into account the constraints which limit the input moves (high and low limits and rate of change).

Self Compensation

Some non measured variables may disturb the process.

With unmeasured ramp-type disturbance, a bias between PV (Process Variable) and SP (Set Point) may appear.

The aim of the self-compensator is to reject this kind of disturbance, and to avoid such a bias.

Predictive Control Description

Introduction

Predictive Control belongs to the Model Based Predictive Control technology and is dedicated to SISO (Single Input Single Output) processes, including feed forwarding facilities.

Predictive Control Design

Predictive Control was initially designed to cope with the control issues met on chemical reactors (batch or continuous).

Therefore, that led to some physical modelling of the typical architectures of heat exchanges used on such chemical plants.

The obtained relationships can be represented by non linear first order systems and model based predictive controllers were designed to cope with these targets.

Several complementary functions were developed as complements to these controllers to match the specific requirements of reactor temperature control, such as an efficient SPLIT RANGE module and a smart temperature profile builder linked with a predictive functional controller, which together perform a close tracking of such profiles without overshoots.

Since non linear first order controllers were developed, they can be used profitably on any other kind of SISO process.

EFBs

Each Predictive Control EFB (Elementary Function Block) is a program which is represented as a block with inputs and outputs.

When a control structure is to be integrated, in case of PLCs the blocks can be graphically linked (according to the IEC 1131-3 norm).

Groups

Group	EFB	Description
Controller	PCR_SF1	simple predictive controller for first order process
	PCR_EF1	enhanced controller for first order process with feed-forward, cascade with MV constraint transfer, split range, self compensation
	PCR_IF1	controller for integrative first order process
	PCR_EIF1	enhanced controller for Integrative first order process with feed-forward, cascade with MV constraint transfer
	PCR_RD1	ramp and docking set point controller for first order process
	PCR_DC3	dedicated controller for third order process
Generator	PCR_ZTR	zone control with non-linear time response
	PCR_FIL	rate limiter filter
	PCR_RSP	ramp and docking set point generator
Model	PCR_FF1	model for first order feed-forward compensation
	PCR_IFF1	model for feed-forward compensation used with integrative first order system
Supervisor	PCR_SR1	supervisor for 2 controllers in split range configuration
	PCR_ESR1	enhanced supervisor for 2 controllers in split range configuration with min constraints different from zero

EFB Descriptions

II

Introduction

The EFB descriptions are documented according to the EFB groups *(see page 19)*.

What's in this Part?

This part contains the following chapters:

Chapter	Chapter Name	Page
3	PCR_SF1: Simple Predictive Controller for First Order Process	23
4	PCR_EF1: Enhanced Controller: First Order with Feed-Forward, Cascade, Split Range, Self Compensation	29
5	PCR_IF1: Controller for Integrative First Order Process	37
6	PCR_EIF1: Enhanced Controller: Integrative First Order Process with Feed-Forward, Cascade, Ramp Set Point	41
7	PCR_RD1: Ramp and Docking Set Point Controller for First Order Process	47
8	PCR_DC3: Dedicated Controller for Third Order Process	55
9	PCR_ZTR: Zone Control with Non-Linear Time Response	59
10	PCR_FIL: Rate Limiter Filter	65
11	PCR_RSP: Ramp and Docking Set Point Generator	71
12	PCR_FF1: Model for First Order Feed-Forward Compensation	77
13	PCR_IFF1: Model for Feed-Forward Compensation Used with Integrative First Order System	83
14	PCR_SR1: Supervisor for 2 Controllers in Split Range Configuration	89
15	PCR_ESR1: Enhanced Split Range Supervisor with Min Constraints Different from Zero	95

PCR_SF1: Simple Predictive Controller for First Order Process

3

Introduction

This chapter describes the PCR_SF1 EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	24
Detailed Description	27

Brief Description

Function Description

PCR_SF1 is an EFB for simple control of first order process with pure time delay.

PCR_SF1 algorithm is based on predictive control principles:

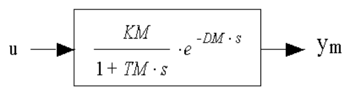
- An internal model of process is used to predict the future behavior of the system. The model is composed of 3 parameters (see figure below):
  - KM: static gain
  - TM: time constant
  - DM: pure time delay
- The following constraints on the manipulated variable (Y) can be taken into account:
  - YMIN: minimum value for Y
  - YMAX: maximum value for Y
  - YRATE maximum variation for Y

Additional parameters EN and ENO can be projected.

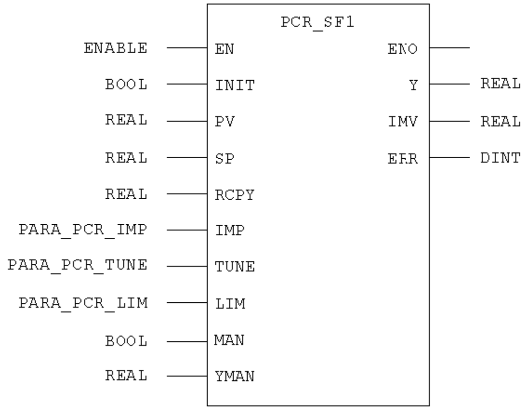
EN should be enabled at the control sampling time TS.

Transfer Function

The continuous transfer function of the internal model is:



Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	command for model INITialization if TRUE
PV	REAL	Process Variable
SP	REAL	Set Point value
RCPY	REAL	ReCoPY of applied Y value
IMP	PARA_PCR_IMP	Internal Model Parameters
TUNE	PARA_PCR_TUNE	Predictive control TUNing parameters
LIM	PARA_PCR_LIM	LIMitations on manipulated variable Y
MAN	BOOL	TRUE = MANual mode
YMAN	REAL	MANual manipulated variable

Outputs

Parameter	Data Type	Meaning
Y	REAL	manipulated variable
IMV	REAL	Internal Model Value process value estimated by model
ERR	DINT	ERRor code

Type Description

PARA_PCR_IMP: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM	TIME	time constant
DM	TIME	pure time delay

PARA_PCR_TUNE: Predictive control TUNing parameters

Parameter	Data Type	Meaning
TS	TIME	sampling time
H	TIME	coincidence point
TRBF	TIME	95% closed-loop response time

PARA_PCR_LIM: LIMitations on manipulated variable Y

Parameter	Data Type	Meaning
YMIN	REAL	minimum value for Y
YMAX	REAL	maximum value for Y
YRATE	REAL	maximum variation for Y (in unit per second)

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	TS is forced to 1
BIT 1 = 1	ABS(KM) < 1.0 e^{-6}	KM is forced to +/- 1.0 e^{-6}
BIT 2 = 1	DM < 0	DM is forced to 0
BIT 3 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 4 = 1	YRATE < 0	YRATE is forced to 0
BIT 5 = 1	YMAX < YMIN	YMIN <-> YMAX and YRATE is forced to 0
BIT 6 = 1	TRBF < 0	TRBF is forced to 0
BIT 7 = 1	H < TS	H is forced to TS

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

Detailed Description

Initialization Mode

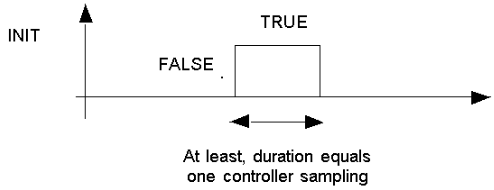
The INIT flag is used to initialize the current and past states of the internal model.

It is needed when the controller inputs (PV, actuator) are not representative of the process.

For instance: temperature measurement of an empty reactor or opened valve without real action on the process.

Depending on the type of process on which the controller is applied (continuous or batch), the initialisation has to be performed once or at the beginning of each production.

INIT has to be done when the process is stabilized, as follows:



Manual Mode

The manual mode is applied if the input MAN is TRUE.

Then, the output of the control block (Y) takes the value of manual manipulated variable YMAN.

PCR_EF1: Enhanced Controller: First Order with Feed-Forward, Cascade, Split Range, Self Compensation

4

Introduction

This chapter describes the PCR_EF1 EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	30
Detailed Description	35

Brief Description

Function Description

PCR_EF1 is an EFB for enhanced control of first order process with pure time delay.

PCR_EF1 algorithm is based on predictive control principles:

- An internal model of process is used to predict the future behavior of the system. The model is composed of 3 parameters:
  - KM: static gain
  - TM: time constant
  - DM: pure time delay
- The following constraints on the manipulated variable (Y) can be taken into account:
  - YMIN: minimum value for Y
  - YMAX: maximum value for Y
  - YRATE: maximum variation for Y

Additional parameters EN and ENO can be projected.

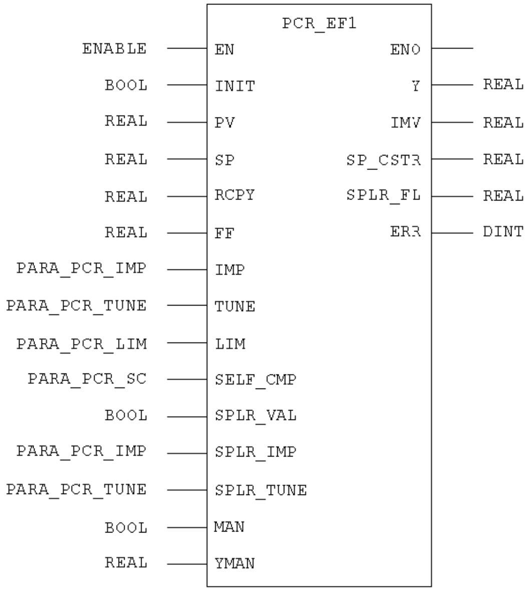
EN should be enabled at the control sampling time TS.

