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TRANSPOWER

P3_E_B1_0341_XDC_A
Aconex No. of Document - Rev.

Pole Control

Training Manual

Benmore Converter Station
Haywards Converter Station

=11VR01+VR1
=11VR02+VR2
=12VR01+VR1
=12VR02+VR2

=21VR01+VR1
=21VR02+VR2
=22VR01+VR1
=22VR02+VR2

New Zealand Inter Island HVDC Pole 3 Project **700 MW**
Transpower New Zealand Ltd. **Contract: P3/CT001**

Index of Revisions

Rev.	Date	Revisions	Name of Reviser	Name of Approver
0	04 Oct 2012	Initial Document	Zeiner	Zimmer
A	07 Nov 2012	For Construction	Zeiner	Zimmer

Siemens AG, Energy Sector - Power Transmission Solutions

Index:

NOTE

- The information in this Manual does not purport to cover all details or variations in equipment, nor to provide for every possible contingency to be met in connection with installation, operation or maintenance.
- Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, please contact your local Siemens office.
- Further, the contents of this Manual shall not become a part of nor modify any prior or existing agreement, commitment or relationship. The sales contract contains the entire obligation of Siemens. The warranty contained in the contract between the parties is the sole warranty of Siemens. Any statements contained herein do not create new warranties nor modify the existing warranty.

1 General Information

This document describes the training for the Pole Control Systems installed in the cubicles

=11VR01+VR1
=11VR02+VR2
=12VR01+VR1
=12VR02+VR2
at Haywards station and

=21VR01+VR1
=21VR02+VR2
=22VR01+VR1
=22VR02+VR2
at Benmore station.

2 Reference Documents

The following documents should be available and known by the trainees:

System Information Manual ....Doc. No.: E_B2_0341_XDC
Maintenance Manual...Doc. No.: E_B4_0341_XDC
C&P Hardware Drawings ....Doc. No.: E_C2_0341_XDC
Single line diagram ....Doc. No.: E_C1_0801_HAY
Single line diagram ....Doc. No.: E_C1_0801_BEN

3 Training Program

- Abbreviations
- Equipment Data
- Safety Instructions

Part 1 - Overview

- Overview Hardware and Software
- Redundancy Functions
- Interfaces
- Sequence of Event Recording

Part 2 – Open Closed Loop

- Principles of HVDC Operation and Control
- Pole Control Functions
- Converter Status of Operation
- Start/Stop Sequences
- Converter Level Sequences
- Converter Tap Changer Control
- DC Filter Sequences
- Switch Gear Control
- Interface Pole Control System and VBE Pole 2

Part 3 - Maintenance

- Installation of Application Software
- Maintenance
- Troubleshooting

4 Appendices

Appendix	Title
E_B1_0341_App1_XDC	Training Presentation Pole Control, Part 1 - Overview
E_B1_0341_App2_XDC	Training Presentation Pole Control, Part 2 - Open Closed Loop
E_B1_0341_App3_XDC	Training Presentation Pole Control, Part 3 - Maintenance

New Zealand
Inter Island HVDC Project Pole 3

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Training Pole Control Part 1 - Overview

E_B1_0341_App1_XDC

For Transpower internal use only

Disclaimer

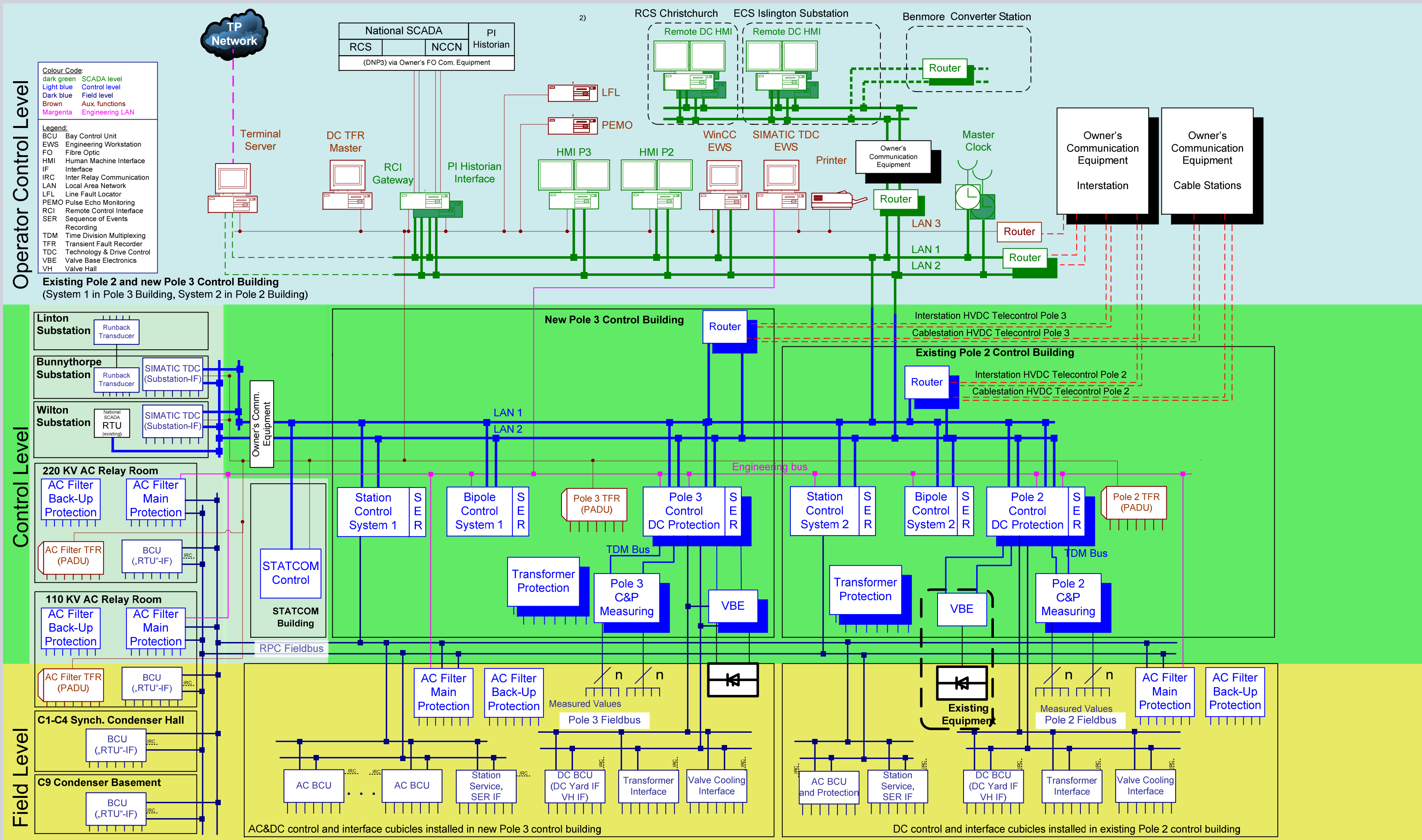
Slides are for training purpose only, they are prepared on a general basis and may not in all cases cover all project specific aspects. Project specifics will also be shown in the direct on site training and in the manuals. The manuals also contain important safety instructions which need to be studied before beginning of the maintenance and inspection activities.

Contents

Overview

Hardware / Software

Control System Hierarchy Haywards



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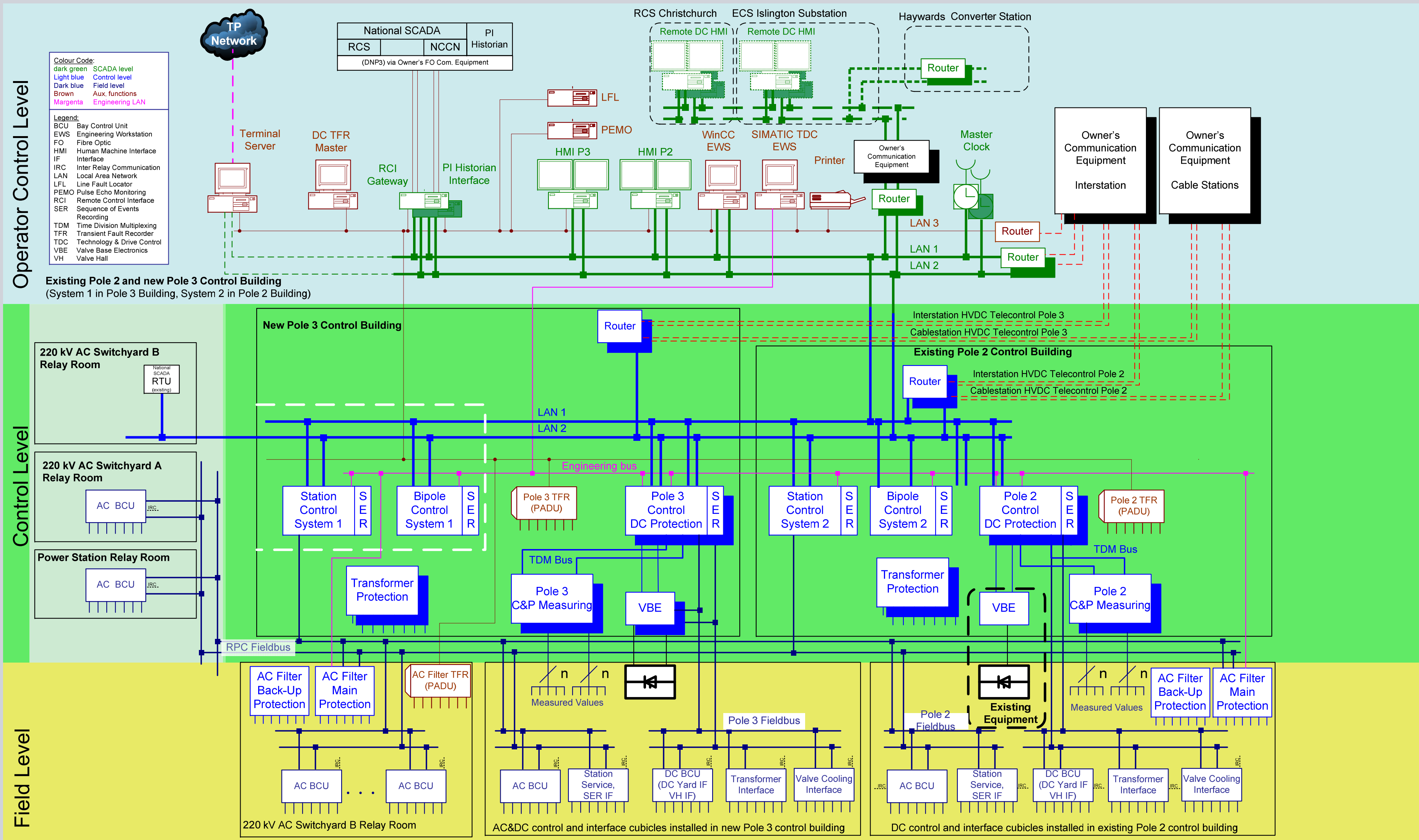
Control System Hierarchy Benmore



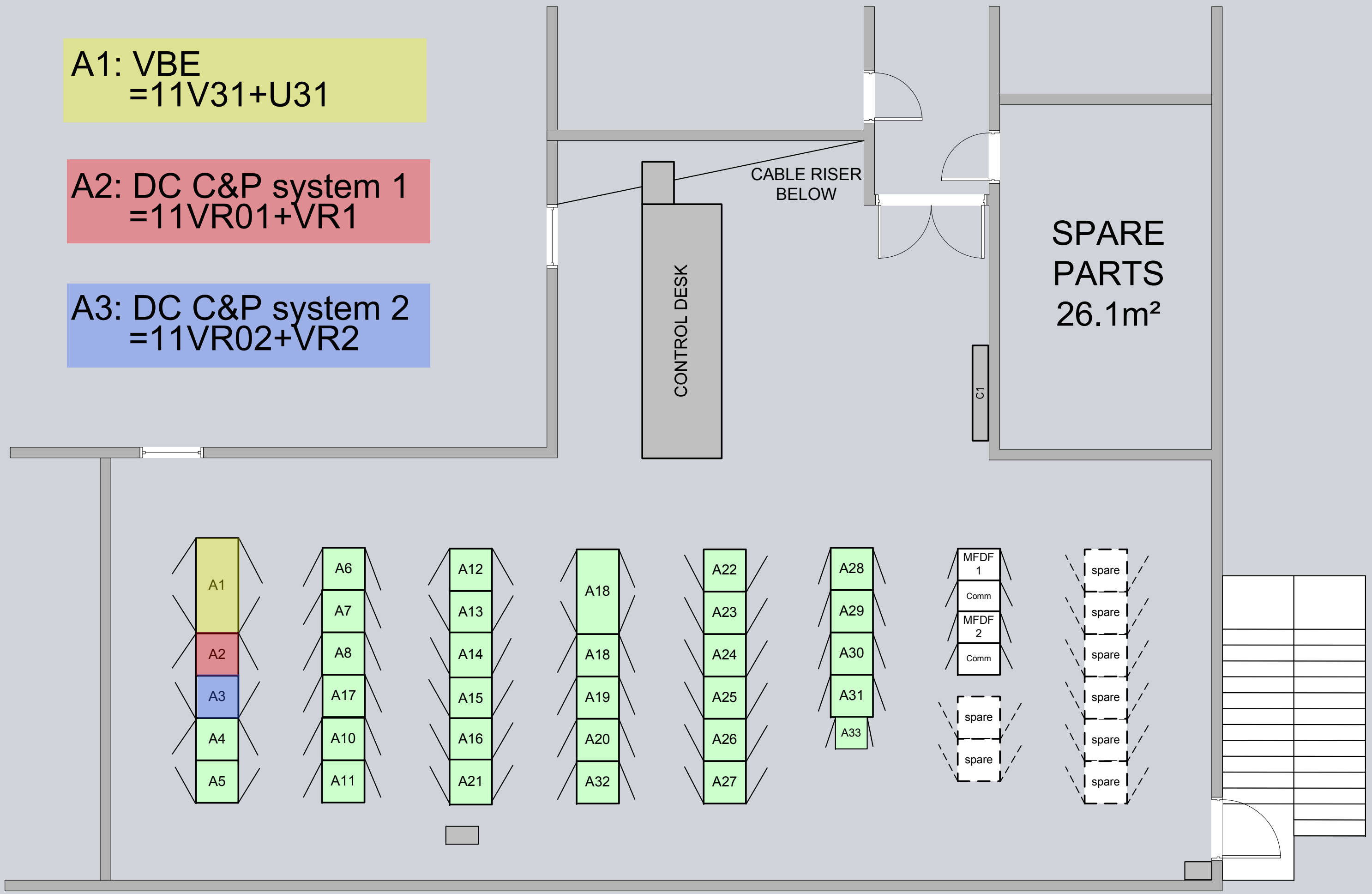
Location of Equipment in Control Room 1st Floor

HAYWARDS CONTROL ROOM POLE 3 (new)