Additional Functions

Compared to PCR_SF1, PCR_EF1 provides the following additional functions:

- FEED FORWARD COMPENSATION:
  to take in account a disturbance variable (issued from a disturbance modelling, see PCR_FF1, or from an other controller)
- SPLIT RANGE COMPENSATION:
  to optimize the association of controllers, see PCR_SR1
- SELF COMPENSATOR:
  to reject unmeasured ramp type disturbances

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	command for model INITialization if TRUE
PV	REAL	Process Variable
SP	REAL	Set Point value
RCPY	REAL	ReCoPY of applied Y value
FF	REAL	Feed-Forward compensation
IMP	PARA_PCR_IMP	Internal Model Parameters
TUNE	PARA_PCR_TUNE	predictive control TUNing parameters
LIM	PARA_PCR_LIM	LIMitations on manipulated variable Y
SELF_CMP	PARA_PCR_SC	SELF CoMPensator parameters
SPLR_VAL	BOOL	TRUE = SPLit-Range VALidation
SPLR_IMP	PARA_PCR_IMP	Internal Model Parameters from associated controller
SPLR_TUNE	PARA_PCR_TUNE	Predictive ContRol TUNing parameters from associated controller

Parameter	Data Type	Meaning
MAN	BOOL	TRUE = MANual mode
YMAN	REAL	MANual manipulated variable

Outputs

Parameter	Data Type	Meaning
Y	REAL	manipulated variable
IMV	REAL	Internal Model Value process value estimated by model
SP_CSTR	REAL	Set Point transferred to upper level
SPLR_FL	REAL	feed back value for associated controller
ERR	DINT	ERRor code

Type Description

PARA_PCR_IMP: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM	TIME	time constant
DM	TIME	pure time delay

PARA_PCR_TUNE: Predictive ContRol TUNing parameters

TS	TIME	sampling time
H	TIME	coincidence point
TRBF	TIME	95% closed-loop response time

PARA_PCR_LIM: LIMitations on manipulated variable Y

Parameter	Data Type	Meaning
YMIN	REAL	MINimum value for Y
YMAX	REAL	MAXimum value for Y
YRATE	REAL	Maximum variation for Y (in unit per second)

PARA_PCR_SC: Self Compensator parameters

Parameter	Data Type	Meaning
KSC	REAL	static gain
TSC	TIME	time constant

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	TS is forced to 1
BIT 1 = 1	ABS(KM) < 1.0 e^{-6}	KM is forced to +/- 1.0 e^{-6}
BIT 2 = 1	DM < 0	DM is forced to 0
BIT 3 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 4 = 1	YRATE < 0	YRATE is forced to 0
BIT 5 = 1	YMAX < YMIN	YMIN <-> YMAX and YRATE is forced to 0
BIT 6 = 1	TRBF < 0	TRBF is forced to 0
BIT 7 = 1	H < TS	H is forced to TS

Invalid setting in Split Range parameters

ERR Bit	Meaning	Behavior
BIT 8 = 1	DM < 0	DM is forced to 0
BIT 9 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 10 = 1	TRBF < 0	TRBF is forced to 0
BIT 11 = 1	H < TS	H is forced to TS

Invalid setting in Self Compensator parameters

ERR Bit	Meaning	Behavior
BIT 14 = 1	TSC < 0	TSC is forced to 0
BIT 15 = 1	KSC < 0	KSC is forced to 0
BIT 16 = 1	KSC >KSC_MAX	KSC is forced to KSC_MAX (2.0)

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

Detailed Description

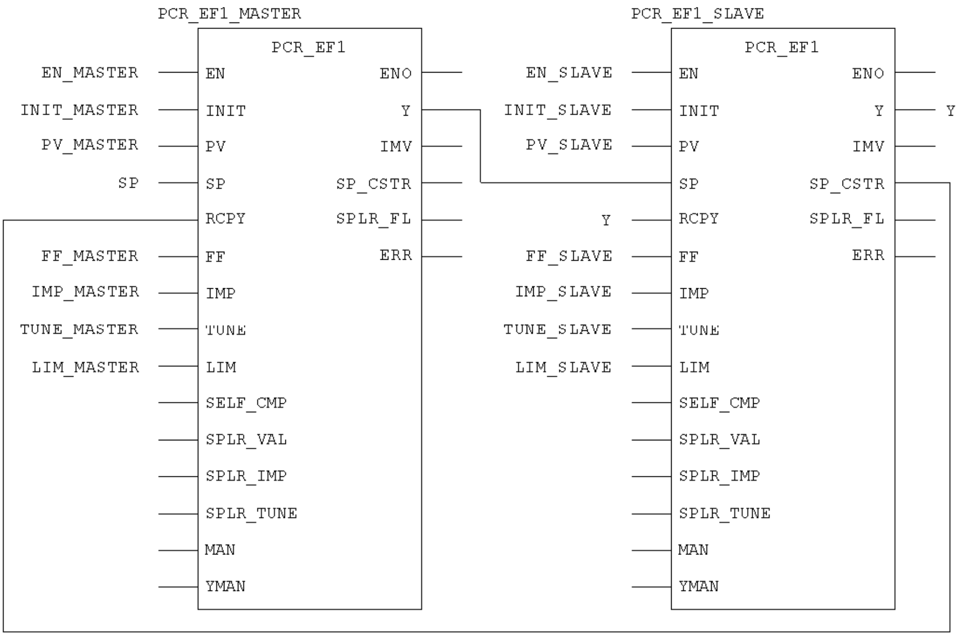
Cascade Configuration

When an PCR_EF1 controller is used as a SLAVE controller in a cascaded architecture, it receives a set point from the MASTER controller.

If the output Y, computed by the SLAVE controller, is constrained, the MASTER Controller must know the value of the set point that can be satisfied by the SLAVE controller.

That value is computed by the SLAVE controller (SP_CSTR) and sent back to the master controller.

Example of cascade configuration, using PCR_EF1 blocks



Tuning of the Self Compensator Parameters

Some non measured variables may disturb the process.

With unmeasured ramp-type disturbance, a bias between `PV` and `SP` may appear.

The aim of the self-compensator is to reject this kind of disturbance.

The gain `KSC` and the time constant `TSC` are the parameters of the `PARA_PCR_SC` structure used with the `SELF_CMP` input.

For stability sake, usual values are:

- $0 \leq$ KSC ≤ 1(KSC=0 means no self compensation)
- TSC $\geq$ max(30*TS, 3*TM, TRBF)

PCR_IF1: Controller for Integrative First Order Process

5

Brief Description

Function Description

`PCR_IF1` is an EFB for control of integrative first order process with pure time delay.

The algorithm is based on predictive control principles:

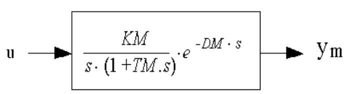
- An internal model of process is used to predict the future behavior of the integrative system with delay.
  The model is composed of 3 parameters (see figure below):
  - KM: static gain
  - TM: time constant
  - DM: pure time delay
- The integrative part is decomposed. This is tuned by `DECOMP` input.
  For stability sake, it is better to set this input at the maximum value among: 30*TS, 3*TM, TRBF
- The following constraints on the manipulated variable (Y) can be taken into account:
  - YMIN: minimum value for Y
  - YMAX: maximum value for Y
  - YRATE: maximum variation for Y

Additional parameters `EN` and `ENO` can be projected.

`EN` should be enabled at the control sampling time TS.

Transfer Function

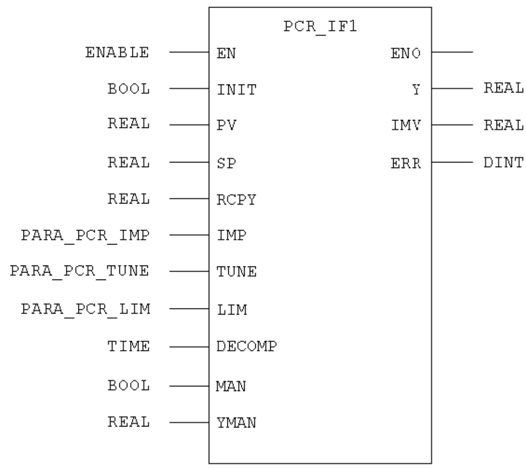
The continuous transfer function of the internal model is:



Note for Initialization

NOTE: When the process variable PV varies as a ramp before switching on the controller, it is necessary to estimate the slope of this process variable PV in order to initialize correctly the model. This estimation is performed during the initialization phase, as long as INIT equals TRUE. The duration of this phase must be long enough to perform an estimation not biased by the noise. In case of heavy noise, more than 10 periods may be required.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	command for model INITialization if TRUE
PV	REAL	Process Variable
SP	REAL	Set Point value
RCPY	REAL	ReCoPY of applied Y value
IMP	PARA_PCR_IMP	Internal Model Parameters
TUNE	PARA_PCR_TUNE	predictive control TUNing parameters
LIM	PARA_PCR_LIM	LIMitations on manipulated variable Y
DECOMP	TIME	DECOMPosition time constant
MAN	BOOL	TRUE = MANual mode
YMAN	REAL	MANual manipulated variable

Outputs

Parameter	Data Type	Meaning
Y	REAL	manipulated variable
IMV	REAL	Internal Model Value process value estimated by model
ERR	DINT	ERRor code

Type Description

PARA_PCR_IMP: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM	TIME	time constant
DM	TIME	pure time delay

PARA_PCR_TUNE: Predictive control TUNing parameters

Parameter	Data Type	Meaning
TS	TIME	sampling time
H	TIME	coincidence point
TRBF	TIME	95% closed-loop response time

PARA_PCR_LIM: LIMitations on manipulated variable Y

Parameter	Data Type	Meaning
YMIN	REAL	MINimum value for Y
YMAX	REAL	MAXimum value for Y
YRATE	REAL	maximum variation for Y (in unit per second)

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	TS is forced to 1
BIT 1 = 1	ABS(KM) < 1.0 e^{-6}	KM is forced to +/- 1.0 e^{-6}
BIT 2 = 1	DM < 0	DM is forced to 0
BIT 3 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 4 = 1	YRATE < 0	YRATE is forced to 0
BIT 5 = 1	YMAX < YMIN	YMIN <-> YMAX and YRATE is forced to 0
BIT 6 = 1	TRBF < 0	TRBF is forced to 0
BIT 7 = 1	H < TS	H is forced to TS
BIT 8 = 1	DECOMP < 0	decomposition time constant DECOMP is forced to 0

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

PCR_EIF1: Enhanced Controller: Integrative First Order Process with Feed-Forward, Cascade, Ramp Set Point

6

Introduction

This chapter describes the PCR_EIF1 EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	42
Detailed Description	46

Brief Description

Function Description

PCR_EIF1 is an EFB for enhanced control of integrative first order process with pure time delay.