A1: VBE
=11V31+U31

A2: DC C&P system 1
=11VR01+VR1

A3: DC C&P system 2
=11VR02+VR2



Location of Equipment in Control Room 1st Floor

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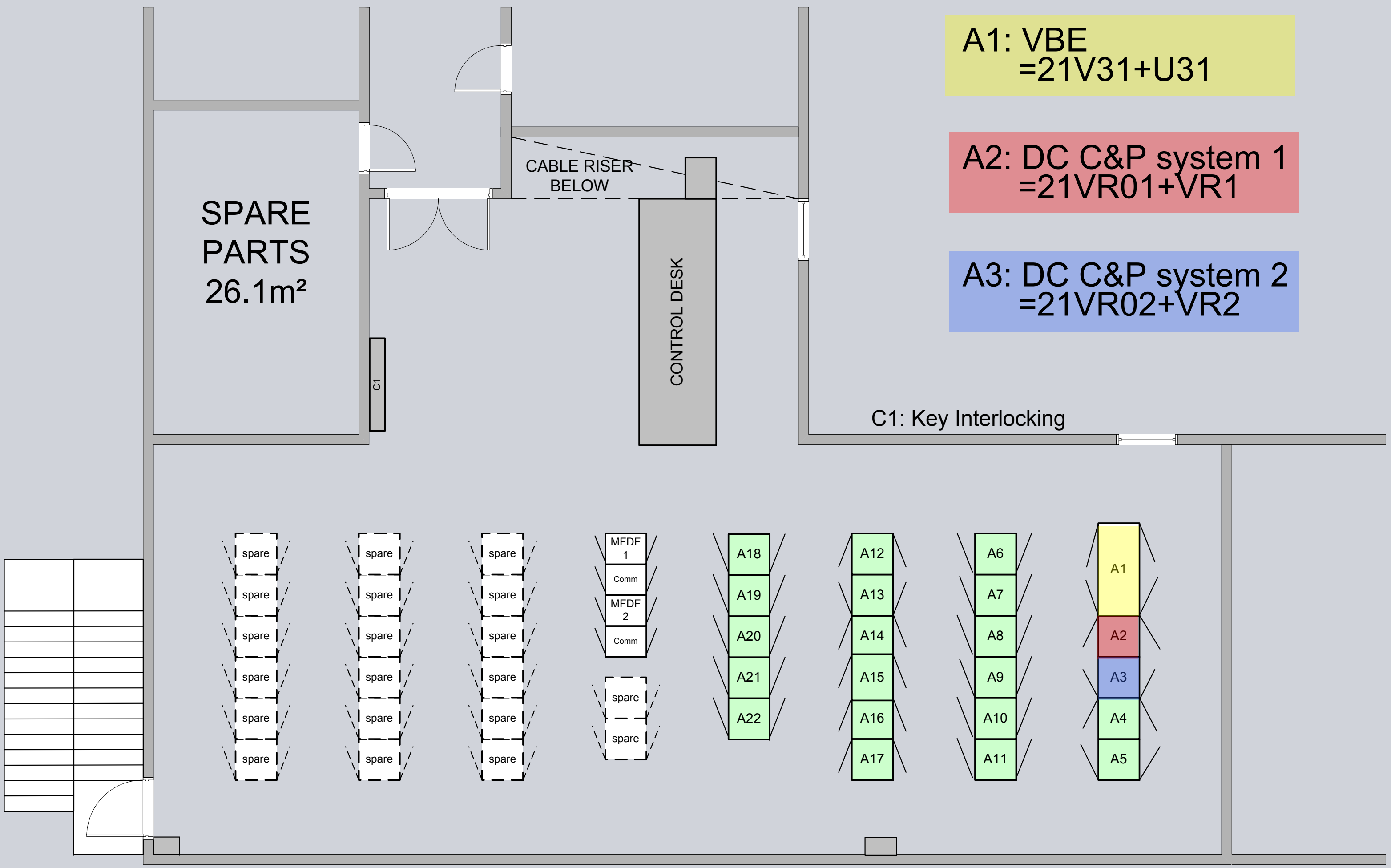
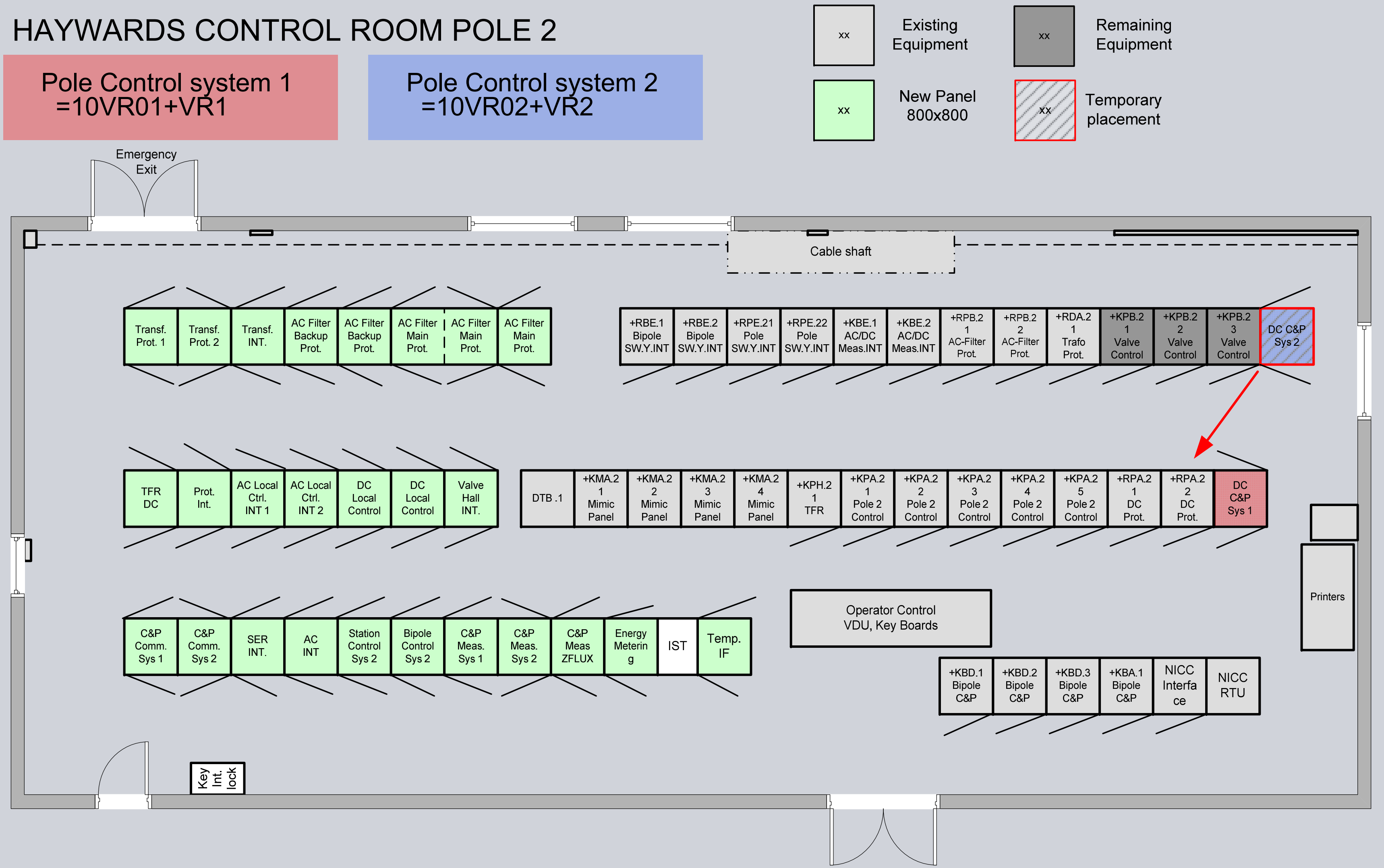
BENMORE CONTROL ROOM POLE 3 (new)



Location of Equipment in Pole 2 Control Room



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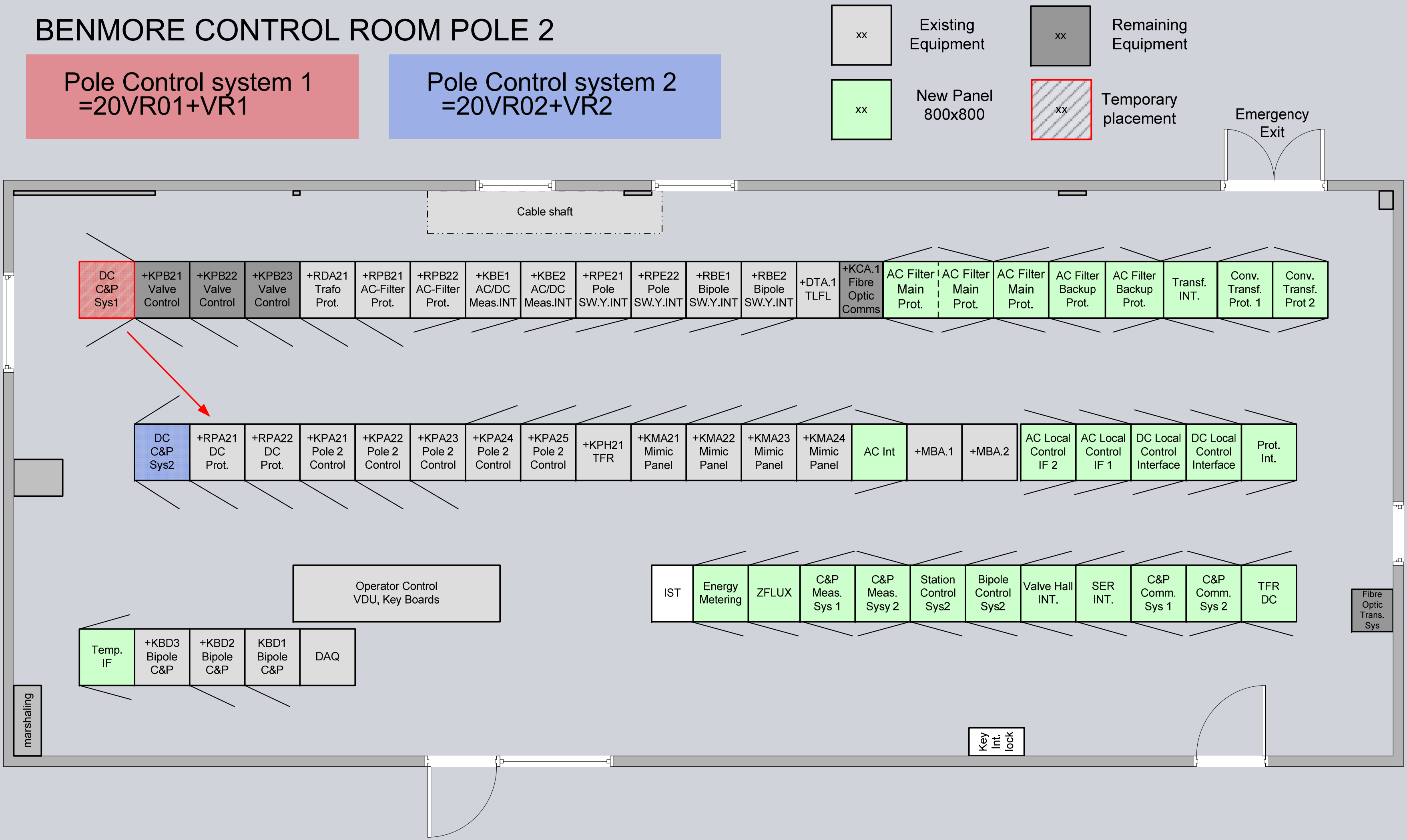
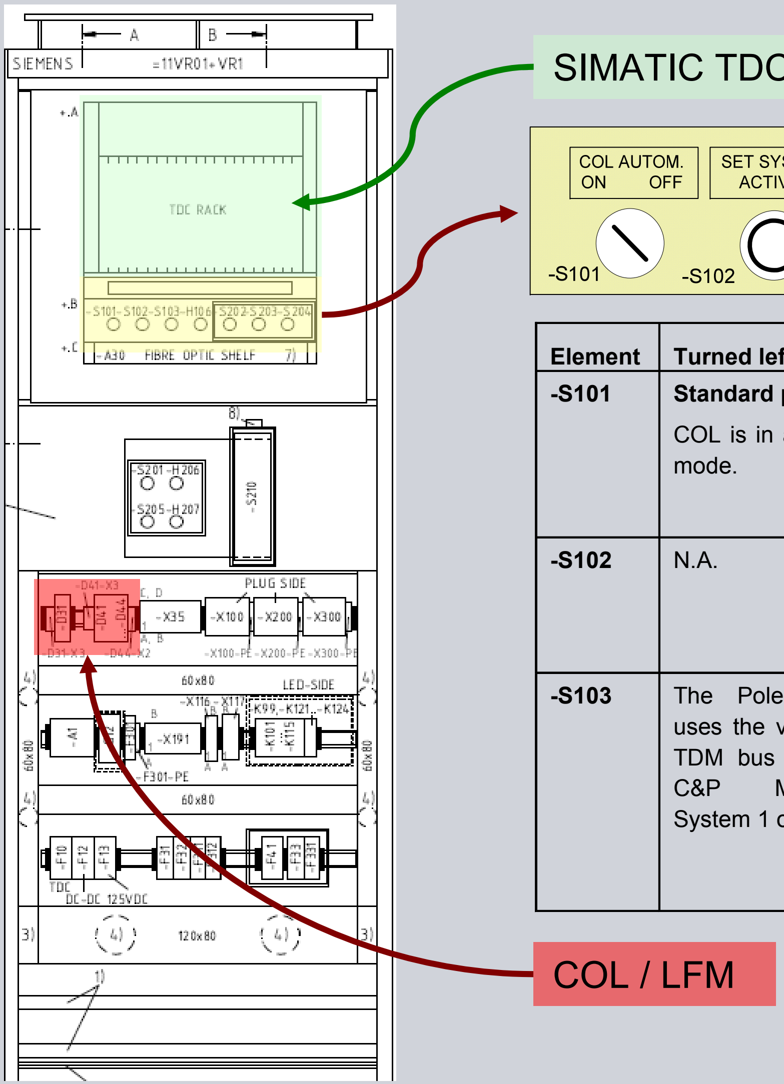
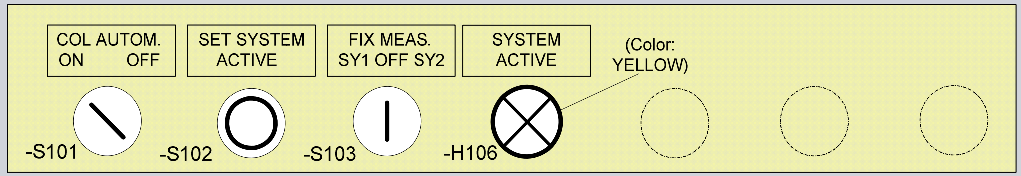
Location of Equipment in Pole 2 Control Room



DC Control and Protection Cubicle





Element	Turned left	Turned right	Middle Position	Pushed
-S101	**Standard position.** COL is in automatic mode.	Maintenance position. The COL is blocked. Changeover from one system to the other is not possible. Loss of redundancy!	N.A.	N.A.
-S102	N.A.	N.A.	N.A.	The Pole Control system of this cubicle will get active
-S103	The Pole Control uses the values via TDM bus from the C&P Measuring System 1 only.	The Pole Control uses the values via TDM bus from the C&P Measuring System 2 only.	**Standard position.** The Pole Control uses the values via TDM bus from the default C&P Measuring System. In case of faults the values from the other C&P Measuring System are used.	N.A.

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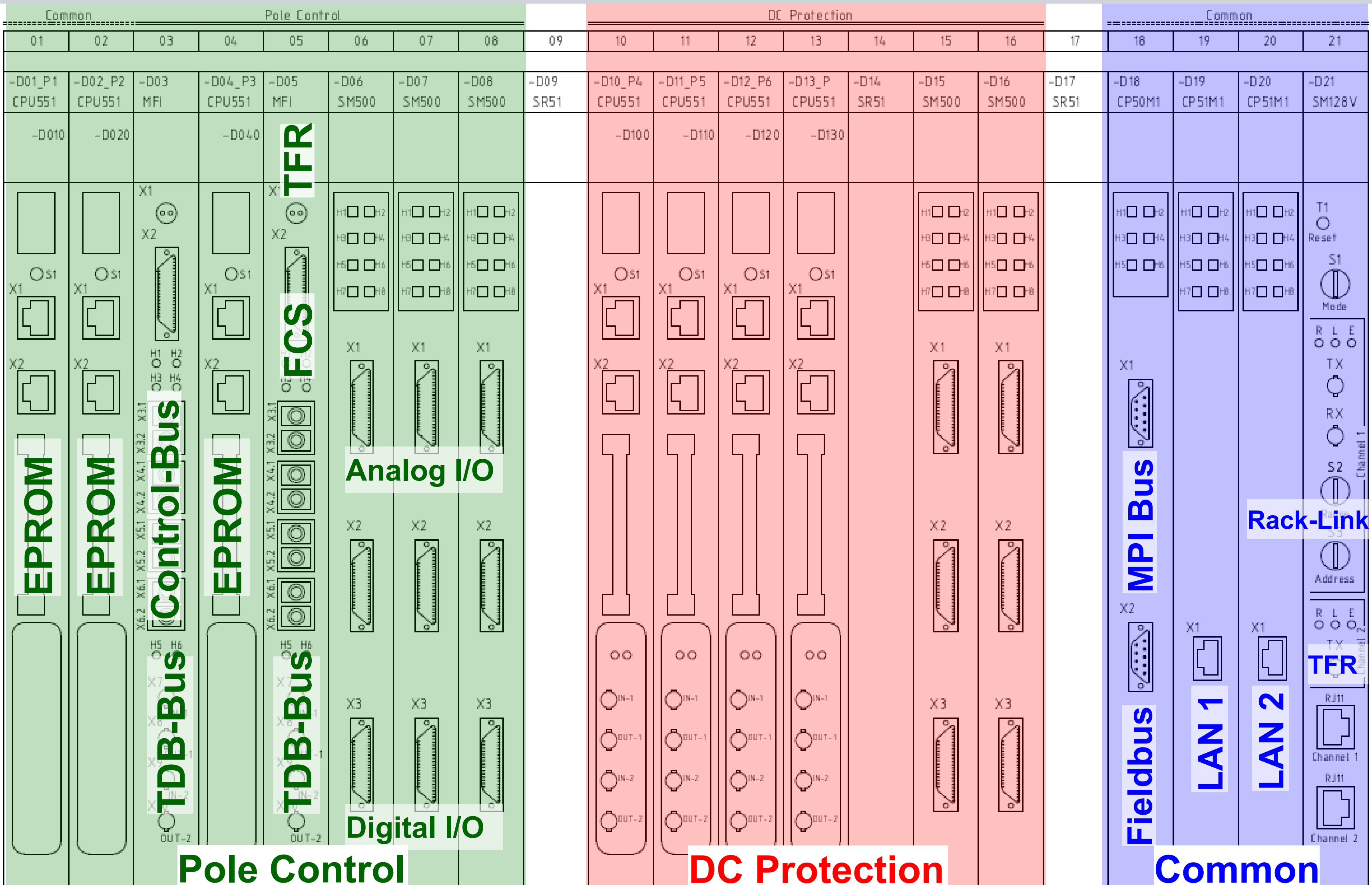
DC Control and Protection - Rack Arrangement



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Software Description - Functions

D01P01 CPU1	HVDC Telecontrol - Telecom Connection Configuration
	Binary and Analog Inputs - Hardwired and LAN
	Communication via Profibus
	COL - Change Over Logic
	Redundency Functions - Follow Up Pulses
D02P02 CPU2	Control Bus – to Bipole Control and other Pole
	TDM Bus – Measuring System
	Control of DC-Switch Yard
	DC Filter Control and Sequences
	Transformer and AC Bay Control
	Tap Changer Control
	Valve Cooling Control
	Valve Hall Control
	DC Configuration Monitoring – OLT, Ground Return, Station Ground, Isolated, Earthed
	DC Start / Stop Sequence
	Converter Status Pole Control – Energy Transfer Mode, Reduced Voltage, DC Line Fault
	POCAC_PC - Power Order Calculation for Stability Functions [AC]
	COCDC - Current Order Calculation for Manual Current Control
	COC_PC - Current Order Calculation (P by U Function)

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Software Description - Functions

D04P03 CPU3	Binary and Analog Data exchange with DC_Protection
	TDM Bus – Measuring System
	Converter Controls – Block Request, Rectifier Inverter Definition
	Current Order Limitation
	Closed Loop Control
Each CPU	Out to TFR
	Monitoring
	SER – Sequence of Event Recording
	Data exchange with Redundant System, Bipole Control, HMI and other Processors

Limits imposed by direction of power flow and by operation via station earth

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- Power Limitation by direction of power flow:
  - Pole 2: P_{lim} north = 700MW, U_{dc} = 350kV
    P_{lim} south = 666MW, U_{dc} = 342kV

- Current Limitation by Station Ground operation IdSG limit:
  - Benmore: I_{dSG} limit = 400A, P_{DC} = 140MW
  - Haywards: I_{dSG} limit = 180A, P_{DC} = 63MW
  - In monopole operation this is the limit for the operating pole, in bipolar operation this is the limit for the unbalance current.