PCR_EIF1 algorithm is based on predictive control principles:

- An internal model of process is used to predict the future behavior of the integrative system with delay.
  The model is composed of 3 parameters:
  - KM: static gain
  - TM: time constant
  - DM: pure time delay
- The integrative part is decomposed. This is tuned by DECOMP input.
  For stability sake, it is better to set this input at the maximum value among: 30*TS, 3*TM, TRBF
- The following constraints on the manipulated variable (Y) can be taken into account:
  - YMIN: minimum value for Y
  - YMAX: maximum value for Y
  - YRATE: maximum variation for Y

Additional parameters EN and ENO can be projected.

EN should be enabled at the control sampling time TS.

Additional Functions

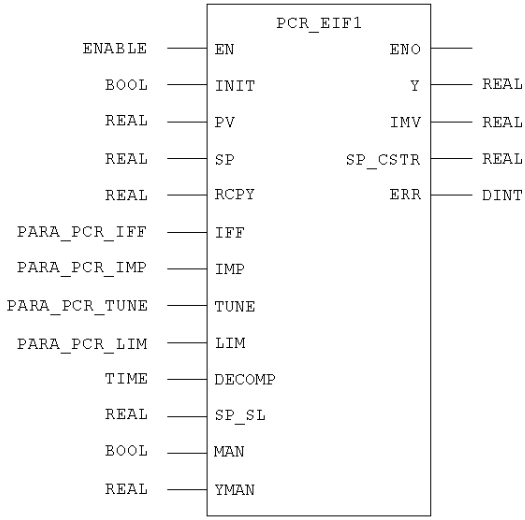
Compared to PCR_IF1, PCR_EIF1 provides the following additional functions:

- FEED FORWARD COMPENSATION
  to take in account a disturbance variable (issued from a disturbance modelling, see PCR_IFF1, or from an other controller)
- CONSTRAINTS TRANSFERRING
- follow up of ramp set points

Note for Initialization

NOTE: When the process variable PV varies as a ramp before switching on the controller, it is necessary to estimate the slope of this process variable PV in order to initialize correctly the model. This estimation is performed during the initialization phase, as long as INIT equals TRUE. The duration of this phase must be long enough to perform an estimation not biased by the noise. In case of heavy noise, more than 10 periods may be required.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	command for model INITialization if TRUE
PV	REAL	Process Variable
SP	REAL	Set Point value
RCPY	REAL	ReCoPY of applied Y value
IFF	PARA_PCR_IFF	Feed-Forward compensation
IMP	PARA_PCR_IMP	Internal Model Parameters
TUNE	PARA_PCR_TUNE	predictive control TUNing parameters
LIM	PARA_PCR_LIM	LIMitations on manipulated variable Y
DECOMP	TIME	DECOMPosition time constant
SP_SL	REAL	SLope (in unit per second) of the future Set Point
MAN	BOOL	TRUE = MANual mode
YMAN	REAL	MANual manipulated variable

Outputs

Parameter	Data Type	Meaning
Y	REAL	manipulated variable
IMV	REAL	Internal Model Value process value estimated by model
SP_CSTR	REAL	Set Point transferred to upper level
ERR	DINT	ERRor code

Type Description

PARA_PCR_IMP: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM	TIME	time constant
DM	TIME	pure time delay

PARA_PCR_TUNE: Predictive control TUNing parameters

Parameter	Data Type	Meaning
TS	TIME	sampling time
H	TIME	coincidence point
TRBF	TIME	95% closed-loop response time

PARA_PCR_IFF: Feed-Forward Compensation

Parameter	Data Type	Meaning
IFF1	REAL	Feed-Forward compensation for process output estimation
IFF2	REAL	Feed-Forward compensation at the coincidence point

PARA_PCR_LIM: LIMitations on manipulated variable Y

Parameter	Data Type	Meaning
YMIN	REAL	MINimum value for Y
YMAX	REAL	MAXimum value for Y
YRATE	REAL	Maximum variation for Y (in unit per second)

Runtime Errors

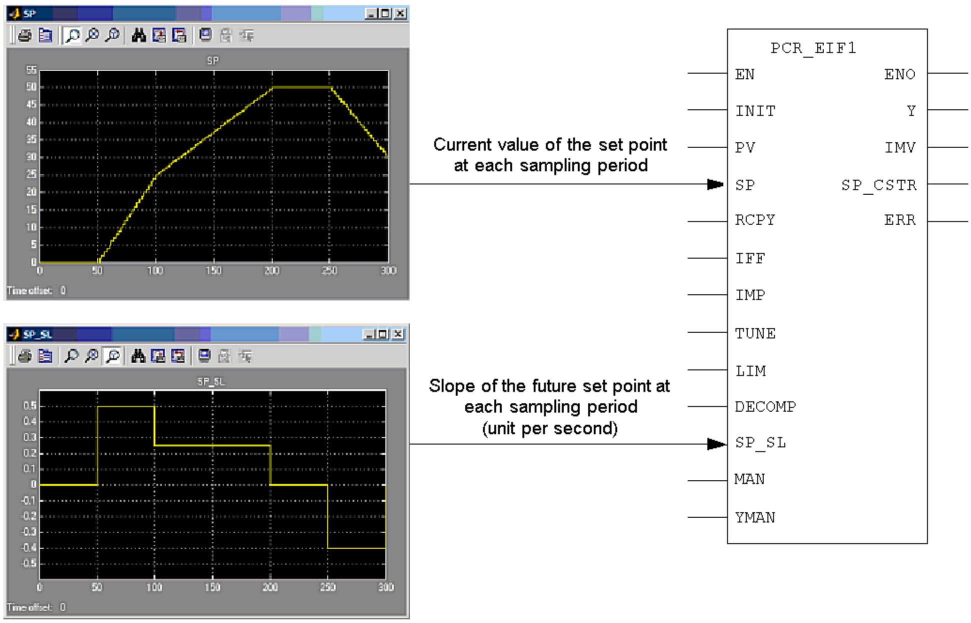
ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	TS is forced to 1
BIT 1 = 1	ABS(KM) < 1.0 e^{-6}	KM is forced to +/- 1.0 e^{-6}
BIT 2 = 1	DM < 0	DM is forced to 0
BIT 3 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 4 = 1	YRATE < 0	YRATE is forced to 0
BIT 5 = 1	YMAX < YMIN	YMIN <-> YMAX and YRATE is forced to 0
BIT 6 = 1	TRBF < 0	TRBF is forced to 0
BIT 7 = 1	H < TS	H is forced to TS
BIT 8 = 1	DECOMP < 0	decomposition time constant DECOMP is forced to 0

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

Detailed Description

Ramp Set Point

Configuration of `PCR_EIF1` in case of ramp set point



PCR_RD1: Ramp and Docking Set Point Controller for First Order Process

7

Introduction

This chapter describes the PCR_RD1 EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	48
Detailed Description	53

Brief Description

Function Description

PCR_RD1 is an EFB for ramp and docking set point control of first order process with pure time delay.

It has to be used with PCR_RSP block which provides docking set points.

PCR_RD1 algorithm is based on predictive control principles:

- An internal model of process is used to predict the future behavior of the system. For first order system with delay, the model is composed of 3 parameters:
  - KM: static gain
  - TM: time constant
  - DM: pure time delay
- The following constraints on the manipulated variable (Y) can be taken into account:
  - YMIN: minimum value for Y
  - YMAX: maximum value for Y
  - YRATE: maximum variation for Y

Additional parameters EN and ENO can be projected.

EN should be enabled at the control sampling time TS.

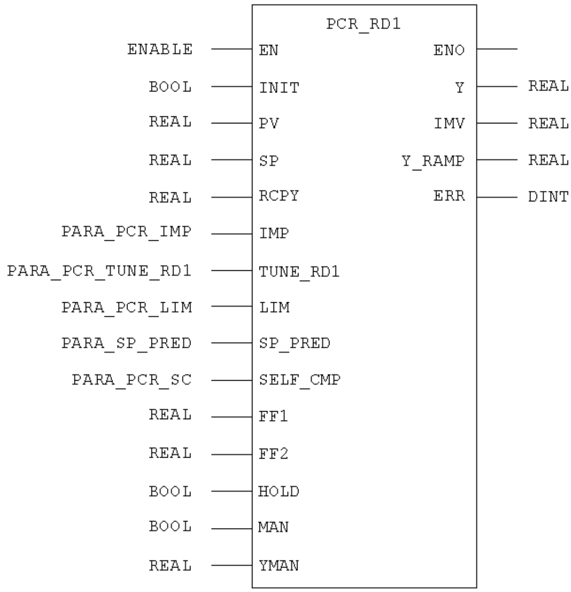
NOTE: This block cannot be used in split-range configuration.

Additional Function

Compared to PCR_EF1, the block PCR_RD1 provides the following additional function:

Follow-up of ramping set points.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	Command for model INITialization if True
PV	REAL	Process Variable
SP	REAL	Set Point value
RCPY	REAL	ReCoPY of applied Y value
IMP	PARA_PCR_IMP	Internal Model Parameters
TUNE_RD1	PARA_PCR_ TUNE_RD1	Predictive control TUNing parameters
LIM	PARA_PCR_LIM	LIMitations on manipulated variable Y
SP_PRED	PARA_SP_PRED	PREDicted Set Points values
SELF_CMP	PARA_PCR_SC	SELF CoMPensator parameters
FF1	REAL	Feed-Forward compensation at coincidence point H1
FF2	REAL	Feed-Forward compensation at coincidence point H2

Parameter	Data Type	Meaning
HOLD	BOOL	If TRUE, the predicted set points are hold to the current set point value.
MAN	BOOL	TRUE = MANual mode
YMAN	REAL	Manual MANipulated Variable

Outputs

Parameter	Data Type	Meaning
Y	REAL	manipulated variable
IMV	REAL	Internal Model Value process value estimated by model
Y_RAMP	REAL	RAMP part of the manipulated variable
ERR	DINT	ERRor code

Type Description

PARA_PCR_IMP: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM	TIME	time constant
DM	TIME	pure time delay

PARA_PCR_TUNE_RD1: Predictive control TUNing parameters

Parameter	Data Type	Meaning
TS	TIME	sampling time
H1	TIME	1st coincidence point
H2	TIME	2nd coincidence point
TRBF	TIME	95% closed-loop response time

PARA_PCR_LIM: LIMitations on manipulated variable Y

Parameter	Data Type	Meaning
YMIN	REAL	MINimum value for Y
YMAX	REAL	MAXimum value for Y
YRATE	REAL	maximum variation for Y (in unit per second)

PARA_PCR_PRED: PREDicted set points values

Parameter	Data Type	Meaning
SPH1	REAL	Set Point at current time + H1
SPH2	REAL	Set Point at current time + H2

PARA_PCR_SC: Self Compensator parameters

Parameter	Data Type	Meaning
KSC	REAL	static gain
TSC	TIME	time constant

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	EFB stays in initialization mode (INIT forced to TRUE)
BIT 1 = 1	ABS(KM) < 1.0 e^{-6}	KM is forced to +/- 1.0 e^{-6}
BIT 2 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 3 = 1	YRATE < 0	YRATE is forced to 0
BIT 4 = 1	YMAX < YMIN	YMIN <-> YMAX and YRATE is forced to 0
BIT 5 = 1	H1 < TS	H1 is forced to TS
BIT 6 = 1	H2 < TS	H2 is forced to TS
BIT 7 = 1	H2 <= H1	H2 is forced to H1 + TS
BIT 8 = 1	KSC < 0	KSC is forced to 0
BIT 9 = 1	KSC >KSC_MAX	KSC is forced to KSC_MAX (2.0)

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

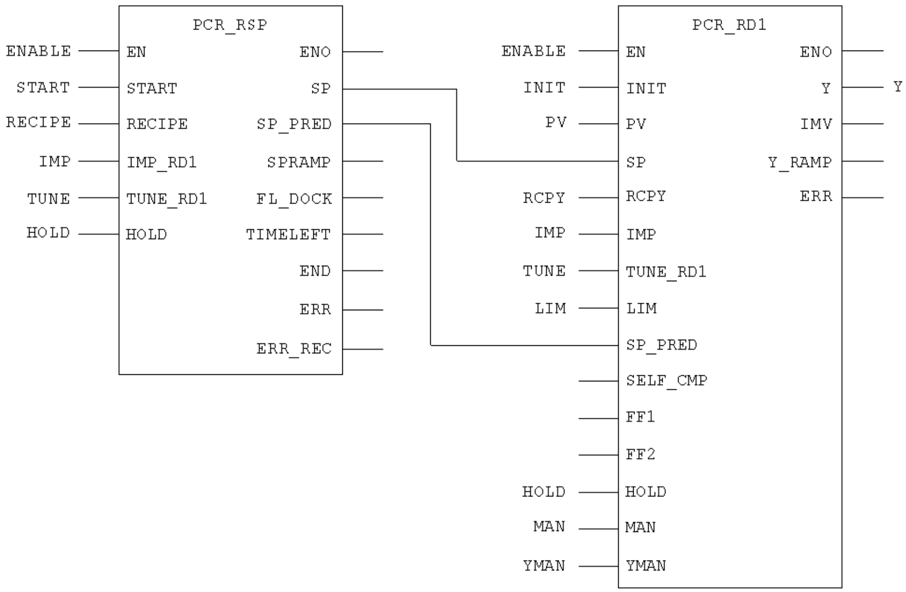
Detailed Description

PCR_RSP and PCR_RD1 Configuration

This configuration involves 2 blocks:

- PCR_RSP generates predicted set points from a recipe table
- PCR_RD1 computes the action Y from the computed predicted set points.

PCR_RSP and PCR_RD1 configuration



NOTE: When the EFB PCR_RD1 is associated with a PCR_RSP EFB, the sampling period TS must be a multiple of 1 second and cannot be decimal.

PCR_DC3: Dedicated Controller for Third Order Process

8

Brief Description

Function Description

PCR_DC3 is an enhanced controller for 3rd order process with pure time delay.

The algorithm is based on predictive control principles:

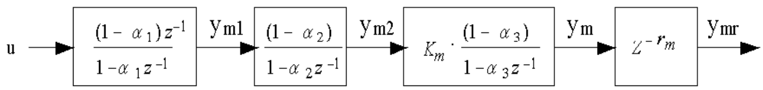
- An internal model of process is used to predict the future behavior of the system. The model is composed of 5 parameters:
  - KM: static gain
  - TM1, TM2, TM3: time constants -> $\alpha_i = exp(-TS/TMi)$ (with TS = sampling time)
  - Dm: pure time delay -> $r_m = DM/TS$
- The following constraints on the manipulated variable (Y) can be taken into account:
  - YMIN: minimum value for Y
  - YMAX: maximum value for Y
  - YRATE: maximum variation for Y

Additional parameters EN and ENO can be projected.

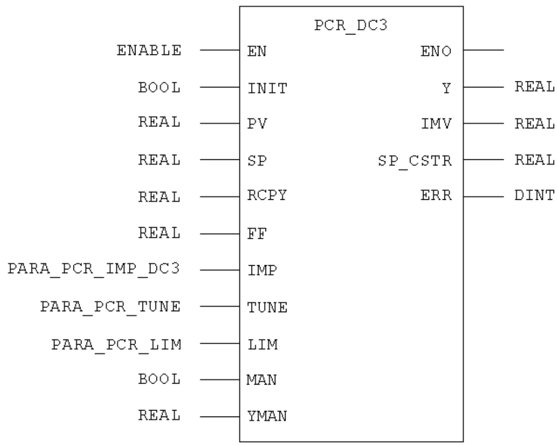
EN should be enabled at the control sampling time TS.

Model

PCR_DC3 is working according to the following discrete model:



Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	command for model INITialization if TRUE
PV	REAL	Process Variable
SP	REAL	Set Point value
RCPY	REAL	ReCoPY of applied Y value
FF	REAL	Feed-Forward compensation
IMP	PARA_PCR_IMP_DC3	Internal Model Parameters
TUNE	PARA_PCR_TUNE	Predictive Control TUNing parameters
LIM	PARA_PCR_LIM	LIMitations on manipulated variable Y
MAN	BOOL	TRUE = MANual mode
YMAN	REAL	MANual manipulated variable

Outputs

Parameter	Data Type	Meaning
Y	REAL	manipulated variable
IMV	REAL	Internal Model Value process value estimated by model
SP_CSTR	REAL	Set Point transferred to upper level
ERR	DINT	ERRor code

Type Description

PARA_PCR_IMP_DC3: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM1	TIME	1st time constant
TM2	TIME	2nd time constant
TM3	TIME	3rd time constant
DM	TIME	pure time delay

PARA_PCR_TUNE: Predictive control TUNing parameters

Parameter	Data Type	Meaning
TS	TIME	sampling time
H	TIME	coincidence point
TRBF	TIME	95% closed-loop response time

PARA_PCR_LIM: LIMitations on manipulated variable Y

Parameter	Data Type	Meaning
YMIN	REAL	MINimum value for Y
YMAX	REAL	MAXimum value for Y
YRATE	REAL	maximum variation for Y (in unit per second)

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	TS is forced to 1
BIT 1 = 1	ABS(KM) < 1.0 e^{-6}	KM is forced to +/- 1.0 e^{-6}
BIT 2 = 1	DM < 0	DM is forced to 0
BIT 3 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 4 = 1	YRATE < 0	YRATE is forced to 0
BIT 5 = 1	YMAX < YMIN	YMIN <-> YMAX and YRATE is forced to 0
BIT 6 = 1	TRBF < 0	TRBF is forced to 0
BIT 7 = 1	H < TS	H is forced to TS

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

PCR_ZTR: Zone Control with Non-Linear Time Response

9

Introduction

This chapter describes the PCR_ZTR EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	60
Detailed Description	62

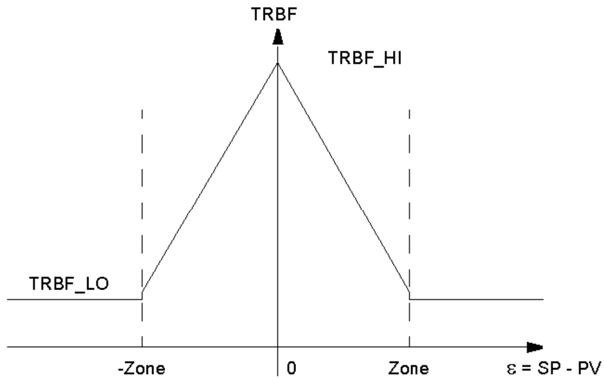
Brief Description

Function Description

PCR_ZTR is an EFB for changing automatically the closed-loop time-response (TRBF) when the process variable (PV) is inside or outside a zone.

PCR_ZTR algorithm is based on basic principle:
- When the PV is outside the zone, TRBF is set to TRBF_LO.
  The Controller will put the PV back inside the zone.
- When the PV is inside the zone, TRBF varies linearly between TRBF_LO and TRBF_HI as a function of the (PV-SP) deviation.

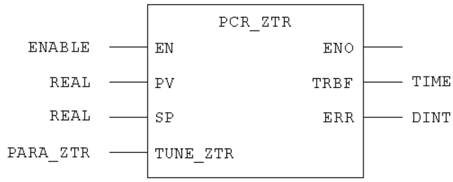
Evolution of TRBF



Additional parameters EN and ENO can be projected.

EN should be enabled at the control sampling time TS.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
PV	REAL	Process Variable
SP	REAL	Set Point value
TUNE_ZTR	PARA_ZTR	ZTR Parameters

Outputs

Parameter	Data Type	Meaning
TRBF	TIME	95% closed-loop response time
ERR	DINT	ERRor code

Type Description

PARA_ZTR: ZTR Parameters

Parameter	Data Type	Meaning
ZONE	REAL	ZONE value
TRBF_LO	TIME	TRBF LOw value
TRBF_HI	TIME	TRBF HIgh value

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TRBF_HI<TRBF_LO	TRBF_HI is set to TRBF_LO
BIT 1 = 1	ZONE < 0	ZONE is set to 0

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

Detailed Description

Principles

The zone control is a way to obtain a smoother controller when the PV is rather close to its set point in order to avoid active control actions produced by noisy measurements.