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Pole Control Overview

General Functions:

- Serial communication
- Valve hall earthing switch control and valve hall interlocking
- DC Filter switchgear control
- DC Switchgear Control and Monitoring
- Cable Station Switchgear Control and Monitoring
- Monitoring of Valve cooling control

Pole Control Overview

Pole Level functions:

- Current Order Calculation (Pole individual I-mode)
- Power Order Calculator for pole level modulation controls
- Operating mode selection (P-mode /I-mode) / switchover features
- Pole-Pole Power Transfer (PPT)
- Current Order Setting Functions
- Pole Start / Stop Sequences
- DC filter control
- Open line test sequence
- Tap changer control
- Control switching devices in valve hall and DC filter

Pole Control Overview

- Converter Level Functions
  - DC voltage / current and extinction angle control
  - Triggerset and interface to thyristor valves via Valve Base Electronic
  - Subsynchronous resonances (SSR) damping control (if required)
  - Block / Deblock sequences
  - ESOF / FASOF sequences
  - DC line fault recovery sequences

- Pole Control Protective Functions
  - Excessive Firing Angle Protection
  - Open Line Test Failure
  - Remote Station Fault Detection
  - AC Undervoltage Monitoring
  - Commutation Failure Protection

Redundancy Functions

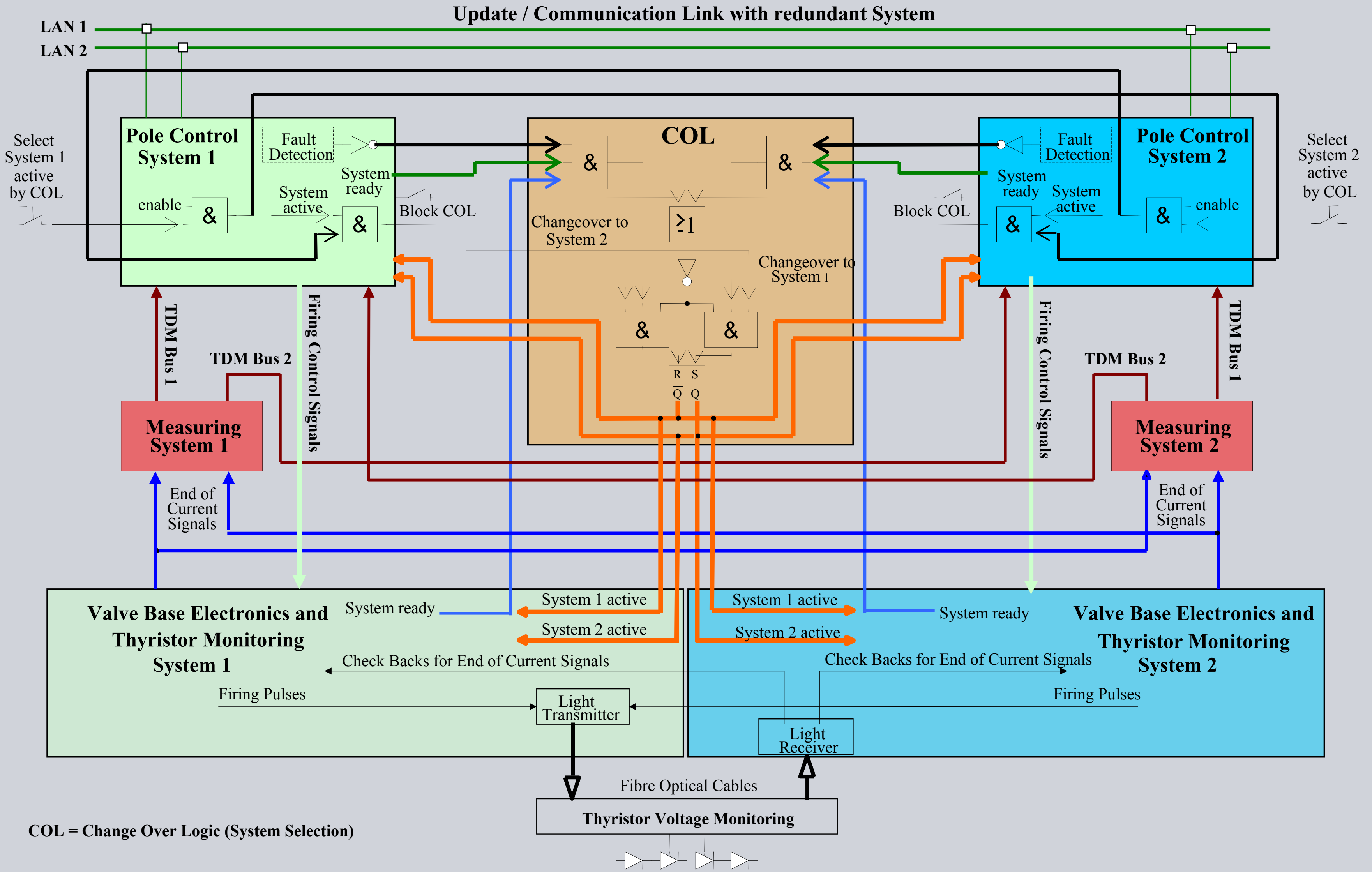
Redundancy Functions

- Two identical Pole Control Systems (system 1, system 2) for each pole
- All input signals are fed to both systems which evaluate these continuously and generate the required firing pulses
- The hot standby (passive) controller is updated by the data from the process (e.g. measured values, equipment status)
- Each Pole Control system receives measured values from both systems of the redundant C&P Measuring System via TDM bus → Cross-Redundancy
- Separate cubicles for system 1 and system 2, mechanically / electrically separated
  - Each rack with its own processor and I/O-boards,
  - Separate 125V DC power supplies
  - Separate changeover logic modules (COL / LFM)
- Hardwired binary output signals of both Pole Control systems are connected to the Logical Function Modules (LFM) which are controlled by the COL

Redundancy Functions

- The Changeover Logic (system selection function) ensures that at any given time only one Pole Control system actively controls the process.
- Binary and analogue output signals from both redundant Pole Control systems are sent to the TFR
- All hardware and software errors of both redundant systems are connected to the COL
- If both systems are faulty, the pole is shut down by the ESOF sequence
- Switchover to the hot-standby system can be initiated
  - Automatically by the self-monitoring function of the active control system
  - Manually by maintenance personal at the control cubicle. In case of a software warning on processor 1 of the passive system it is not possible to set that system as active. The cause of the software warning has to be solved first.

Redundancy Functions
COL / TDM-Bus / VBE Pole 3



COL = Change Over Logic (System Selection)

Redundancy Functions
COL / LFM / VBE Pole 3

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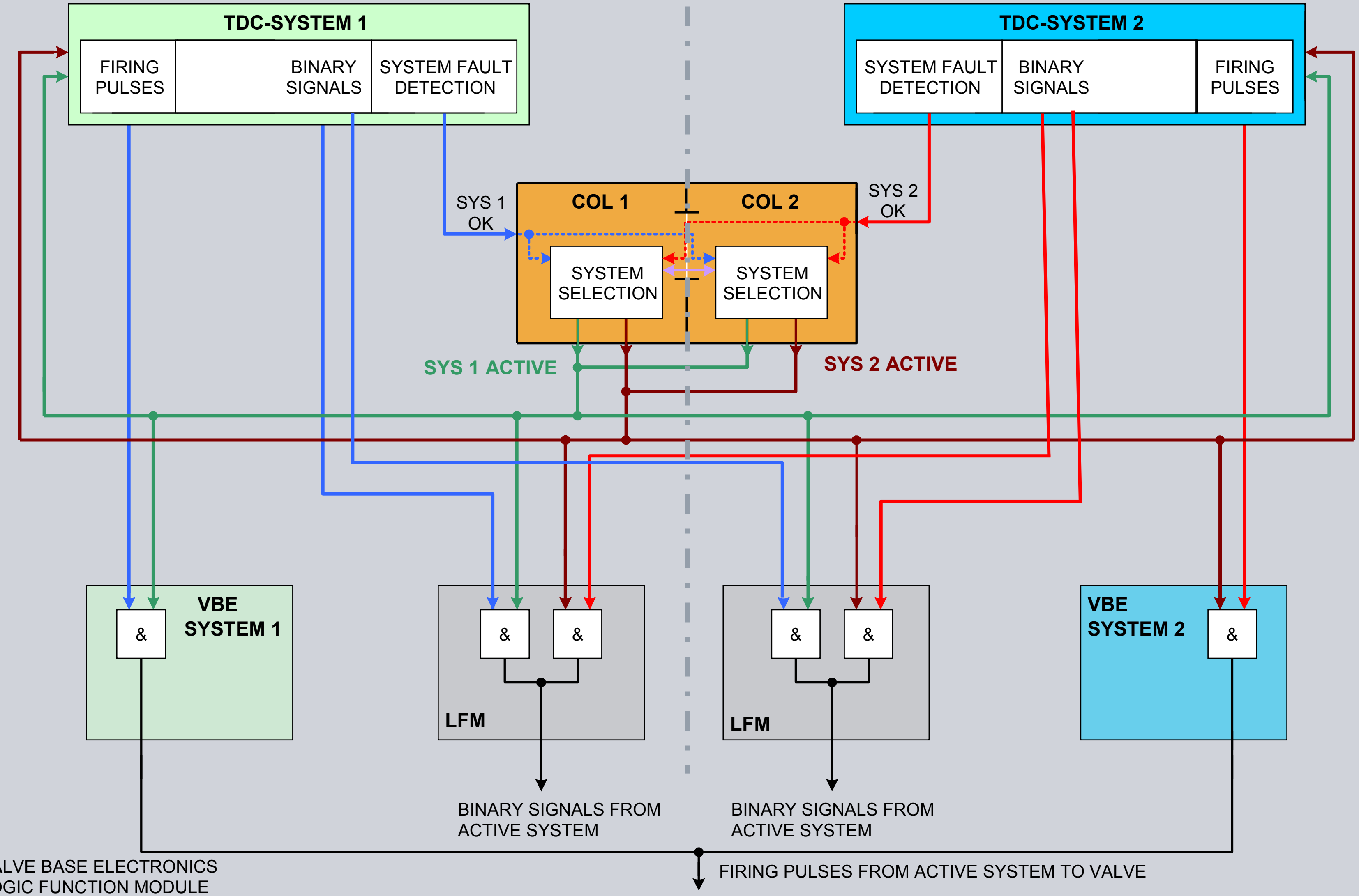

VBE VALVE BASE ELECTRONICS
LFM LOGIC FUNCTION MODULE
COL CHANGE OVER LOGIC

Redundancy Functions
Monitoring of LAN

- Communication monitoring by active and hot standby Pole Control system
- The Pole Control can detect the following faults:
  - CP51M1 communication module faults
  - Communication connection faults with communication partners

- For LAN status supervision, the Pole Control generates the following warning messages:
  - LAN communication disturbance
  - No communication with a given partner, neither via LAN1 nor LAN2
  - No communication to any partner via LAN1 (respectively LAN2)

Redundancy Functions
Monitoring of TDM Bus

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- C&P Measuring System transfers all measurement values via optical TDM bus to the Pole Control processors
- Detectable faults
  - Cyclic redundancy check (CRC) faults
  - Bus response timeout
  - At the Pole Control all valid information signals of the measured values used by the Pole Control are grouped to generate a combined fault status
  - Further checks are performed based on the valid bits to identify faulty or invalid measured values
- Redundancy switchover of the Measuring Systems does not affect the active / hot standby status of the Pole Controls
- Switch back to the default bus / Measuring System occurs automatically with a 1sec dead time when the default bus is healthy again
- If both redundant Measuring Systems or TDM busses are unavailable at the active Pole Control system a redundancy change-over to the standby system is initiated
- If the faults are persisting in the newly-active system after the redundancy change-over, the pole is tripped via ESOF.

Redundancy Functions
Monitoring of other Serial Communication Links

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- Communication monitoring by active and hot standby Pole Control system for
  - Fieldbus communication (CP50M1)
  - Control Bus communication to DC Bipole Control (MFI module)
  - Control Bus communication to Pole Control other pole (MFI module)
  - Rack Link communication to DC Protection redundant System (SM128V module)
- Based on the communication supervision active and passive system independently determine a communication fault status
- Switchover to passive system is carried out based on the communication fault status, i.e. passive system has a “better“ communication status than active system

Interfaces

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Binary Inputs

- Identifier Bit
- Binary Signal Voltage ok
- Active Status from COL
- Passive Status from COL
- System Ready from COL
- Redundant System Ready from COL
- TDM bus fixed on Measuring System 1
- TDM bus fixed on Measuring System 2
- COL blocked (Manual Mode)
- Valve Base Electronic Ready
- Converter Trip 1
- Select System active by COL pushbutton
- Abnormal Operating Range other system
- OLM Hardware OK (optical fieldbus)
- Trigger Signal from Simulator
- DC Protection own System outputs released
- DC Protection other System outputs released
- Converter Trip 2
- No ESOF Request from COL
- No ESOF Request from COL other System
- Block SW changeover (wait for LAN signals)

Binary Outputs

- Software OK Pole Control
- Changeover to other system
- Block SW changeover (wait for LAN signals)
- Abnormal operating range to other system
- ESOF by Pole Control SW
- Transformer Circuit Breaker closed
- Firing Pulses Enabled
- Firing Pulses not enabled
- AC Undervoltage 1P or MP (U AC < 30%)
- Converter De-energised to VBE Pole 2 only
- Neutral Area Control enabled

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Analog Inputs and Outputs / Alarm to SER

- Analog Inputs
  - Firing Angle other System

- Analog Outputs
  - Firing Angle (to other System)
  - Weighted Firing Signals for Diagnostic

- Alarms to SER
  - PC_HW_FLT
  - PC_TDC_SW_FLT
  - PC_LFM_FLT
  - PC_COL_BLOCKED
  - PC_SYS_1_ESOF
  - PC_SYS_1_ACTIVE

Other Interfaces

- Fieldbus (Switch Yard, Transformer Interface, Valve Cooling, VBE)
- Local Area Network (Interstation Telecontrol/Telecom, Own Station, Cable Station)
- TDM Bus (Measuring System)
- MPI Bus (Engineering Workstation)
- Control Bus (Other Pole, Bipole Control)
- Rack Link / TFR Link Communication via module SM128 (Other System, TFR)
- Time Synchronization

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Sequence of Event Recording

Sequence of Event Recording

Kind of Event	SER-Numbers	
Group Messages	Begin	00001
	End	00200
	Total No.	200
Hardware Messages (via 6MD66)	Begin	00201
	End	02520
	Total No.	2320
Pole Control Messages (Applicat.-SW)	Begin	02601
	End	05320
	Total No.	2720
DC Protection Messages (Applicat.-SW)	Begin	05321
	End	06472
	Total No.	1152
VBE	Begin	06501
	End	100000
	Total No.	3500

Offsets of SER Messages

Haywards Pole 3: 100000
Haywards Pole 2: 130000
Benmore Pole 3: 200000
Benmore Pole 2: 230000

Hardware Messages

Hardware messages are created and time-tagged if a binary input of the I/O unit BCU 6MD66 changes from LOW to HIGH or vice versa.

Software Messages

Software messages are created in all CPU units of SIMATIC TDC. These messages are time-tagged with the SIMATIC TDC system time, which has a resolution of 1 ms. The signals are sent via the LAN interface to the Operator Control Level.

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SER

Message List
Short Term
Long Term
Lock List
Scroll ON
Scroll OFF
local Speaker
Store Start Time
Store Stop Time
Set Filter Start Time
Set Filter Start & Stop Time
Reset Filter
only for commissioning
PM Open Export
CSV Export
Select Paper Format
A4 L
A4 P
0
SER Report
Filter:
R

...	Date	Time	Number	Device	Message text	Class	Status	FCT GRP	DLS	Duration
289	25/06/2012	22:12:33.112	234761	22VR00	EXTERNAL / PROT TRIP	EMCY	Ack-System	0		0:13:51
290	25/06/2012	22:12:33.113	234753	22VR00	CONV SUMMARY BLOCK REQUEST	STAT	+	0		0:00:00
291	25/06/2012	22:12:33.113	234761	22VR00	EXTERNAL / PROT TRIP	EMCY	+	0		0:00:00
292	25/06/2012	22:12:33.123	232494	22T00+R1	CONV LOCKOUT RELAY TC1 ENERGIZED	EMCY	Ack-System	0		0:13:51
293	25/06/2012	22:12:33.123	232495	22T00+R2	CONV LOCKOUT RELAY TC2 ENERGIZED	EMCY	Ack-System	0		0:13:51
294	25/06/2012	22:12:33.124	232494	22T00+R1	CONV LOCKOUT RELAY TC1 ENERGIZED	EMCY	+	0		0:00:00
295	25/06/2012	22:12:33.124	232495	22T00+R2	CONV LOCKOUT RELAY TC2 ENERGIZED	EMCY	+	0		0:00:00
296	25/06/2012	22:12:33.139	232454	20DB83-Q0	CONV TRANSF CB CLOSED	STAT	-	0		0:01:10
297	25/06/2012	22:12:33.155	250803	22X61+X1	TFR IS RECORDING	STAT	+	0		0:00:00
298	25/06/2012	22:12:33.171	232453	20DB83-Q0	CONV TRANSF CB OPEN	STAT	+	0		0:00:00
299	25/06/2012	22:12:33.175	233733	22VR00	START SEQUENCE RUNNING	STAT	-	0		0:01:17
300	25/06/2012	22:12:33.175	233734	22VR00	STOP SEQUENCE RUNNING	STAT	+	0		0:00:00
301	25/06/2012	22:12:33.226	150803	12X61+X1	TFR IS RECORDING	STAT	+	0		0:00:00
302	25/06/2012	22:12:33.234	250563	21X61+X1	TFR IS RECORDING	STAT	+	0		0:00:00
303	25/06/2012	22:12:33.302	233904	20DB83-Q0	CONV TRANSF CB GENERAL FAULT	WRN	Ack-System	0		0:13:51
304	25/06/2012	22:12:33.303	233742	22T01	TAP CHANGER ANGLE CONTROL	STAT	+	0		0:00:00
305	25/06/2012	22:12:33.303	233744	22T01	TAP CHANGER FORCED UDI0 MODE	STAT	-	0		0:01:10
306	25/06/2012	22:12:33.303	233904	20DB83-Q0	CONV TRANSF CB GENERAL FAULT	WRN	+	0		0:00:00
307	25/06/2012	22:12:33.319	150563	11X61+X1	TFR IS RECORDING	STAT	+	0		0:00:00
308	25/06/2012	22:12:33.708	133760	12T01	TAP CHANGERS AT POSITION 8	STAT_wo_go	#	0		0:00:00
309	25/06/2012	22:12:34.280	232136	22D04-Q9	DC LINE DS CLOSED	STAT	-	0		0:00:54
310	25/06/2012	22:12:35.693	250803	22X61+X1	TFR IS RECORDING	STAT	-	0		0:00:02
311	25/06/2012	22:12:35.714	150803	12X61+X1	TFR IS RECORDING	STAT	-	0		0:00:02
312	25/06/2012	22:12:35.737	250563	21X61+X1	TFR IS RECORDING	STAT	-	0		0:00:02
313	25/06/2012	22:12:35.822	150563	11X61+X1	TFR IS RECORDING	STAT	-	0		0:00:02
314	25/06/2012	22:12:37.975	233761	22T01	TAP CHANGERS AT POSITION 9	STAT_wo_go	#	0		0:00:00
315	25/06/2012	22:12:38.906	163975	10K11	SHUNT REACTOR 1 AUTO MODE	STAT	+	0		0:00:00
316	25/06/2012	22:12:38.906	165157	10K11	SHUNT REACTOR 1 AUTO MODE CMD	CMD_wo_go	#	0		0:00:00
317	25/06/2012	22:12:40.780	133761	12T01	TAP CHANGERS AT POSITION 9	STAT_wo_go	#	0		0:00:00
318	25/06/2012	22:12:47.184	164023	10K51-SC3	SYNC COND 3 BALANCE LOWER REQUEST	STAT_wo_go	#	0		0:00:00
319	25/06/2012	22:12:47.820	133762	12T01	TAP CHANGERS AT POSITION 10	STAT_wo_go	#	0		0:00:00
320	25/06/2012	22:12:50.283	232135	22D04-Q9	DC LINE DS OPEN	STAT	+	0		0:00:00
321	25/06/2012	22:12:52.620	250803	22X61+X1	TFR IS RECORDING	STAT	+	0		0:00:00
322	25/06/2012	22:12:52.700	250563	21X61+X1	TFR IS RECORDING	STAT	+	0		0:00:00