The controller is thus less active than when the PV is far from the set point. This technique is not equivalent to a dead zone which does not act as long as the PV is within the dead zone.

The zone control does not leave any constant deviation. It will make the PV move back slowly to the set point value.

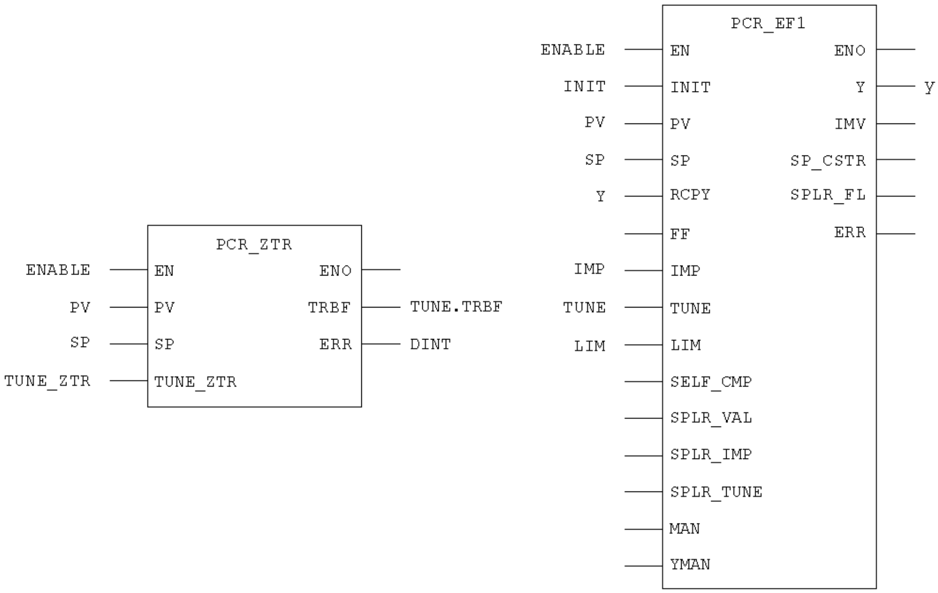
- When PV is outside the zone, the TRBF is set to TRBF_LO (fastest response).
- When PV is inside the zone, TRBF is computed as follows:
  - TRBF = TRBF_HI - (TRBF_HI - TRBF_LO) x |EPS| / ZONE
  - with: EPS = SP - PV

This continuous variation of TRBF with EPS avoids bumps when crossing the zone borders and makes the controller strength proportional to the deviation.

The output TRBF is to be one of the parameters of the PARA_PCR_TUNE of a controller block.

Usage

Use of zone control with an PCR_EF1 block



PCR_FIL: Rate Limiter Filter

10

Introduction

This chapter describes the PCR_FIL EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	66
Detailed Description	68

Brief Description

Function Description

The PCR_FIL block limits the first derivative of a signal passing through it.

The input is supposed to be generated at a sampling period TS1 which is a multiple of the period TS0 of a block using it downward.

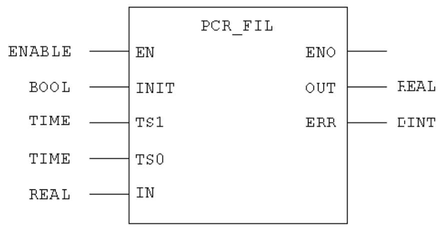
For instance, TS1 is the period of a master controller and TS0 the period of a slave controller.

The output signal joins the new input by (TS1/TS0) small steps.

Additional parameters EN and ENO can be projected.

EN should be enabled at the control sampling time TS.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	Command for INITialization if TRUE
TS1	TIME	sampling period of the block generating the IN signal
TS0	TIME	sampling period of the block using the OUT signal
IN	REAL	signal to be filtered

Outputs

Parameter	Data Type	Meaning
OUT	REAL	filtered signal
ERR	DINT	ERRor code

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS1 < TS0	TS1 is forced to TS0, so OUT=IN
BIT 1 = 1	(TS1 / TS0) > 128	The OUT joins the new IN in 128 sampling TS0.

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

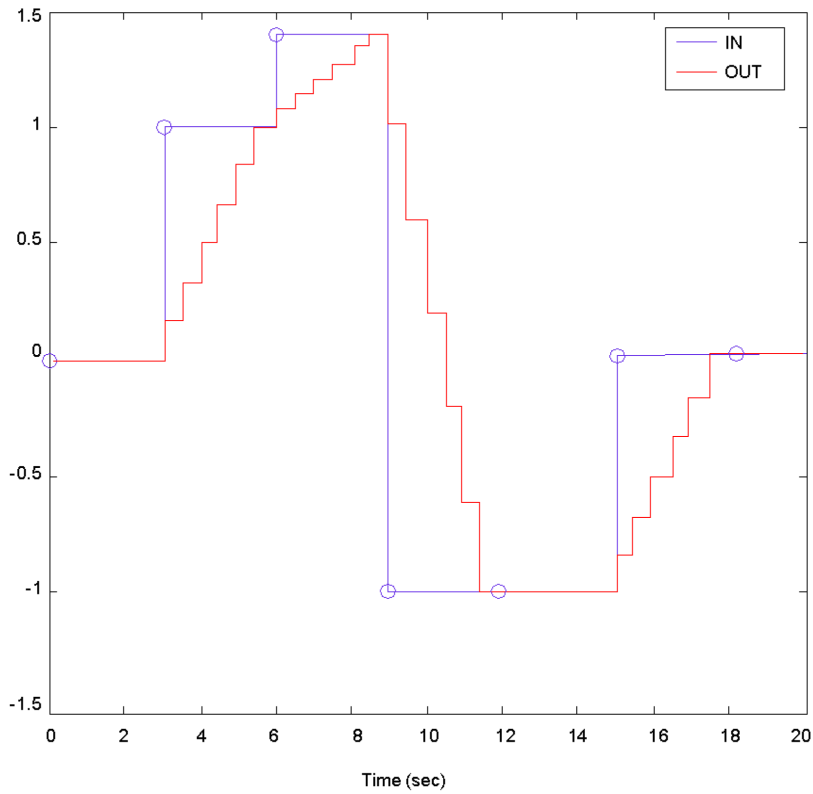
Detailed Description

Principles

The output is generated by a meaning filter working at period `TS0`, according to the equation below:

$$OUT(n) = \frac{IN(n) + IN(n\text{-}1) + ... + IN(n\text{-}R\text{+}1)}{R} \qquad \text{with:} \quad R = TS1 / TS0$$

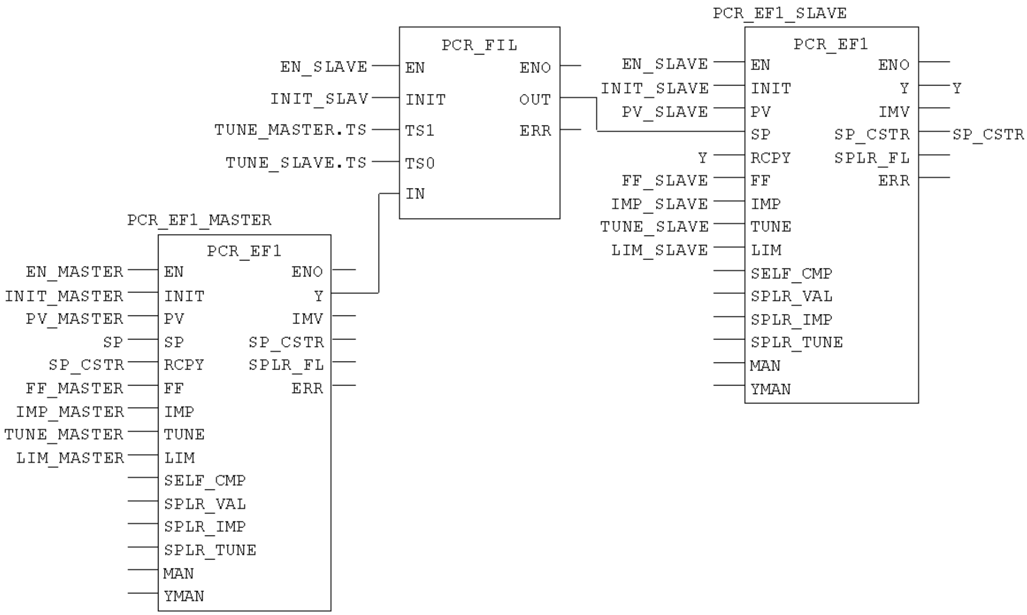
See below an example with a ratio R between the periods equal to 6:



PCR_FIL with: TS1 = 3 s and TS0 = 0.5 s

Usage

Use of `PCR_FIL`



PCR_RSP: Ramp and Docking Set Point Generator

11

Brief Description

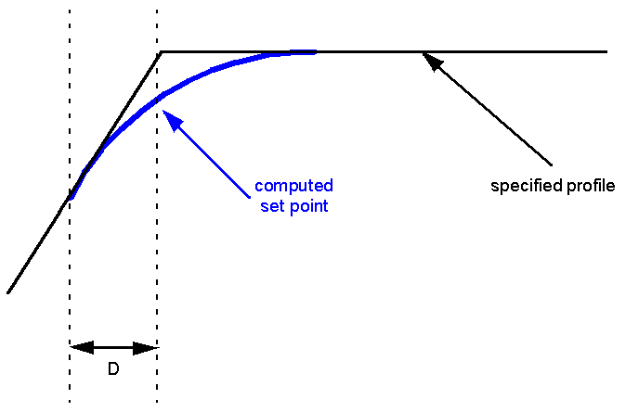
Function Description

`PCR_RSP` is an EFB to compute ramp and docking set points necessary for PCR_RD1 EFB *(see page 53)*, from a recipe table.

A recipe table is a set point profile composed of several breaking points (up to 15).

Each of them is defined by 3 values (T: time, V: value, D: docking horizon).

The docking horizon represents the length of the rounded target before and after the breaking point.



`PCR_RSP` algorithm provides 4 set points each time:
- SP: docking set point at current time
- SP_PRED: structure which contains 2 predictive docking set points
  - SPH1: future set point at H1 time
  - SH2: future set point at H2 time
- SPRAMP: set point at current time without docking

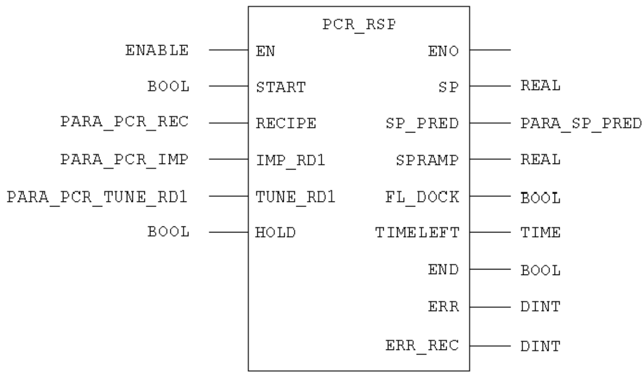
The algorithm is designed for real time use:
- the profile specifications may be modified in real time during the progress of the profile but such modifications are to be avoided during the docking phases
- capability to switch to standby mode in order to manipulate the controller set point manually
- bumping minimization on the docked set points in case the target is modified by the user
- delivery of complementary information:
  - remaining time before the next docking
  - flag `FL_DOCK` set to TRUE when the present time is a 'sensitive' period (if the local target is modified now, the computed set points may bump)
  - flag `END` set to TRUE when at the end of the recipe

Additional parameters `EN` and `ENO` can be projected.

`EN` should be enabled at the control sampling time TS.

NOTE: For this EFB, the sampling period TS must be a multiple of 1 second and cannot be decimal.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
START	BOOL	block activation
RECIPE	PARA_PCR_REC	profile defined by the recipe
IMP	PARA_PCR_IMP	Internal Model Parameters of associated PCR_RD1 block
TUNE_RD1	PARA_PCR_ TUNE_RD1	TUNing parameters of the PCR_RD1 controller
HOLD	BOOL	block status FALSE -> active, TRUE -> standby

Outputs

Parameter	Data Type	Meaning
SP	REAL	Set Point value
SP_PRED	PARA_SP_PRED	PREDicted Set Point values
SPRAMP	REAL	raw Set Point value
FL_DOCK	BOOL	Flag: set to TRUE when the docked set point values are being computed. Changing the target when FL_DOCK=TRUE may cause bumps on the set point.
TIMELEFT	TIME	remaining time before the next docking
END	BOOL	TRUE = the profile is completed
ERR	DINT	ERRor code
ERR_REC	DINT	ERRor code on the profile

Type Description

PARA_PCR_REC: profile to be fulfilled

Parameter	Data Type	Meaning
NPOINT	INT	Number of POINTs
TABPT	ARRAY[15] of PARA_RECIPE	profile

PARA_RECIPE: point defining the profile

Parameter	Data Type	Meaning
T	TIME	Time to reach the point
V	REAL	Value of the point
D	TIME	Docking horizon

PARA_PCR_IMP: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM	TIME	time constant
DM	TIME	pure time delay

PARA_PCR_TUNE_RD1: Predictive control TUNing parameters

Parameter	Data Type	Meaning
TS	TIME	sampling time
H1	TIME	1st coincidence point
H2	TIME	2nd coincidence point
TRBF	TIME	95% closed-loop response time

PARA_PCR_PRED: PREDicted set points values

Parameter	Data Type	Meaning
SPH1	REAL	Set Point at current time + H1
SPH2	REAL	Set Point at current time + H2

Runtime Errors

Invalid setting on the block

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	block in stop mode (START is set to FALSE)
BIT 1 = 1	H1 < TS	H1 is forced to TS
BIT 2 = 1	H2 < TS	H2 is forced to TS
BIT 3 = 1	H2 <= H1	H2 is forced to H1 + TS

Invalid setting on the profile

ERR_REC Bit	Meaning	Behavior
BIT 0 = 1	RECIPE.NPOINT > 15	RECIPE.NPOINT set to 15
BIT 1 = 1	TABPT[0].T < Ts	TABPT[0].T set to Ts
BIT 2 = 1	TABPT[0].D>(TABPT[0].T/2)	TABPT[0].D set to(TABPT[0].T/2)
...	...	...
BIT 2*NPOINT-1 = 1	TABPT[NPOINT-1].T < Ts	TABPT[NPOINT-1].T set to Ts
BIT 2*NPOINT = 1	TABPT[NPOINT-1].D >(TABPT[NPOINT-1].T/2	TABPT[NPOINT-1].D set to (TABPT[NPOINT-1].T/2)

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

PCR_FF1: Model for First Order Feed-Forward Compensation

12

Introduction

This chapter describes the PCR_FF1 EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	78
Detailed Description	81

Brief Description

Function Description

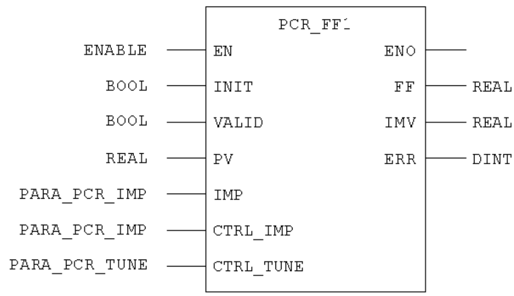
PCR_FF1 computes a compensation value to be applied to the controller in order to compensate a first order disturbance:

- As input, this block receives:
  - the parameters of the disturbance model
  - the controller model and tuning parameters
- As output, this block computes the feed forward compensation to be applied to the controller.

Additional parameters EN and ENO can be projected.

EN should be enabled at the control sampling time TS.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	command for model INITialization if TRUE
VALID	BOOL	VALIDation of disturbance compensation if TRUE
PV	REAL	Process Variable (measured disturbance)
IMP	PARA_PCR_IMP	Internal Model Parameters for disturbance
CTRL_IMP	PARA_PCR_IMP	Internal Model Parameters of ConTRoLler
CTRL_TUNE	PARA_PCR_TUNE	TUNing Parameters of ConTRoLler

Outputs

Parameter	Data Type	Meaning
FF	REAL	Feed-Forward compensation
IMV	REAL	Internal Model Value disturbance value estimated by model
ERR	DINT	ERRor code

Type Description

PARA_PCR_IMP: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM	TIME	time constant
DM	TIME	pure time delay

PARA_PCR_TUNE: Predictive control TUNing parameters

Parameter	Data Type	Meaning
TS	TIME	sampling time
H	TIME	coincidence point
TRBF	TIME	95% closed-loop response time

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	TS is forced to 1
BIT 2 = 1	disturbance DM < 0	disturbance DM is forced to 0
BIT 3 = 1	disturbance DM >127 * TS	disturbance DM is forced to 127 * TS
BIT 4 = 1	DM < 0	DM is forced to 0
BIT 5 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 6 = 1	TRBF < 0	TRBF is forced to 0
BIT 7 = 1	H < TS	H is forced to TS

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

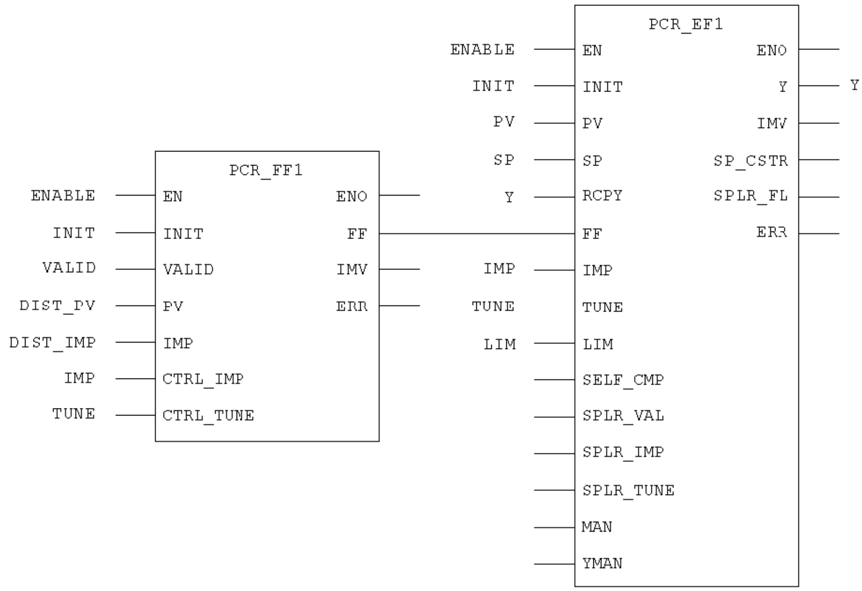
Detailed Description

Usage

The block is used as shown below:

- PCR_FF1 computes the effect of the disturbance DIST_PV on the process output PV
- PCR_EF1 computes the action Y, taking account the disturbance effect.

Example of feed-forward configuration, using PCR_FF1 and PCR_EF1 blocks



PCR_IFF1: Model for Feed-Forward Compensation Used with Integrative First Order System

13

Introduction

This chapter describes the PCR_IFF1 EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	84
Detailed Description	87

Brief Description

Function Description

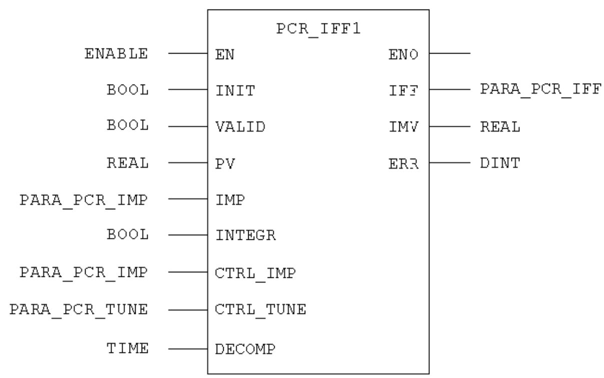
PCR_IFF1 computes a compensation value to be applied to the controller of an integrative first order process, in order to compensate a first order disturbance integrative or not.

- As input, this block receives:
  - the parameters of the disturbance model
  - the controller model and tuning parameters
- As output, this block computes the feed forward compensation to apply to the controller.