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Leading in HVDC Technology

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Inter Island HVDC Project Pole 3

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Training Pole Control
Part 2 - Open & Closed Loop

E_B1_0341_App2_XDC

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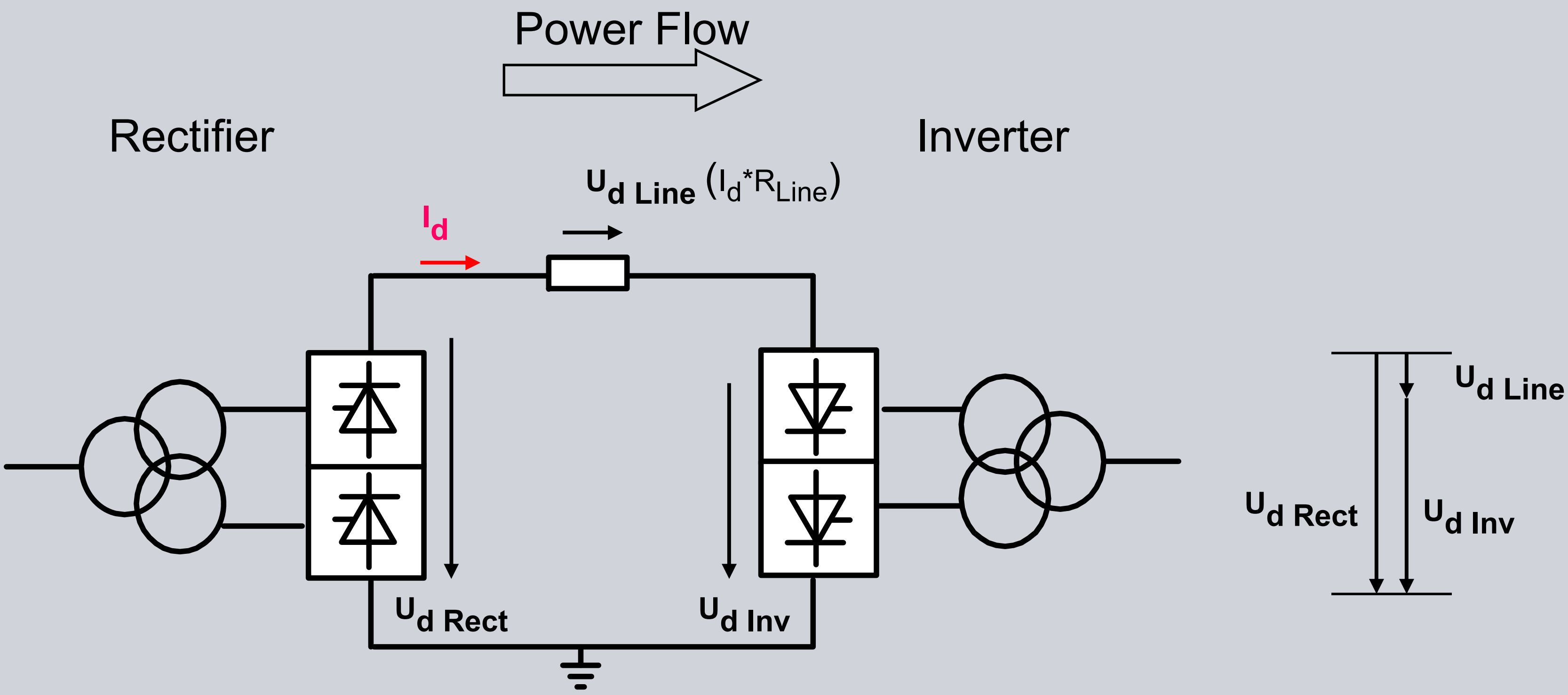
Contents

- Principles of HVDC Operation and Control
- Pole Control Functions
- Converter Status
- Start- / Stop Sequences
- Tap changer Control
- DC Filter Switching Sequences
- Switchgear Interlocking
- Interface Pole Control System and existing Pole 2 VBE

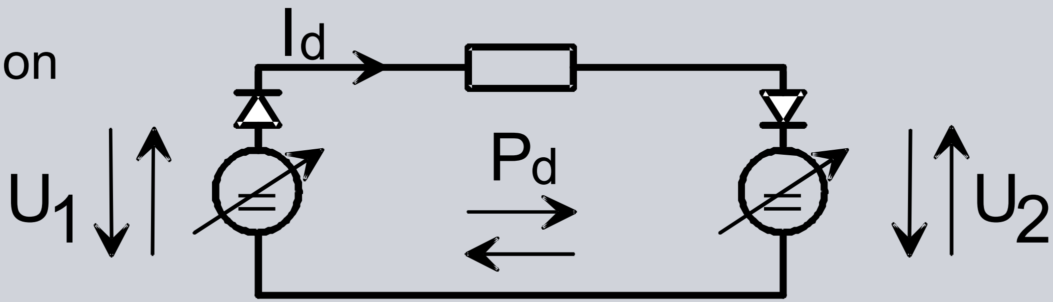
Principles of HVDC Operation and Control

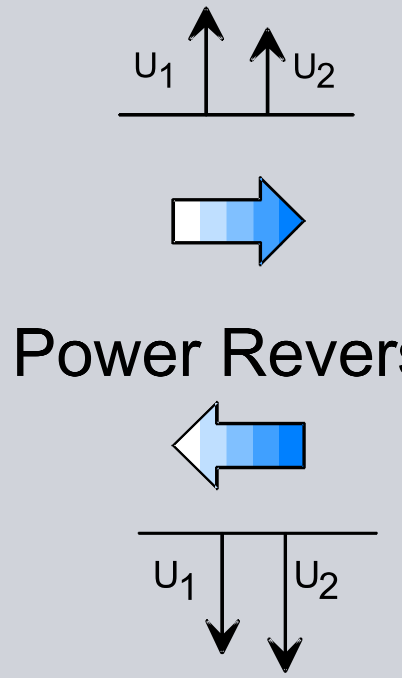
DC Circuit Variables



Control of Powerflow

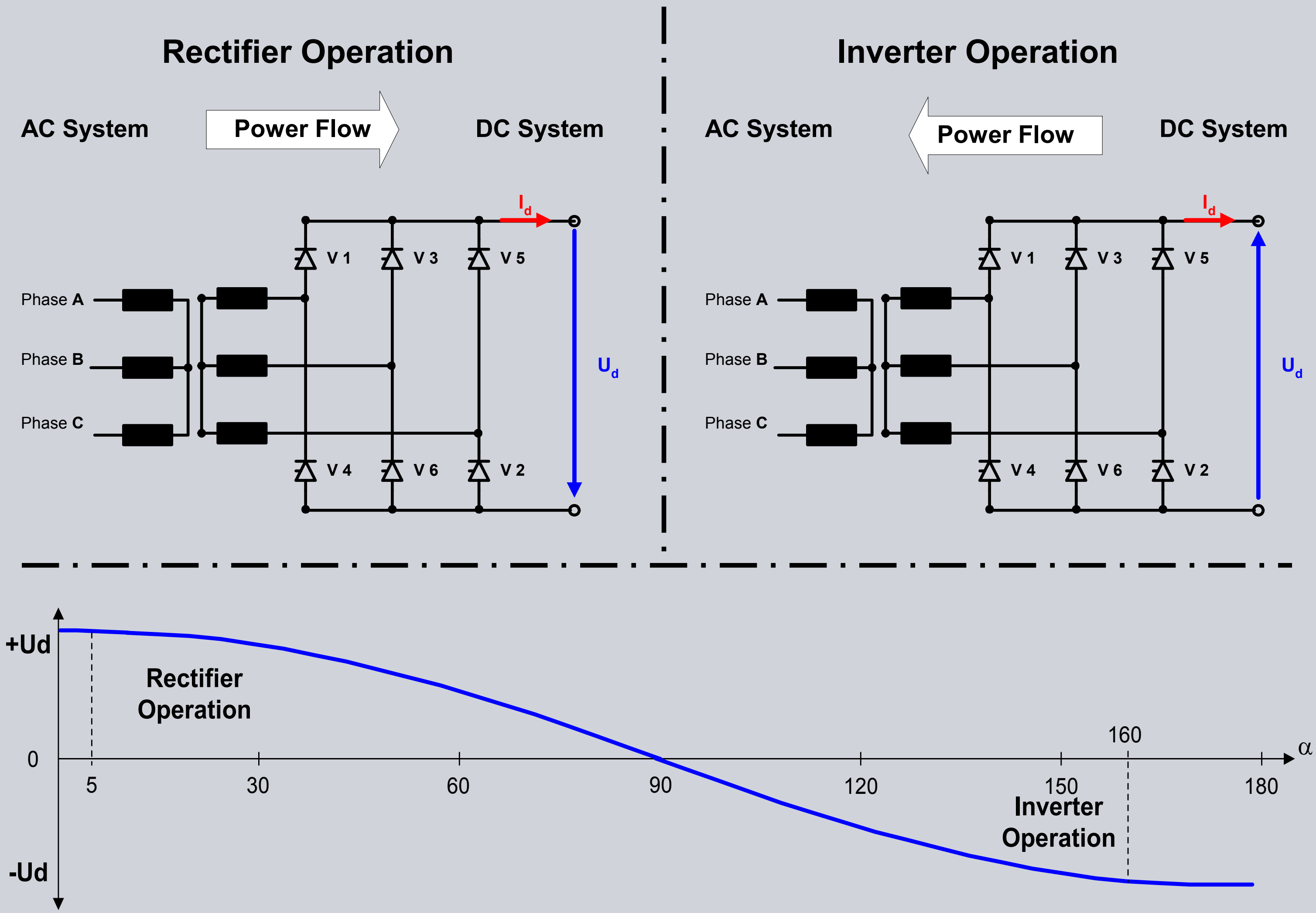
- Power Transmission



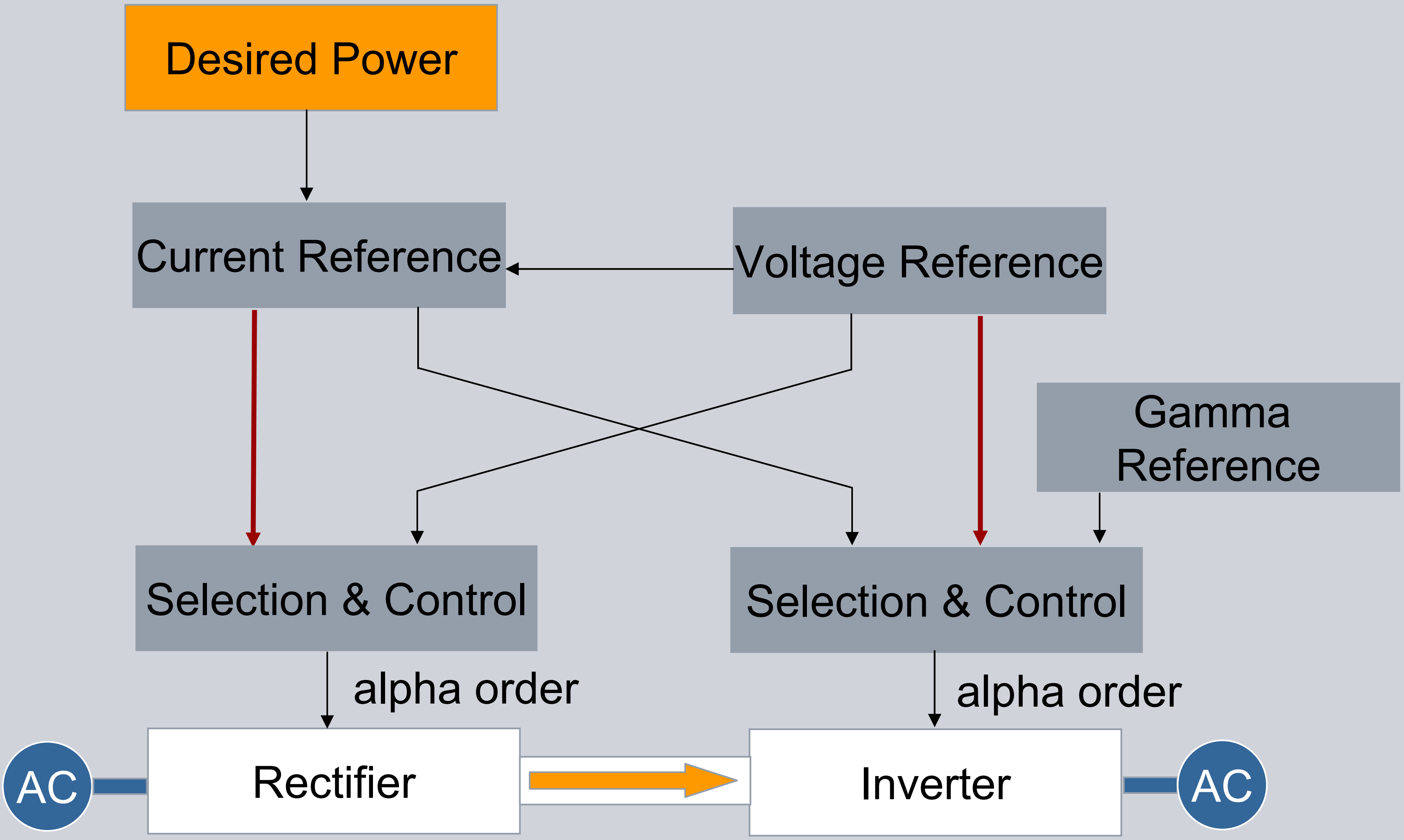


- Power Reversal

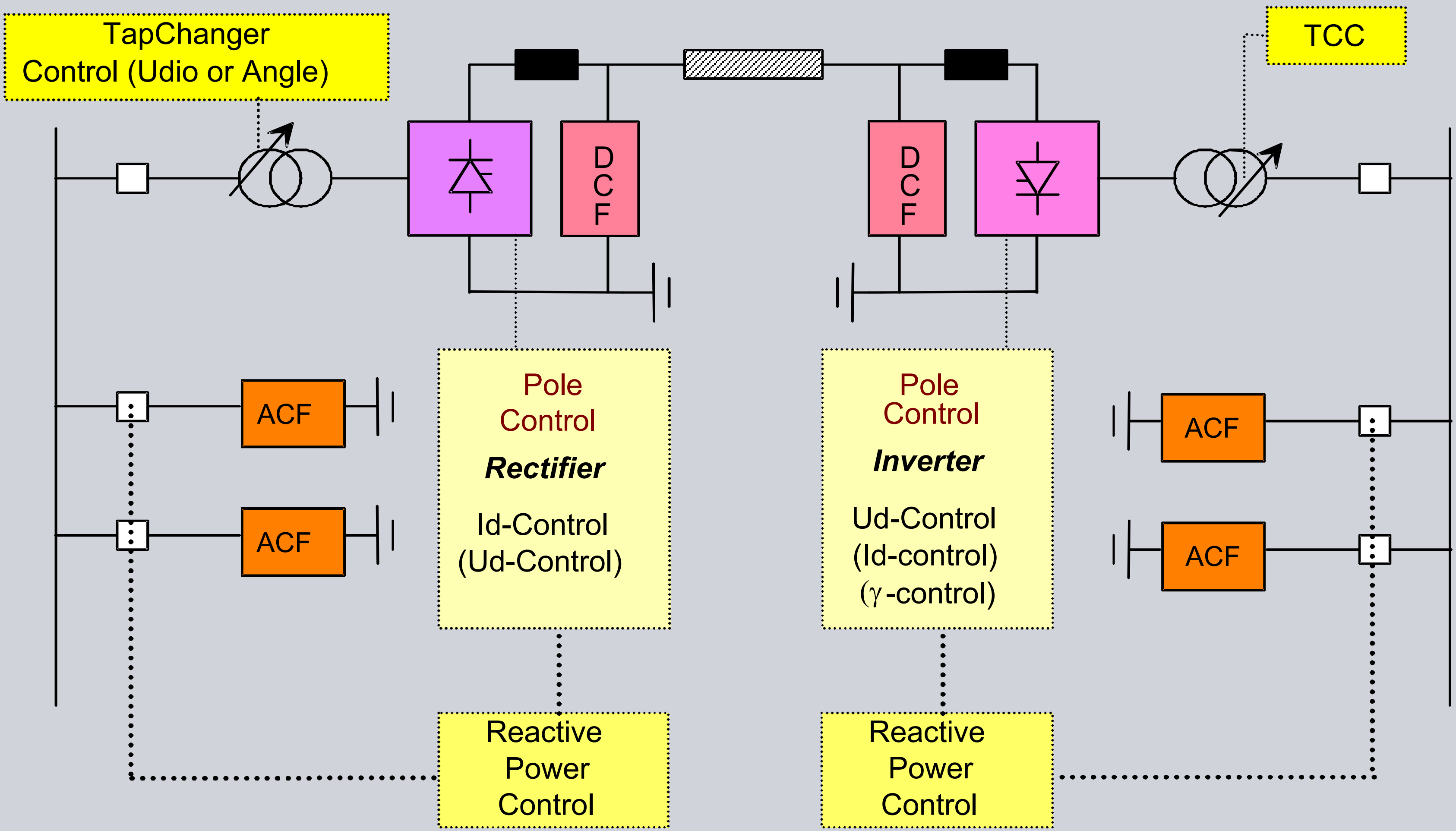
Converter 6puls Bridge, Control of DC Voltage