Additional parameters EN and ENO can be projected.

EN should be enabled at the control sampling time TS.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
INIT	BOOL	command for model INITialization if TRUE
VALID	BOOL	VALIDation of disturbance compensation if TRUE
PV	REAL	Process Variable (measured disturbance)
IMP	PARA_PCR_IMP	Internal Model Parameters for disturbance
INTEGR	BOOL	TRUE = the disturbance model is INTEGRative
CTRL_IMP	PARA_PCR_IMP	Internal Model Parameters of ConTRoLler
CTRL_TUNE	PARA_PCR_TUNE	TUNing Parameters of controller
DECOMP	TIME	DECOMPosition time constant

Outputs

Parameter	Data Type	Meaning
IFF	PARA_PCR_IFF	Feed-Forward compensation
IMV	REAL	Internal Model Value disturbance value estimated by model
ERR	DINT	ERRor code

Type Description

PARA_PCR_IMP: Internal Model Parameters

Parameter	Data Type	Meaning
KM	REAL	static gain
TM	TIME	time constant
DM	TIME	pure time delay

PARA_PCR_TUNE: Predictive control TUNing parameters

Parameter	Data Type	Meaning
TS	TIME	sampling time
H	TIME	coincidence point
TRBF	TIME	95% closed-loop response time

PARA_PCR_IFF: Feed-Forward Compensation

Parameter	Data Type	Meaning
IFF1	REAL	Feed-Forward compensation for process output estimation
IFF2	REAL	Feed-Forward compensation at the coincidence point

Runtime Errors

ERR Bit	Meaning	Behavior
BIT 0 = 1	TS = 0	TS is forced to 1
BIT 2 = 1	disturbance DM < 0	disturbance DM is forced to 0
BIT 3 = 1	disturbance DM >127*TS	disturbance DM is forced to 127 * TS
BIT 4 = 1	DM < 0	DM is forced to 0
BIT 5 = 1	DM > 127 * TS	DM is forced to 127 * TS
BIT 6 = 1	TRBF < 0	TRBF is forced to 0
BIT 7 = 1	H < TS	H is forced to TS

The runtime error system uses binary type outputs (power of 2). So you can detect several runtime errors occurring at the same time. The output number is the sum of all ERR bits.

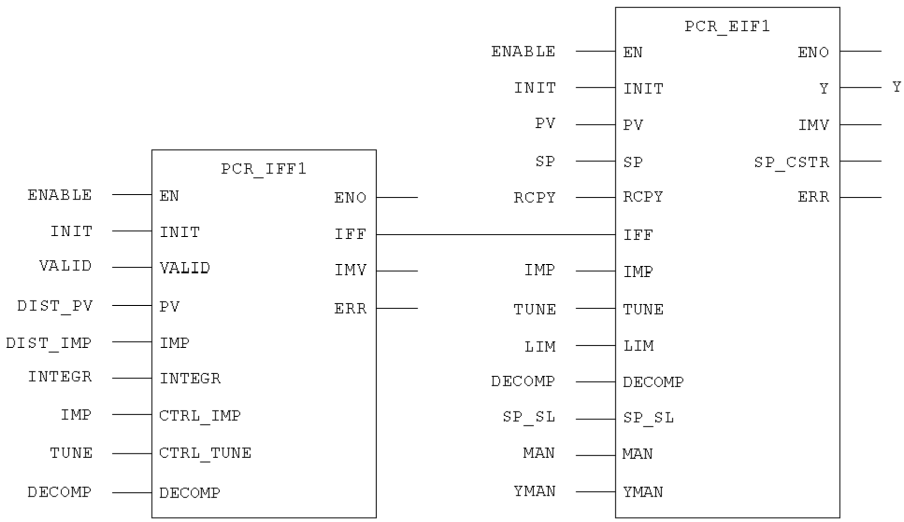
Detailed Description

Usage

The block is used as shown below:

- PCR_IFF1 computes the effect of the disturbance DIST_PV on the process output PV
- PCR_EIF1 computes the action Y, taking account the disturbance effect.

Example of feed-forward configuration, using PCR_IFF1 and PCR_EIF1 blocks



PCR_SR1: Supervisor for 2 Controllers in Split Range Configuration

14

Introduction

This chapter describes the PCR_SR1 EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	90
Detailed Description	92

Brief Description

Function Description

Here the target system has 2 manipulated variables and 1 controlled output.

The 2 actuators (for instance cooling and heating) can be manipulated separately for controlling the same process output (for instance temperature).

The PCR solution uses 2 separate PCR_EF1 controllers, each of them being dedicated to the specific dynamic of its own manipulated variable.

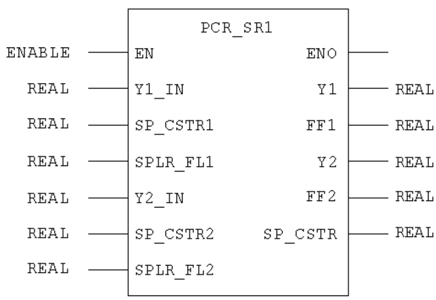
The complementary block PCR_SR1 selects which of the 2 calculated MVs is to be applied.

PCR_SR1 receives the actions calculated by the 2 controllers and informs both controllers of final decided action.

Additional parameters EN and ENO can be projected.

EN should be enabled at the control sampling time TS.

Representation



Parameter Description

Inputs

Parameter	Data Type	Meaning
Y1_IN	REAL	manipulated variable Y from controller 1
SP_CSTR1	REAL	SP_CSTR from controller 1
SPLR_FL1	REAL	feed back value from controller 1
Y2_IN	REAL	manipulated variable Y from controller 2
SP_CSTR2	REAL	SP_CSTR from controller 2
SPLR_FL2	REAL	feed back value from controller 2

Outputs

Parameter	Data Type	Meaning
Y1	REAL	manipulated variable Y for actuator 1
FF1	REAL	feed-forward value toward controller 1
Y2	REAL	manipulated variable Y for actuator 2
FF2	REAL	feed-forward value toward controller 2
SP_CSTR	REAL	Set Point transferred to upper level

Detailed Description

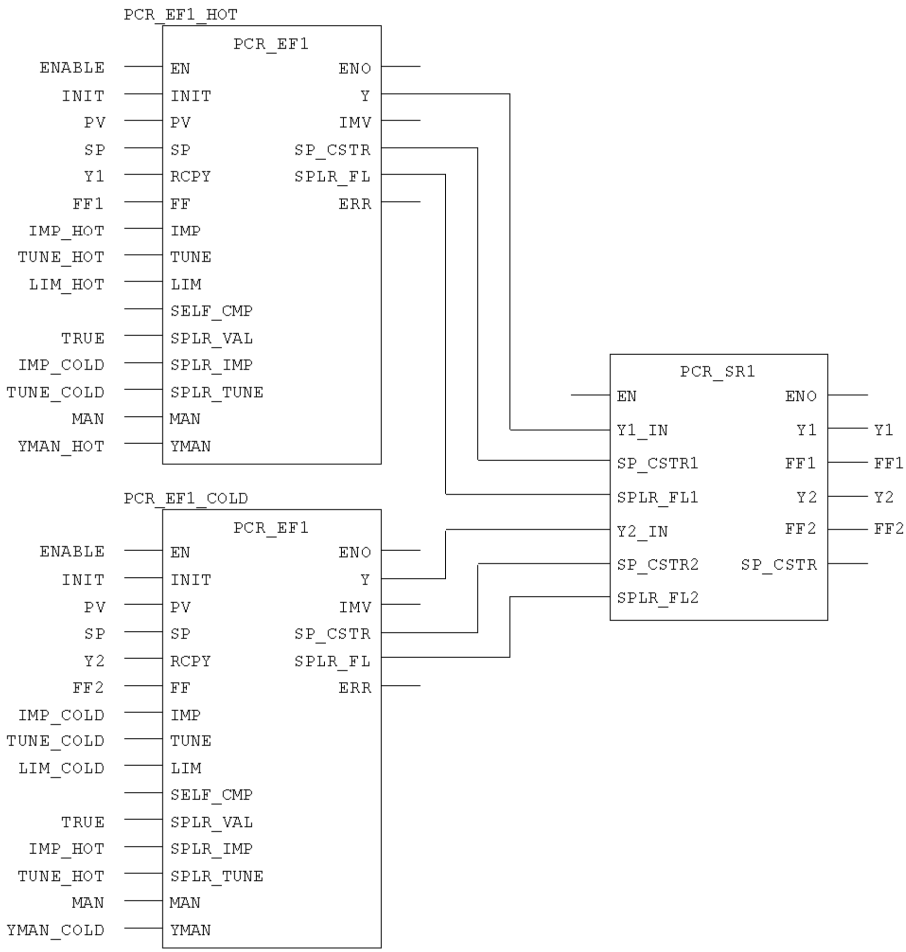
Usage

An example of the structure is represented below.

The configuration involves 3 blocks:

- 2 PCR_EF1 compute the action Y on each subsystem (cooling and heating for instance)
- PCR_SR1 chooses the final decision from past actions and from both controller demands

Configuration of PCR_EF1 in split-range control systems



Principles

The target is to control the PV by 1 of the 2 actuators (for instance heating or cooling).

As the model explaining the PV is usually different for each action, a specific controller is used to compute separately each of the 2 actions (the cooling action and the heating one).

Since only 1 actuator can be active at a time (the inactive one is equal to 0), the supervisor has to decide which action (heating or cooling) must be applied.

When 1 action is equal to 0.0, the action to be applied is the positive action.

The critical cases are when both actions are positive. In that case the action computed by the last active controller is applied.

A flag is used to remember which controller is working (heating or cooling).

Detailed Logic

The logic is detailed in the following table.

Split range logic with minimum constraints equal to 0.0

-	**Status of Calculated MV**		**Flag Active**	**Decision of Supervisor**			
Case	**Y1_IN**	**Y2_IN**	**0 -> controller 1** **1 -> controller 2**	**Y1**	**Y2**	**SP_CSTR**	**Flag**
1	+	0.0	0/1	Y1_IN	0.0	SP_CSTR1	0
2	0.0	+	1/0	0.0	Y2_IN	SP_CSTR2	1
3	0.0	0.0	0	0.0	0.0	SP_CSTR1	0
4	0.0	0.0	1	0.0	0.0	SP_CSTR2	1
5	+	+	0	Y1_IN	0.0	SP_CSTR1	0
6	+	+	1	0.0	Y2_IN	SP_CSTR2	1

The 2 feed-forward outputs are given by:

- FF1 = SPLR_FL2
  FF2 = SPLR_FL1

PCR_ESR1: Enhanced Split Range Supervisor with Min Constraints Different from Zero

15

Introduction

This chapter describes the PCR_ESR1 EFB.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Brief Description	96
Detailed Description	100

Brief Description

Function Description

In most cases the min constraints of the actuators are 0%, but one can meet applications for which these constraints are different from zero.

In the version of the PCR split range described in the previous section *(see page 89)*, the logical block `PCR_SR1` assumes that both min constraints are zero.

Then the control block (for example "hot controller") currently computing the action to be applied, considers that the other action (for example "cold valve") is closed.

The prediction based on that assumption (for example cold valve position = 0 and hot valve position being computed) gets wrong if the min constraint of the "non-active" controller (for example "cold controller") is not zero.

In order to take the non-zero min constraints into account, the `PCR_ESR1` split-range block is created, having 2 complementary inputs (the limitations `LIM1` and `LIM2` on the manipulated variables of both controllers), since the logical rule is now based on min constraints that are different from zero.

Additional parameters `EN` and `ENO` can be projected.

`EN` should be enabled at the control sampling time TS.

Note for Time-Varying Min Constraints

This version works correctly if the min constraints are different from zero, but as long as these min constraints are kept constant.

If the min constraint values were to be modified in real time, then one should pay attention for the following reason:

The blocks architecture is such that any min constraint value modification will be taken into account with 1 control period delay.

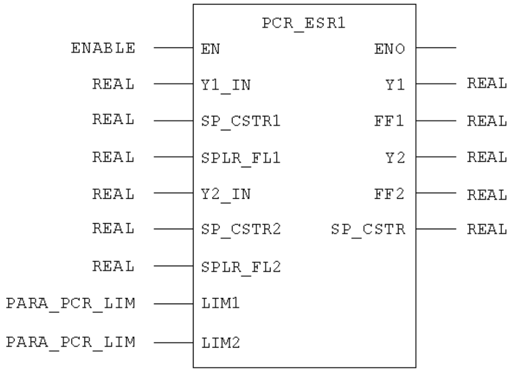
This delay produces a non measured disturbance for 1 sampling period.

The magnitude of the effect depends on the size of the constraint value modification which should be limited.Therefore, it is recommended that a ramping is applied to the min constraints in order to slow down the change and minimize the non desired effect.

A closed loop simulation could help select the magnitude of each acceptable min constraint step and, consequently, define the slope of the ramp.

The experience of this situation shows that ramping the min constraints is acceptable because these constraints are not modified frequently on a given unit.

Representation

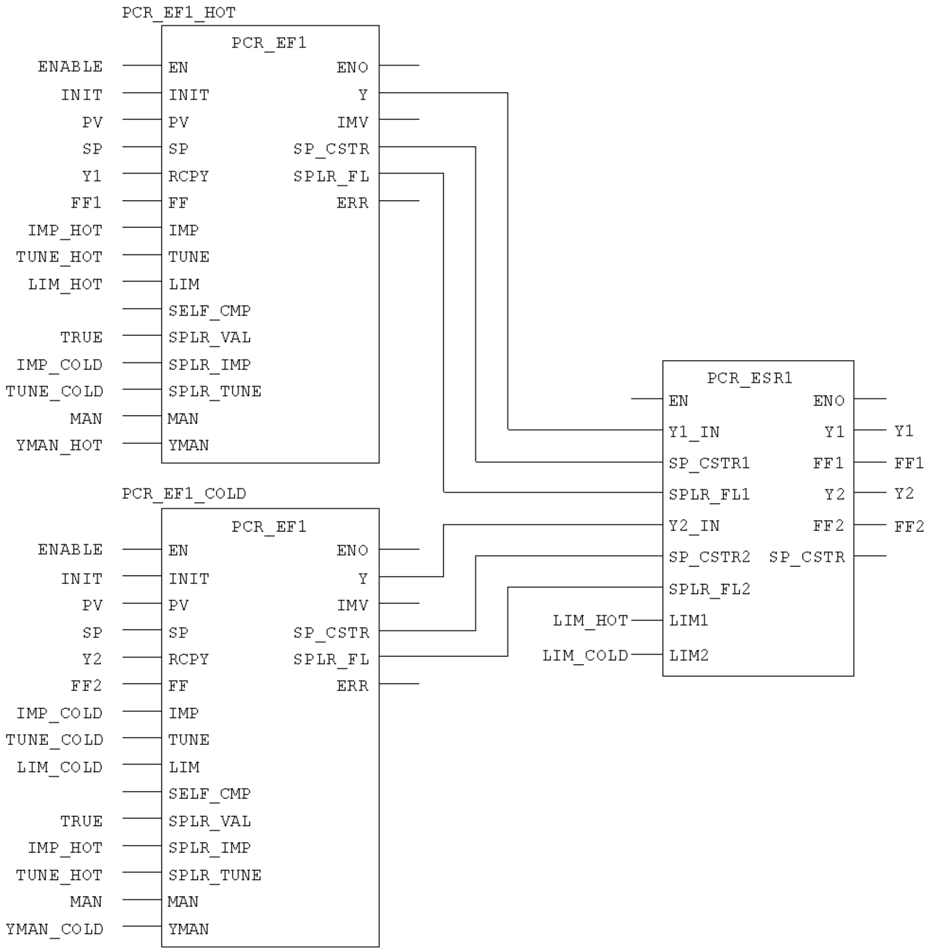


Usage

The PCR_ESR1 block has to be used with 2 PCR_EF1 blocks, as shown below:

- 2 PCR_EF1, each one computes the action Y on each subsystem (cooling and heating for instance)
- PCR_ESR1 chooses the final decision from past actions and from both controller demands.

Example of split range configuration, using PCR_EF1 and PCR_ESR1 blocks



Parameter Description

Inputs

Parameter	Data Type	Meaning
Y1_IN	REAL	manipulated variable Y from controller 1
SP_CSTR1	REAL	SP_CSTR from controller 1
SPLR_FL1	REAL	feed back value from controller 1
Y2_IN	REAL	manipulated variable Y from controller 2
SP_CSTR2	REAL	SP_CSTR from controller 2
SPLR_FL2	REAL	feed back value from controller 2
LIM1	PARA_PCR_LIM	LIMitations on manipulated variable of controller 1
LIM2	PARA_PCR_LIM	LIMitations on manipulated variable of controller 2

Outputs

Parameter	Data Type	Meaning
Y1	REAL	manipulated variable Y for actuator 1
FF1	REAL	Feed-Forward value toward controller 1
Y2	REAL	manipulated variable Y for actuator 2
FF2	REAL	Feed-Forward value toward controller 2
SP_CSTR	REAL	Set Point transferred to upper level

Type Description

PARA_PCR_LIM: LIMitations on manipulated variable Y

Parameter	Data Type	Meaning
YMIN	REAL	MINimum value for Y
YMAX	REAL	MAXimum value for Y
YRATE	REAL	maximum variation for Y (in unit per second)

Detailed Description

Principles

The target is to control the PV by 1 of the 2 actuators (for instance heating or cooling).

As the model explaining the PV is usually different for each action, a specific controller is used to compute separately each of the 2 actions (the cooling action and the heating one).

Since only 1 actuator can be active at a time (the inactive one is equal to its minimum constraint), the supervisor has to decide which action (heating or cooling) must be applied.

When 1 action is equal to its min constraint, the action to be applied is the other one.

The critical cases are when both actions are greater than their min constraints. In that case the action computed by the last active controller is applied.

A flag is used to remember which controller is working (heating or cooling).

Detailed Logic

The logic is detailed in the following table.

Split range logic with non-zero min constraints

-	**Status of Calculated MV**		**Flag Active**	**Decision of Supervisor**			
Case	Y1_IN	Y2_IN	**0 -> controller 1** **1 -> controller 2**	**Y1**	**Y2**	**SP_CSTR**	**Flag**
1	> YMIN1	YMIN2	0/1	Y1_IN	YMIN2	SP_CSTR1	0
2	YMIN1	> YMIN2	1/0	YMIN1	Y2_IN	SP_CSTR2	1
3	YMIN1	YMIN2	0	YMIN1	YMIN2	SP_CSTR1	0
4	YMIN1	YMIN2	1	YMIN1	YMIN2	SP_CSTR2	1
5	> YMIN1	> YMIN2	0	Y1_IN	YMIN2	SP_CSTR1	0
6	> YMIN1	> YMIN2	1	YMIN1	Y2_IN	SP_CSTR2	1

The 2 feed-forward outputs are given by:

- FF1 = SPLR_FL2
  FF2 = SPLR_FL1

Index

A

availability of the PCR EFBs, *13*, *14*

C

Concept with Predictive Control library, *12*

G

general information
    predictive control, *15*

P

PCR EFBs
    availability, *13*, *14*
    PCR_DC3, *55*
    PCR_EF1, *29*
    PCR_EIF1, *41*
    PCR_ESR1, *95*
    PCR_FF1, *77*
    PCR_FIL, *65*
    PCR_IF1, *37*
    PCR_IFF1, *83*
    PCR_RD1, *47*
    PCR_RSP, *71*
    PCR_SF1, *23*
    PCR_SR1, *89*
    PCR_ZTR, *59*
PCR_DC3, *55*
PCR_EF1, *29*
PCR_EIF1, *41*
PCR_ESR1, *95*
PCR_FF1, *77*
PCR_FIL, *65*
PCR_IF1, *37*
PCR_IFF1, *83*
PCR_RD1, *47*
PCR_RSP, *71*
PCR_SF1, *23*
PCR_SR1, *89*
PCR_ZTR, *59*
predictive control
    general information, *15*
    general principles, *16*
Predictive Control description, *18*
Predictive Control library with Unity Pro or Concept, *12*
principles
    predictive control, *16*

U

Unity Pro with Predictive Control library, *12*