HVDC Control Concepts



HVDC Control Concepts



ACF: AC Filter
I_d: DC Current
U_d: DC Voltage
γ: Extinction Angle

Principle of HVDC
Converter Control Characteristic - Operating Point

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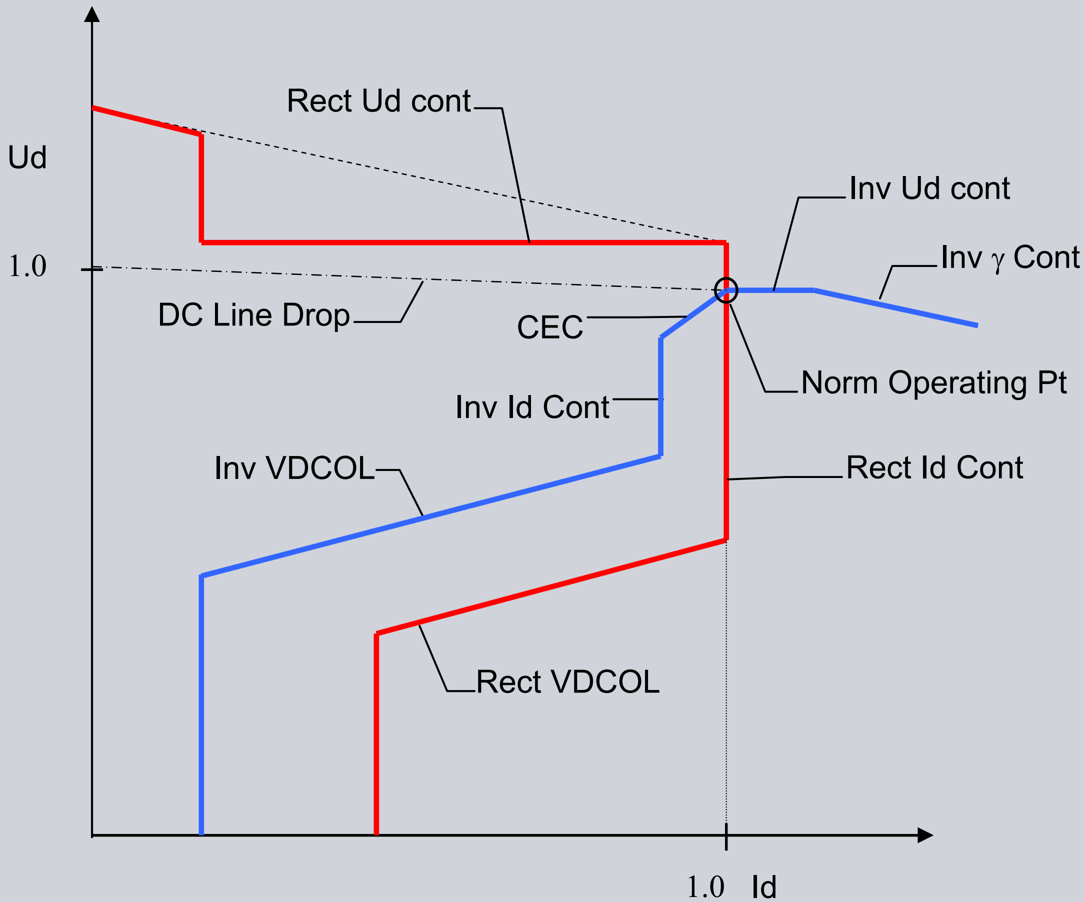

Rectifer Control Modes:

⇨ **Normal DC Current Control**

⇨ **Backup DC Voltage Control**

Inverter Control Modes:

⇨ **Normal DC Voltage Control**

⇨ **Backup DC Current Control**

⇨ **Backup Extinction Angle Control**

Abbreviations:

VDCOL	Voltage Dependent Current Limit
CEC	Current Error Characteristic
Ud	DC Voltage
Id	DC Current
γ	Extinction Angle

Pole Control Functions

Pole Control Functions

- Active Power Control
- DC Current Control
- DC Voltage Control
- Extinction Angle Control
- Converter Status of Operation
- Start / Stop Sequences
- Converter Level Sequences
- Converter Tap Changer Control
- Switchgear Control and Monitoring

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Energy Transfer Mode

- Active power control mode (P-Mode)
  - Operator determines the power order and the power ramp rate
  - Distributing the current orders to each pole according to the bipole DC voltage

- Round Power Operation
  - Both poles operate with different power directions

- Current control mode (I-Mode)
  - Pole-related mode
  - Operator determines the current order and the current ramp rate

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DC Current Control

- The current control functions operate pole dependent.
- DC current order defined directly by the operator in current control mode (I-Mode) or
- Is calculated by the Current Order Calculator when power control mode

Bipolar operation:	$I_{\text{Ref Pole}} = \dfrac{P_{\text{Ref Bipole}}}{U_{\text{d act own Pole}} + U_{\text{d act other Pole}}}$
Monopolar operation:	$I_{\text{Ref Pole}} = \dfrac{P_{\text{Ref Bipole}}}{U_{\text{d act own Pole}}}$
Round Power operation Master Pole:	$I_{\text{Ref Pole}} = \dfrac{P_{\text{Ref Bipole}} + P_{\text{Slave Pole}}}{U_{\text{d act own Pole}}}$
Round Power operation Slave Pole:	$I_{\text{Ref Pole}} = \dfrac{P_{\text{Slave Pole}}}{U_{\text{d act own Pole}}}$

Power Order Calculation for DC Power Control (POCDC)

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- Issued by Bipole Control
- ΔP_{ref} Runup/back (P-Limit): DC Power Limits, Runbacks and Runups are calculated in the Station Control and transferred to the Bipole Control and Pole Control.
- BP P-Limit is calculated by P-Limit from the Station Control
- ΔP_{ref} Modulation: is calculated by the frequency and modulation Control functions operating in the Bipole Control
- P_{ref} DC Bipole transferred to the Pole Control of both poles where the I_{ref} Pole is calculated

Power Order Calculation for DC Power Control (POCDC)

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- Determine the correct active steady state Bipole power order P_{ref}DC from the operator
- The power of the rectifier DC terminal is then controlled accordingly by
  - Controlling the DC terminal voltage and DC current
  - DC voltage is controlled at the inverter
  - DC current is controlled at the rectifier
- The current order for control is obtained by dividing the Bipole power order by the measured Bipole rectifier DC voltage

Active Power Control

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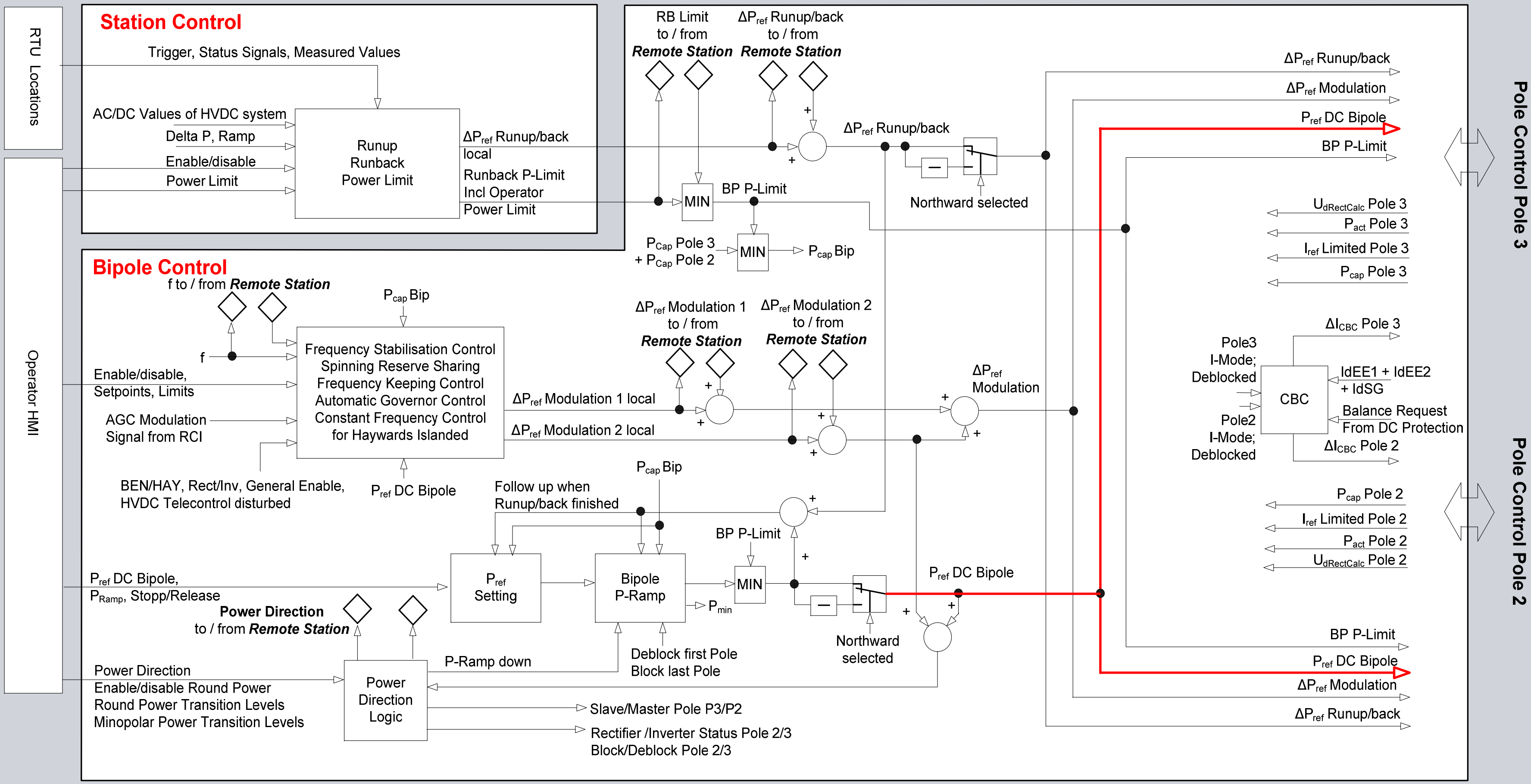

Abbreviations:

ΔP_{ref} Modulation 1: Modulations which are not selected to trigger round power transitions
ΔP_{ref} Modulation 2: Modulations which are selected to trigger round power transitions

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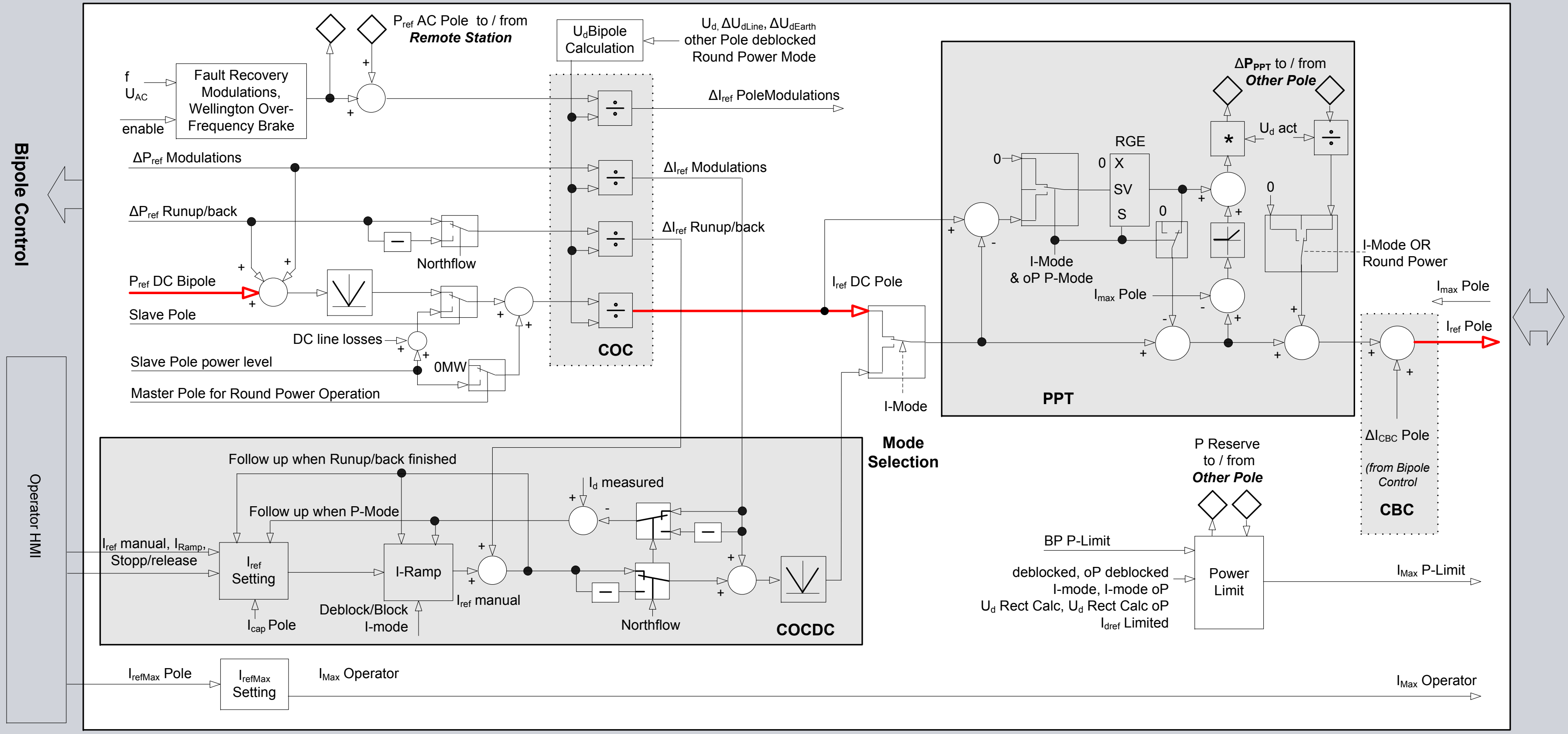
Pole-Pole Power Transfer

Function:

Shifting additional power order between poles to achieve constant power when:

- One pole is in I-Mode and the other pole is in P-Mode.
- One pole is operating against a current limit.

Current Order Setting Functions (COC, COCDC)



<u>Abbreviations</u>

RGE	Ramp Generator
S	Set Command
SV	Set Value
COC	Current Order Calulator
COCDC	Current Order Calulator for scheduled Current
PPT	Pole to Pole Power Transfer
CBC	Current Balance Control
ref	reference value
U_d	DC Voltage
U_{AC}	AC Voltage
I_d	DC Current
I_{max}	Maximum DC Current Limit

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Pole Current Limitation Function (PCL)

Functions:

- Application of the pole current limitations
- Coordination of the maximum current with the remote station

- The limits are minimum selected and sent to the remote station
- Create a signal "Imax Pole". This signal is the primary pole current limit

Pole Current Limitation and Current Capability Function (Imax)

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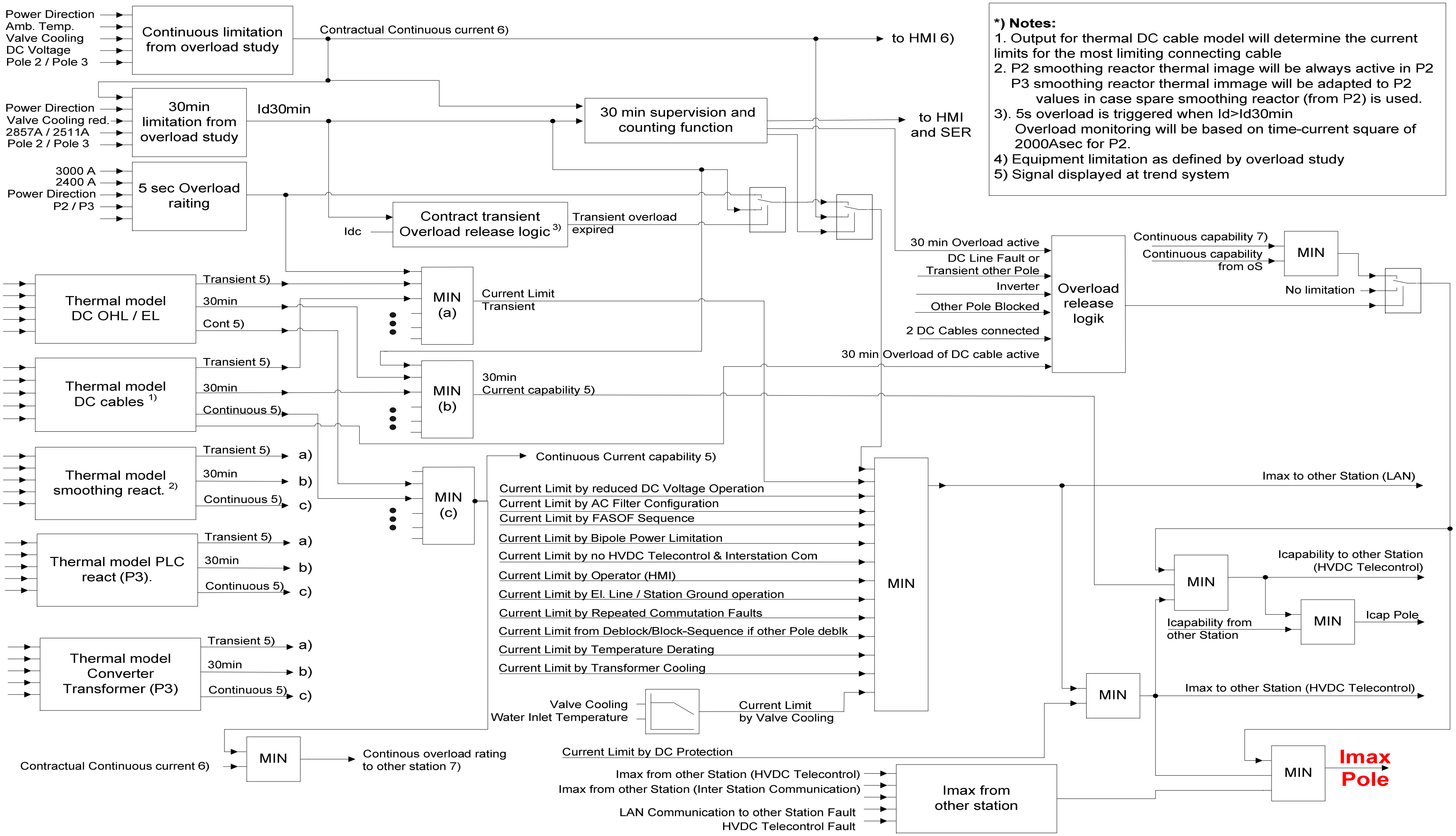

*) Notes:
1. Output for thermal DC cable model will determine the current limits for the most limiting connecting cable
2. P2 smoothing reactor thermal image will be always active in P2
P3 smoothing reactor thermal immage will be adapted to P2 values in case spare smoothing reactor (from P2) is used.
3). 5s overload is triggered when Id>Id30min
Overload monitoring will be based on time-current square of 2000Asec for P2.
4) Equipment limitation as defined by overload study
5) Signal displayed at trend system

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Pole Power Capability Calculation

- The power transmission capability of a pole is calculated continuously
- Based on the pole current limit and the DC voltage

  (rectifier voltage UdRect_Calc, directly measured at the rectifier and calculated at the inverter)
- The most limiting equipment is identified and the overload capability is calculated based on its maximum DC current.

$$P_{cap\ Pole} = U_{dRect\_Calc} \times I_{Cap\ Pole}$$

Current Margin Compensation (CMC)

Maintains Pole I_d in case of Inverter Current Control (current margin control)

- Only active when Rectifer becomes limited in α_0 (can not maintain current; e.g. AC voltage reduction at rectifier station)
- When Id decreases below I_{ref}, then it operates as an integrator to increase current order (up to the value of I_{marg}, e.g. 10%) by inverter current control until I_d again equals I_{ref}.
- Upon removal of the rectifier limitation, the integrator output is automatically reduced to zero.

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Pole Current Order Coordination PCOC

- It selects the current orders for the converter control depending on rectifier or inverter and HVDC Interstation Telecontrol OK or faulty
- When Telecontrol is operational the inverter station operates with the current order from the rectifier station
- The PCOC maintains in all cases the current order margin for the inverter current controller to prevent inadvertent current control at inverter

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Pole Current Order Coordination PCOC

Current Order Processing at the Rectifier Station

- Current order from own station
- Current order from other station (check-back)
- Check-back ensures that at the inverter side current order is never greater than at the rectifier side

  - Current order decrease -> reduction at Rectifire after check-back only
  - Current order increase -> increase goes throgh without waiting for check-back

- Telecontrol faulty -> no check-back, current order always from COC

Pole Current Order Coordination PCOC

Current Order Processing at the Inverter Station

- Current Order recieved from Rectifire
- Sent back to Rectifire for check-back

Telecontrol faulty - > current order is frozen, minimum selected with the tracked DC current and is used for current control

Pole Level Control Functions

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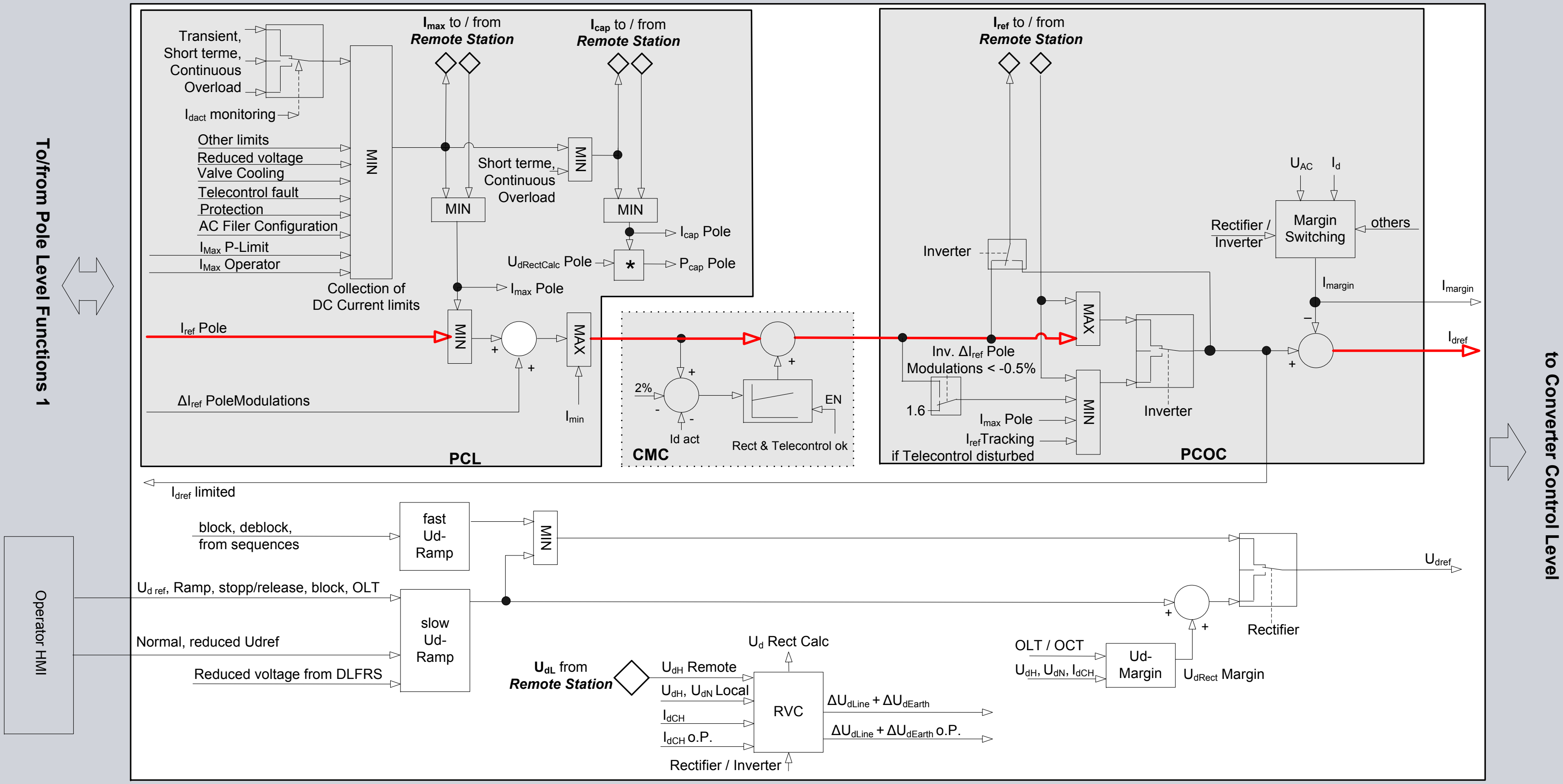

Abbreviations

CMC	Current Margin Compensation	ref	reference value
PCL	Pole Current Limit	U_d	DC Voltage
PCOC	Pole Current Order Co-ordinator	U_{AC}	AC Voltage
OLT/OCT	Open Line / Converter Test	I_{max}	Maximum DC Current Limit
RVC	Rectifier Voltage Calculator	I_{min}	Minimum DC Current Limit

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DC Current Control

- Main controller at the rectifier station
- Back-up function at inverter station

- DC Controller at rectifier
  - Minimum selection ΔI_d, ΔU_d (largest negative)
  - Rise of I_d -> ΔI_d becomes negative -> the controller reduces α to increase I_d

- DC Controller at inverter
  - Maximum selection ΔI_d, ΔU_d, $\Delta\gamma$ (controller error)
  - If $I_d < I_{ref} – I_{mag}$ -> ΔI_d becomes positive
  - If $\Delta I_d > \Delta U_d$, $\Delta\gamma$ than current controller will decrease α to increase I_d

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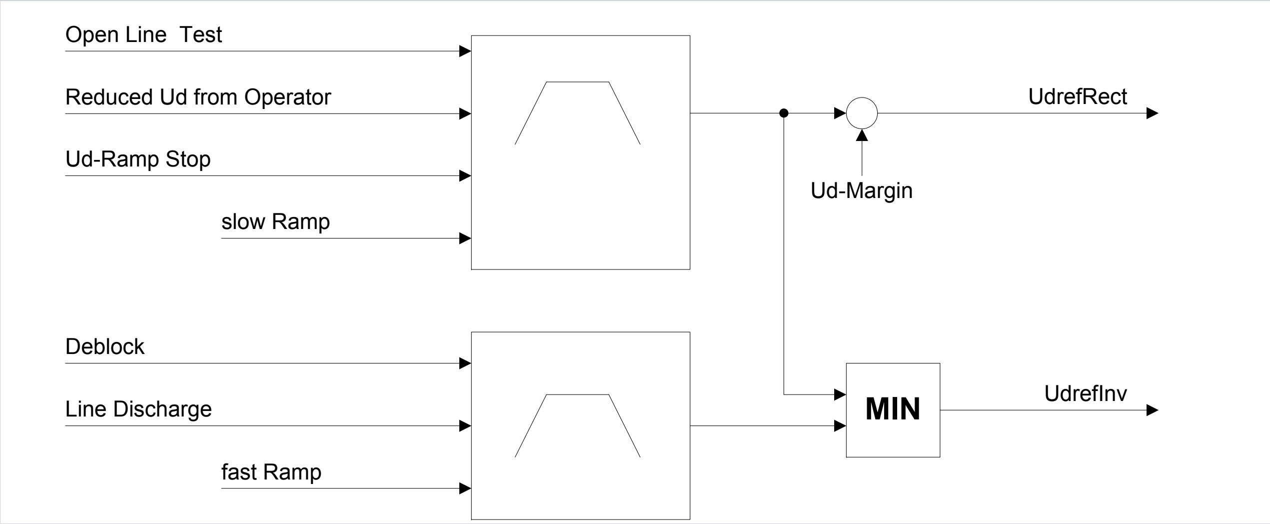
DC Voltage Control

- Main controller at the inverter
- Back-up function at rectifier station



- At the inverter, U_{ref} is the reference setting for the inverter voltage controller and is normally set to 1.0 p.u. (nominal value) relative to the rectifier terminals.
- The inverter controls the calculated rectifier DC voltage
- The rectifier DC voltage controller would come into operation only transiently where Ud increase above the Uref + Umarg

DC Voltage Control

- DC Voltage for Open Line Test
  - Range: 0kV to 353kV, slow ramp
  - Ramp can be stopped and released by the operator

- DC Voltage for Reverse Power Direction
- Only for Pole 2:
- In Reverse Power Direction (Haywards to Benmore) the DC Voltage Reference is 342 kV up to 1460 A and then linearly falling to 333kV and 2000 A.

- Voltage calculation
  - $U_{d\ RECTCalc} = U_{d\ INV} + (R_{DC} \cdot I_{dL})$
  - $U_{d\ Inv} = U_{dL} - U_{dN}$

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Reduced Voltage Operation

- Reduced voltage operation is provided to the converter control by
  - an explicit operator command or
  - automatically by the DC line fault recovery sequence
- Initiated by operator command, the Ud-ramp will released 20kV/min
- Following a DC Line fault, the voltage reference value is directly set to 0.715 pu without ramping and reduced voltage operation is activated without delay.
- Uref normally 350 kV (1 pu, compounded to rectifier)
- Uref reduced Voltage 250 kV (0.715 pu, compounded to rectifier)
- During operation with DC voltage below 1.01 p.u. a margin of e.g. 0.3 p.u. is added to the nominal DC voltage at the rectifier. This avoids interference with the dynamic performance of the current controller especially on recoveries from AC and DC faults
- In case the DC voltage is above 1.01 p.u. the margin at the rectifier is reduced to e.g. 0.02 p.u. to ensure that the DC voltage does not exceed the steady state design limit for DC overvoltage conditions.

Extinction Angle Control

Back-up function at inverter station

The extinction angle control is different for pole 2 and pole 3.

- Pole 3:
  - For the new pole 3 the extinction angle is calculated by
    - Evaluating End-of-current signals from VBE
    - The transformer primary voltage measurement
    - The transformer vector group
  - The extinction angle is controlled according to the angle reference

- Pole 2:

  For the existing pole 2 the VBE will remain i.e. the “End-of-Current” will not be available. Therefore the extinction angle controls will be replaced by a function which keeps the minimum extinction angle by calculation the respective max. inverter limit.

Extinction angle reference γ_{ref} = 17°

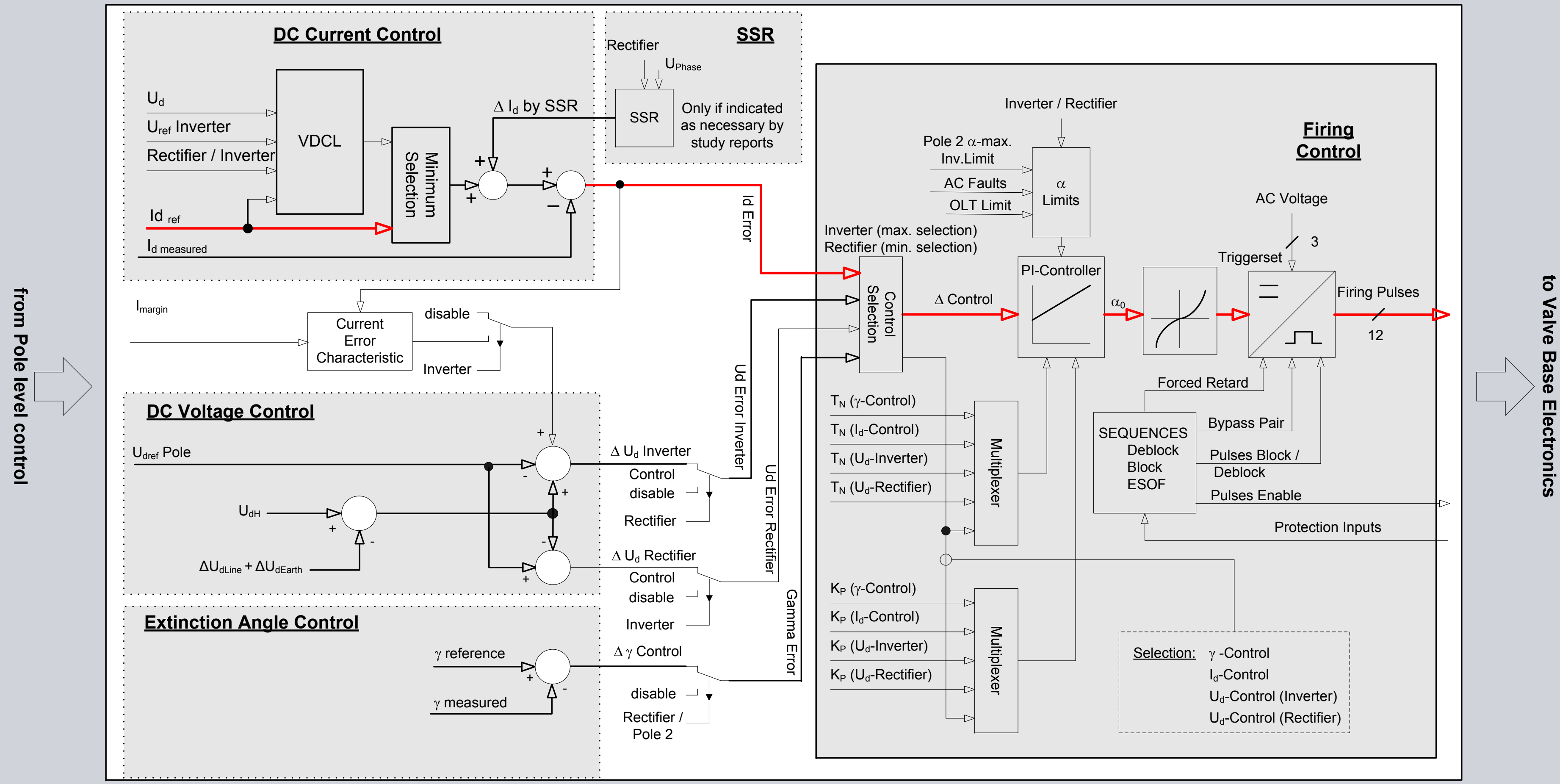
Extinction Angle Control

Extinction angle control is realized with a PI controller (when selected by controller selection) that operates to prevent inverter extinction angles from decreasing below gamma minimum.

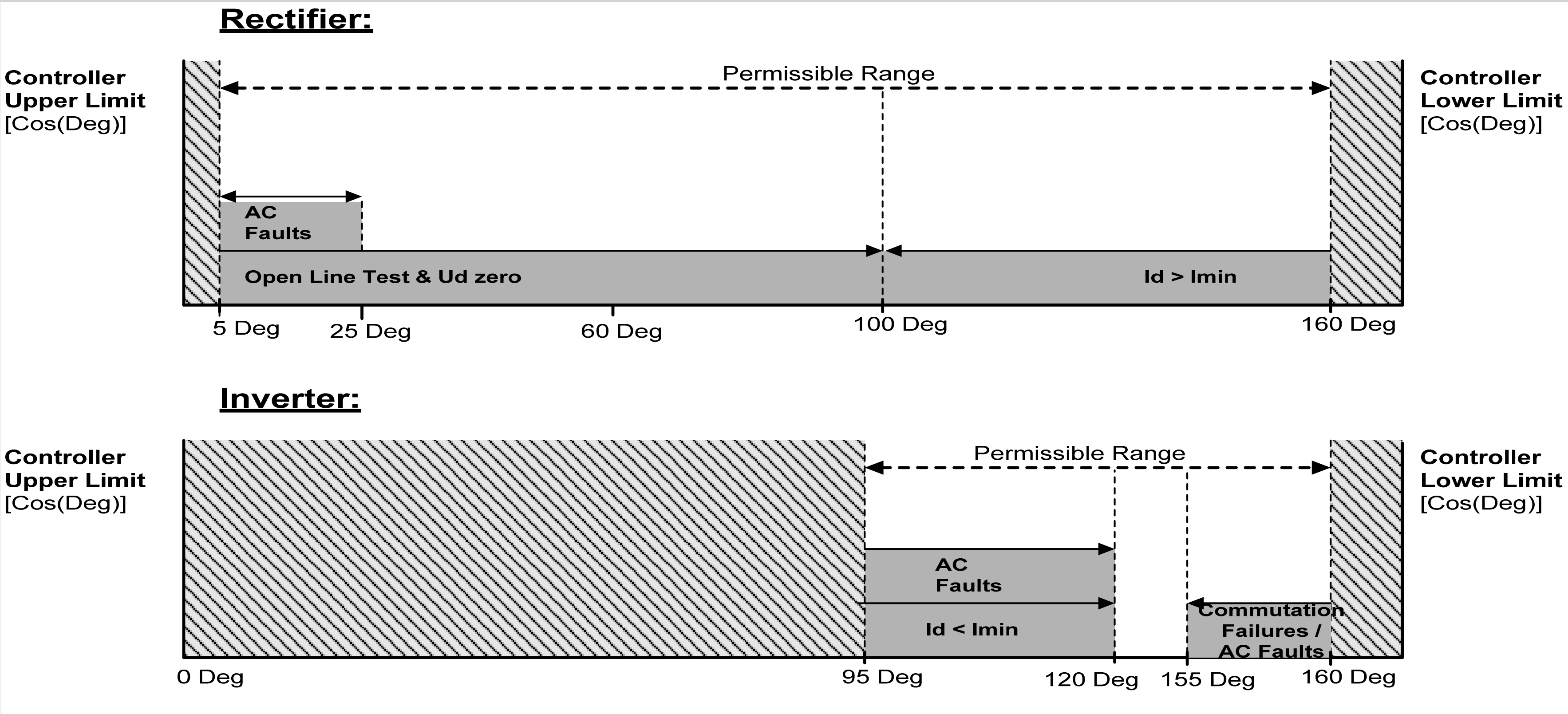
When $\Delta\gamma$ becomes more positive (due to decreasing γ) than the errors of the other controllers (DC voltage, DC current), it is selected and decreases α_0 to limit γ to the minimum value.

This helps to inhibit commutation failures

Converter Level Control Functions Overview



Alpha Limits



Firing angle

- Nominal 15.0°
- Normal range 12.7° - 17.3°
- Min. dynamic range 5.0°

Extinction angle

- Nominal 18.0°
- Normal range 18.0° - 20.5°
- Min. (gamma ctrl.) 17.0°

Pole Level Power Order Setting Functions for Transient Stability (POCAC)

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Functions are carried out in the pole control.

- Wellington Over-Frequency Brake
  - Using a frequency limit control
  - Maximum frequency limit 52Hz; can be changed using the SIMATIC TDC Engineering Workstation
  - Reduces DC power according to the frequency error (below the maximum limit) to control the frequency to the maximum limit value
  - Provided for both stations but enabled at Haywards only when inverter

- Fault Recovery Modulation Function
  - Damp the voltage swings at the Haywards AC buses at high power transfer levels
  - Fault recovery modulation can't be disabled by the operator from the Operator Control Level.

Power Actual Value

- DC power is calculated by means of the pole DC current and the pole DC voltage
- The active and reactive power is computed from
  - Converter transformer primary currents and
  - AC busbar voltage by the C&P Measuring system.
- The active and reactive power is used for indication at the DC HMI and for reactive power control in the DC Station Control.

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Converter Status of Operation

Converter Status

- EARTHED
- STOPPED
- STANDBY
- BLOCKED (Ready for deblocking)
- DEBLOCKED
- OPEN LINE TEST (OLT)

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Converter Status - Pole Status Definition

	EARTHED	STOPPED	STANDBY	BLOCKED	DEBLOCKED	OLT
Door and Key Interlocking fulfilled	X	1	1	1	1	X
Valve Hall AC Grounding Switches (Star/Delta)	1	0	0	0	X	X
Valve Hall DC Earthing Switches (HV / LV)	1	0	0	0	X	X
DC Filter isolated	1	X	X	X	X	X
Transformer primary Earthing Switch Closed	1	X	0	0	X	X
DC Yard LV and HV Earthing Switch (Converter Side) Closed	1	X	0	0	X	X
AC Busbar Disconnector	0	X	1	1	X	X
Valve Cooling System	X	X	1	1	X	X
Tap Changer Start Position	X	X	1	X	X	X
Transformer Cooling System	X	X	X	1	X	X
Valve Cooling System ready for Power Transmission	X	X	X	1	X	X
Tap Changer Automatic Control	X	X	X	1	X	X
DC Neutral Bus Configuration	X	X	1	1	X	X
High Speed Neutral Bus Switch	X	X	X	1	X	X
DC Line Disconnector	X	0	0	X	X	X
DC Configuration OK for Power Transfer	X	X	X	X	1	0
DC Configuration OK for OLT	X	X	X	X	0	1
Transformer Circuit Breaker	0	0	0	1	X	X
Firing Pulses enabled	0	0	0	0	1	1
Pole Isolated	1	1	0	0	X	X

Index: 0 = Off, Open; False 1 = On; Closed; True X = Any Status

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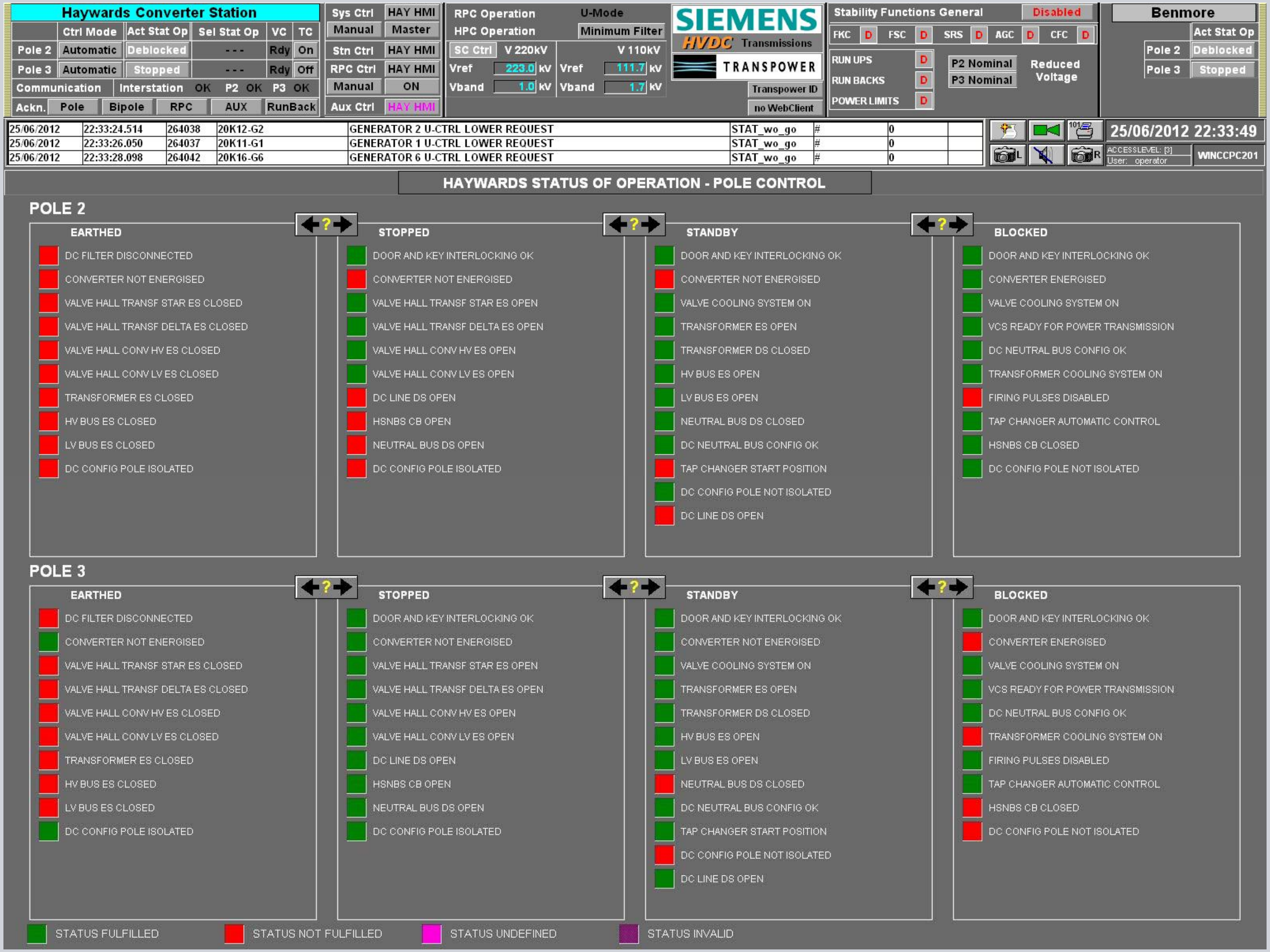
Converter Status – Status Monitoring at DC HMI



Start- / Stop Sequences

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Start- / Stop Sequences

- For start-up and shut-down of the HVDC converter station (EARTHED – DEBLOCKED / OLT status)
- Transition between different converter status with one command from HMI
  Pole Control carries out all intermediate steps
  → Automatic Control Mode
- Transition between different converter status by operation from individual devices and equipment from HMI or other locations (e.g. locally at devices)
  → Manual Control Mode
- Interlocking conditions are checked in Automatic as well as in Manual Control Mode

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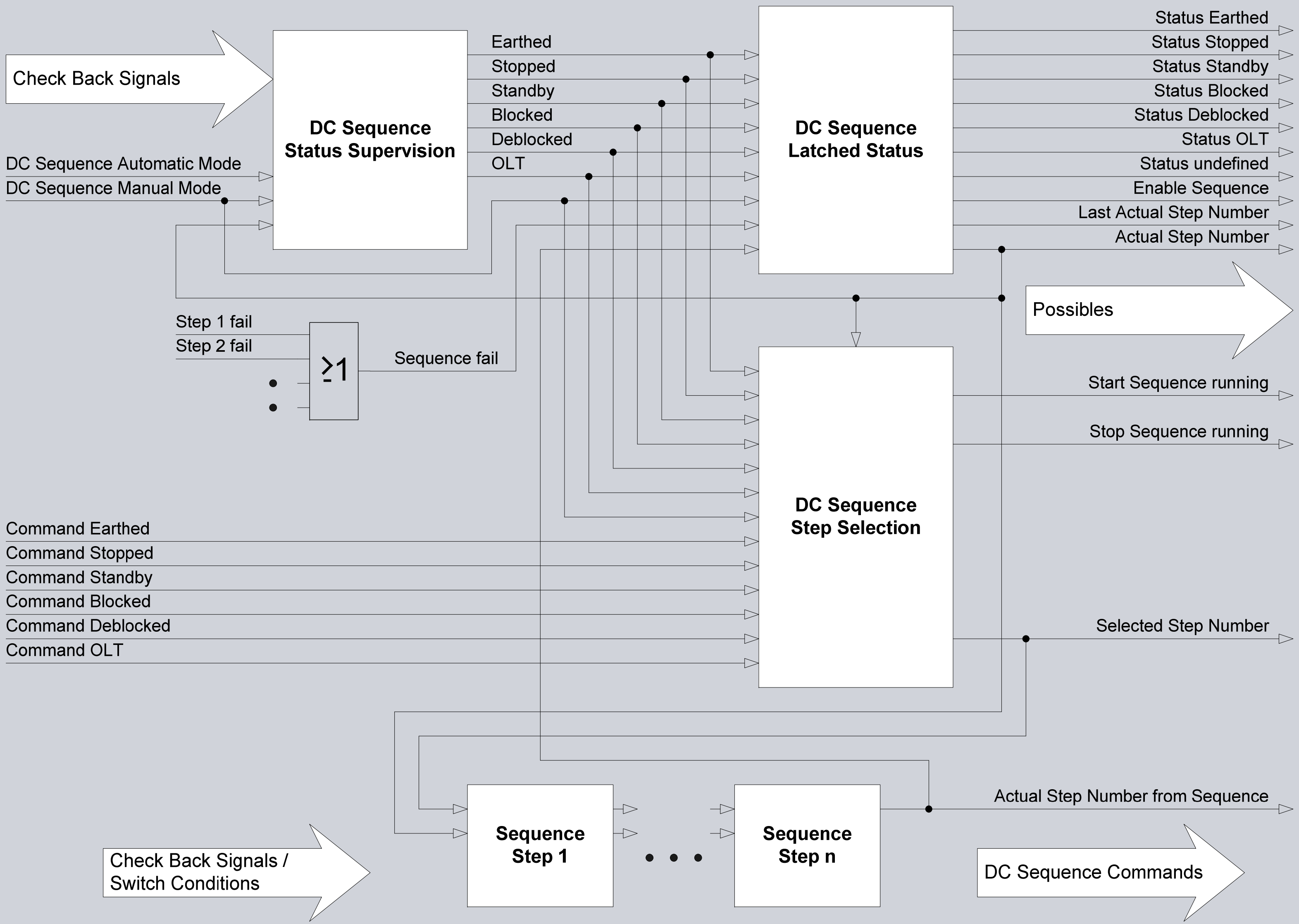
Overview Start / Stop Sequence



Start- / Stop Sequences

SIEMENS

Earthed

⇩

Stopped

⇩

Standby

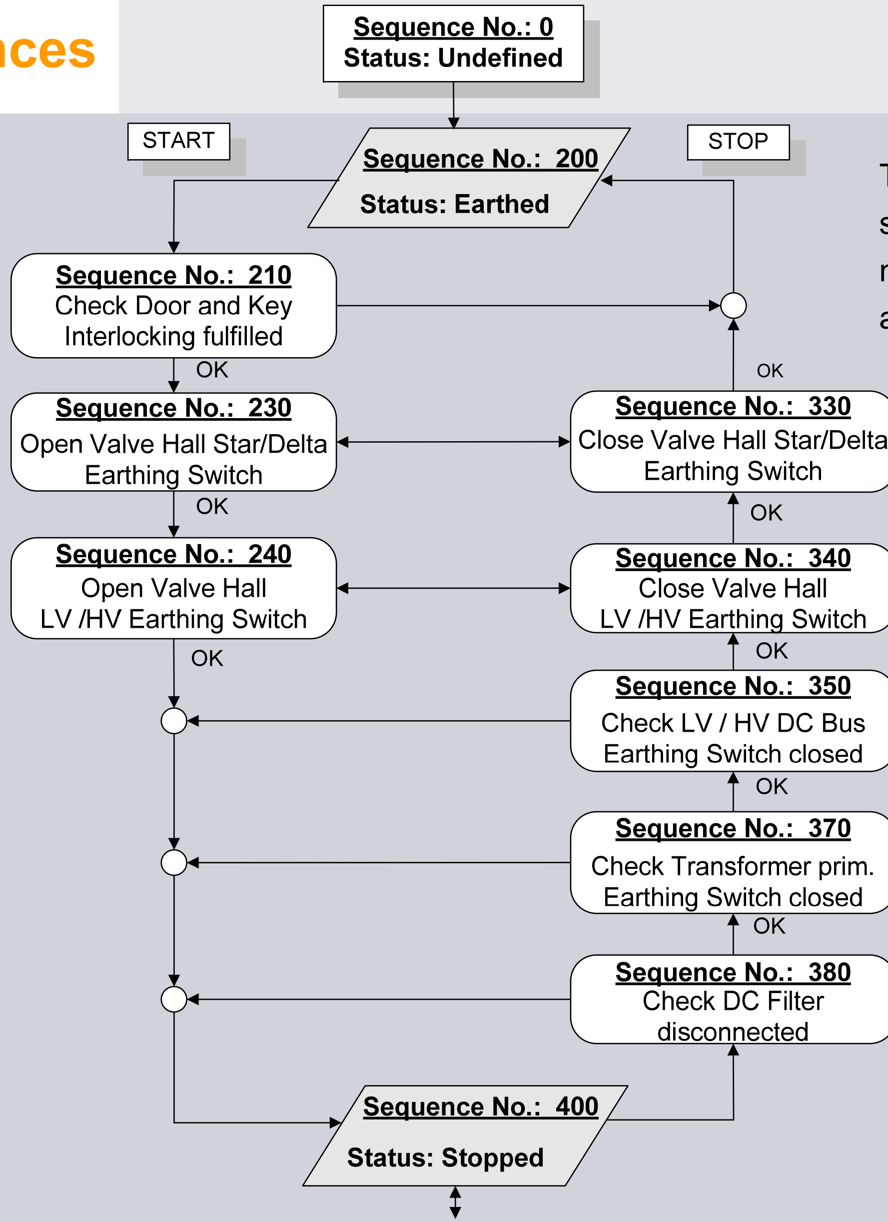
⇩

Blocked

⇩

Deblocked

OLT



Transformer primary side earthing switches must be operated locally at the device

Start- / Stop Sequences

SIEMENS

Earthed

⇩

Stopped

⇩

Standby

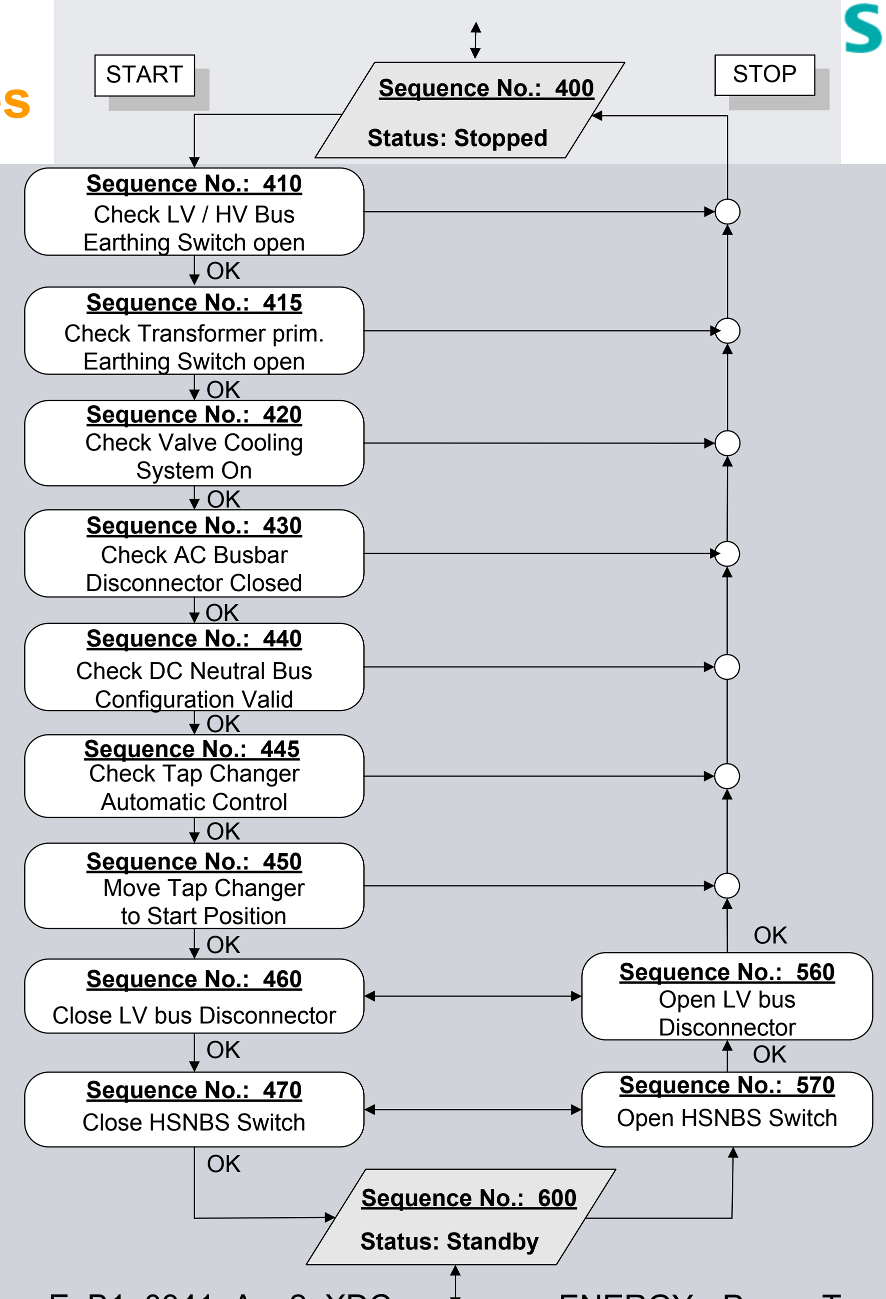
⇩

Blocked

⇩

Deblocked

OLT



Start- / Stop Sequences

Earthed

⇩

Stopped

⇩

Standby

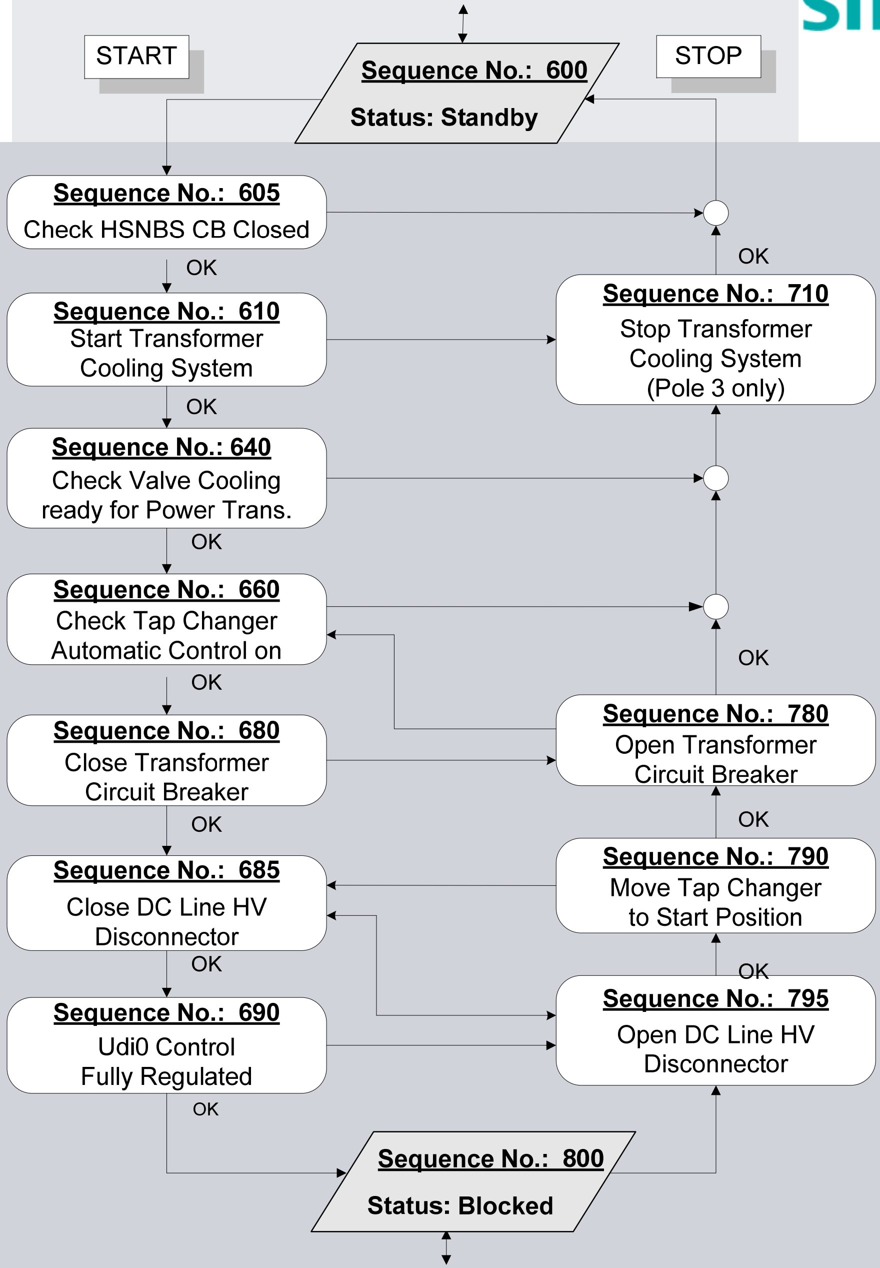
⇩

Blocked

⇩

Deblocked

OLT



Start- / Stop Sequences

Earthed

⇩

Stopped

⇩

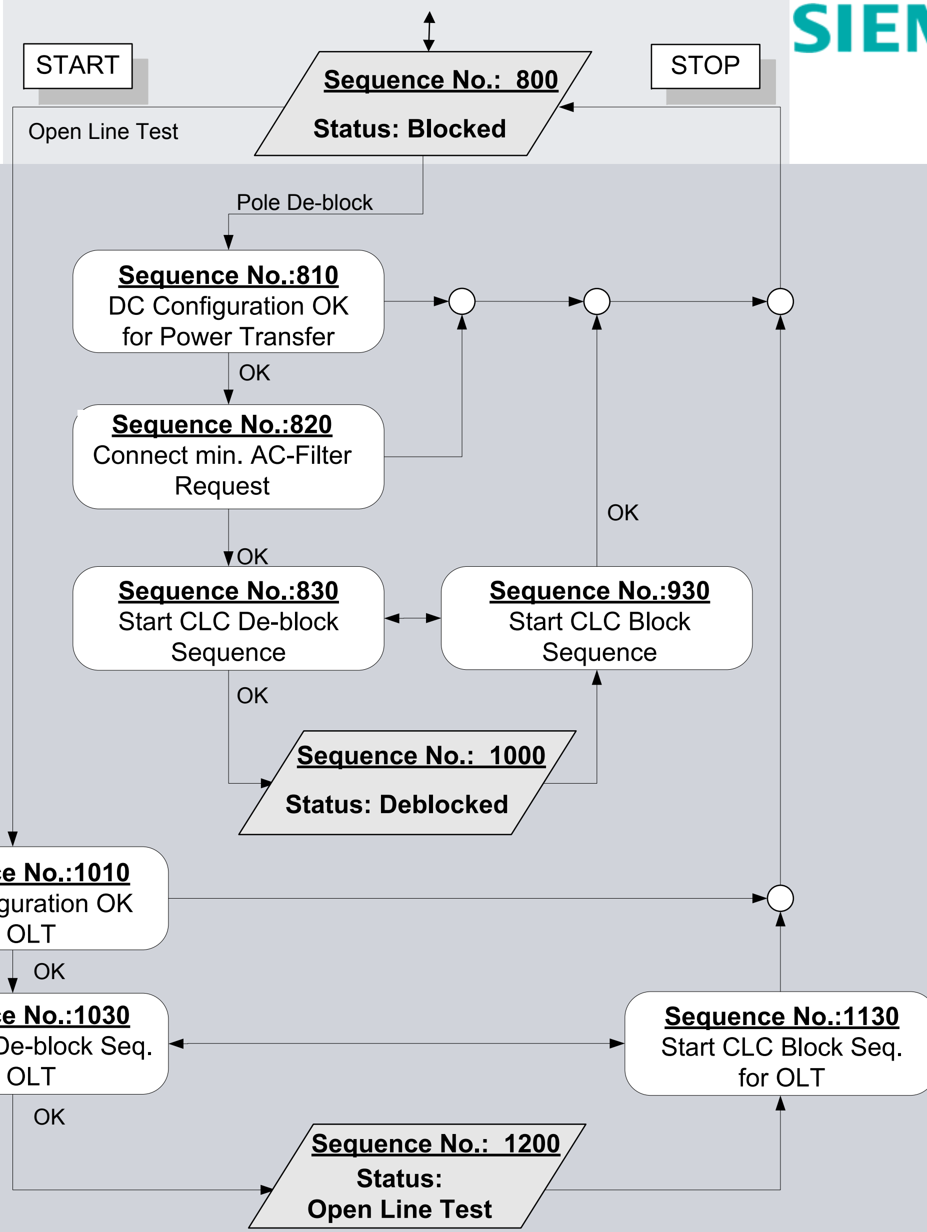
Standby

⇩

Blocked

⇩

Deblocked
OLT



Start- / Stop Sequences
Status of Operation Selection by Operator (1)

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- Selection of another status is possible
  - in a defined status of operation or
  - during a running sequence to reverse or cancel the actual running sequence
- The selection of status of operation is restricted as described below
  - In Station Control Level
    - any status between EARTHED and BLOCKED can be selected
    - transition BLOCKED ↔ DEBLOCKED must be coordinated via telephone
  - In System Control Level
    - any status between EARTHED and BLOCKED can be selected
    - transition BLOCKED ↔ DEBLOCKED
      - is only possible at the master station
      - necessary interactions with the slave station will be coordinated automatically between the Pole Controls of master and slave station

Start- / Stop Sequences
Status of Operation Selection by Operator (2)

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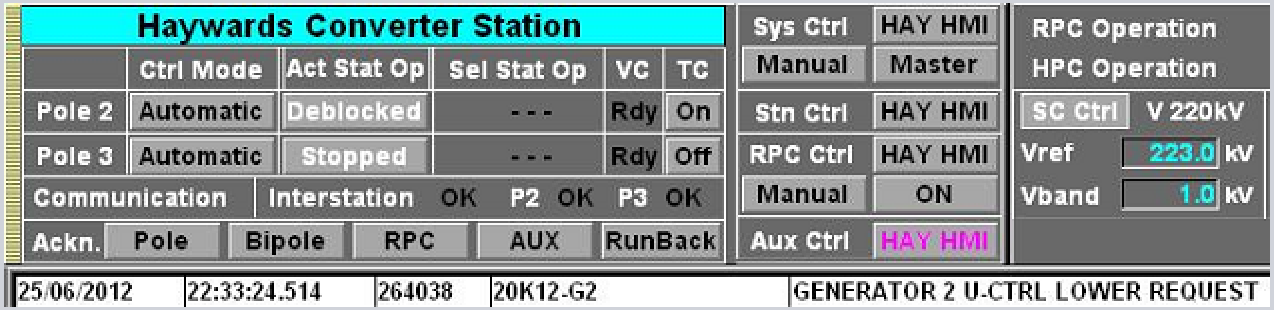
Selectable DC Sequence Status in Automatic Mode



Actual Status	Selectable Status					
	Earthed	Stopped	Standby	Blocked	Deblocked	OLT
Earthed	0	1	0	0	0	0
Stopped	1	0	1	1	0	0
Standby	0	1	0	1	0	0
Blocked	0	1	1	0	1	1
Deblocked	0	0	0	1	0	0
OLT	0	0	0	1	0	0

Start- / Stop Sequences
Transition Automatic ↔ Manual Control Mode (1)

- The changeover to DC sequence manual control mode is possible if:
  - Start / Stop Sequences are in automatic mode,
  - The converter is not in DEBLOCKED or OPEN LINE TEST status and
  - No Deblock- / OLT - sequence is running
- The changeover to automatic mode is possible if:
  - The converter is in manual mode,
  - The converter is in a defined status of operation EARTHED, STOPPED, STANDBY or BLOCKED and
  - Defined DC filter status
    - DC filter HV and LV disconnectors are both closed and HV and LV grounding switches are both open (DC filter on) or
    - DC filter HV and LV disconnectors are both open and HV and LV grounding switches are both closed (DC filter off)

Start- / Stop Sequences
Transition Automatic ↔ Manual Control Mode (2)

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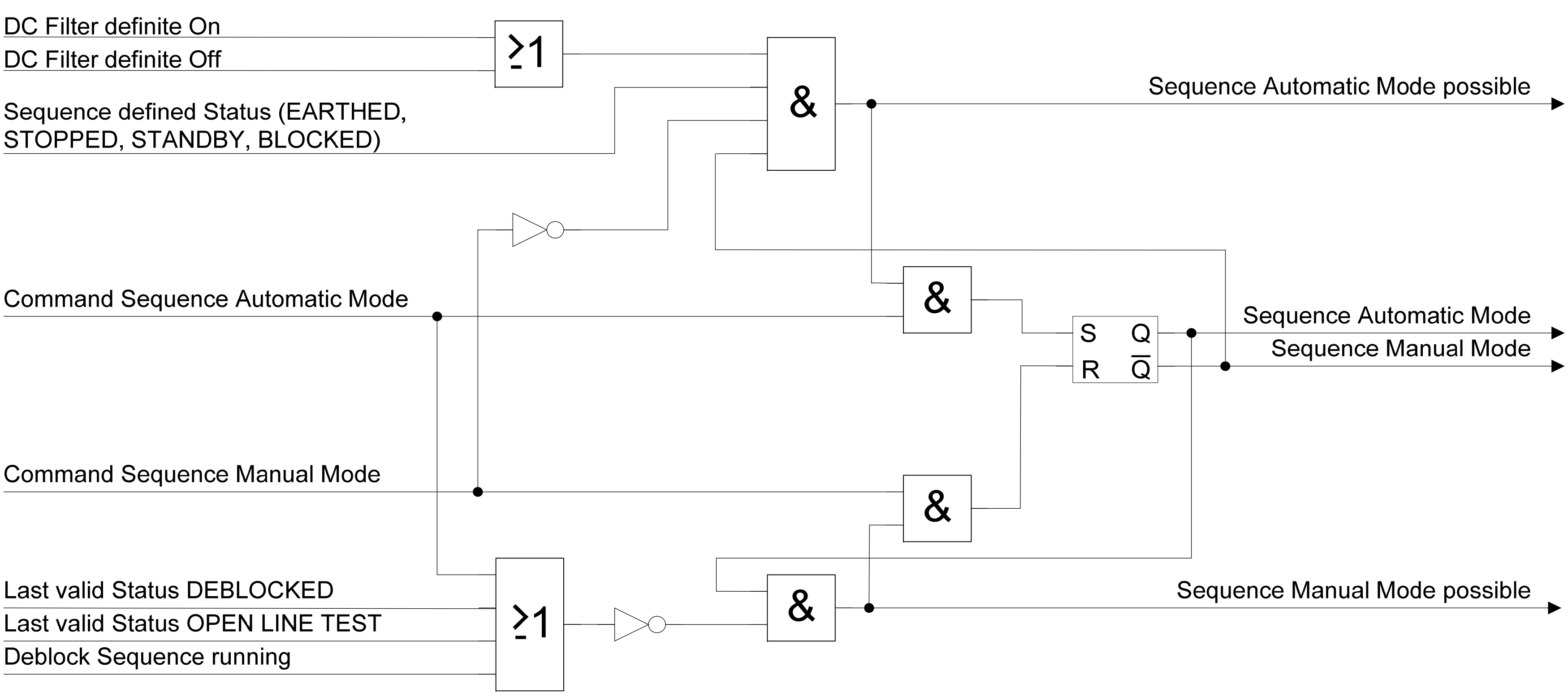

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Converter Level Sequences

Converter Deblock Sequence

Deblocked converter means:

- Firing pulses are released and,
- DC current and voltage is maintained.

Converter deblock-sequence can be initiated provided:

- Required conditions are met:
  DC Configuration OK and AC Filters connected are fulfilled.
- No converter block is active
- No ground fault on AC phases of transformer secondary side.

Converter deblock sequence ensures:

- Inverter is deblocked before rectifier (through telecom)
- Connect AC filters when $I_d > I_{dmin}$
- Release $U_{dref} = 0$ at inverter when $I_d > I_{dmin}$
- Power ramp is released when $U_d > 0.3$ pu

Converter Deblock Sequence

- Deblock Start command
- If INV deblock pulses, send status to RECT via Telecom
- Release INV PI control α_0 from 90° to α_{min}
- Deblock RECT with indication INV pulses Deblocked
- Release RECT PI control α_0 from 90° toward α_{min} (5°) & release Force Retard
- DC Current begins to flow
- When $I_{dc} > I_{min}$ release $U_{ref} = 0$ at INV
- U_d ramps to 1 p.u. dc current controlled by RECT to I_{ref}
- If this is 1st pole to Deblock P_{ref} begins ramp from P_{min} to set value
- If other pole is already in operation the U_d of Deblocking pole is added to U_{dBP} at $P_{controller}$ and I_{ref} is reduced by 50% to maintain $P_{constant}$

SIEMENS

Converter Block Sequence

Blocked converter means:

- Firing pulses are blocked but,
- Converters are left connected to high voltage systems.
- At I_d = 0 signal to connect minimum filters is reset

Converter block-sequence can be initiated by:

- Converter high level sequences (Start / Stop Sequence)
- Protection initiated

Converter block sequence ensures:

- Rectifier is blocked before inverter (through fast telecontrol)
- If telecontrol is unavailable inverter fires bypass pair which causes rectifier to block by dc undervoltage protection.
- If telecontrol is disturbed and rectifier blocks remote station fault detection at inverter blocks inverter

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Converter Block Sequence

- BLOCK Start command
- If Both poles being Blocked ramp P_{ref} to P_{min}
- If O.P. remaining in Operation ramp P_{ref} to capability of Monopole
- At RECT set $I_{ref} = 0$ to bring I_d toward 0, O.P. increases I_{ref} at same time
- INV send Block seq initiate to RECT via Telecom
- When INV $I_d = I_{min}$ set $U_{ref} = 0$
- I_{ref} to remaining pole doubled from P/U_d
- When RECT $I_d = I_{min}$ for ~ 50 ms FR α_0 to 100°
- At RECT when $I_d = 0$ wait 100 ms FR α_0 to 160° & block pulses
- At INV when $I_d = 0$ for ~ 500 ms FR α_0 to 160° & block pulses

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Emergency Switch Off Sequence (ESOF)

ESOF sequence is used when:

- Some primary protection has acted, or by change over logic
- AC voltages must be removed from converter.

ESOF action:

- Converter transformer protection opens AC side breakers
- At rectifier FR to ~100°, send block request to inv and when I_d ~ 0 for 10 ms block FP and FR to 160°. At inverter fire bypass and when I_d ~ 0 for 500 ms FR to 160° and block.
- The ESOF signal is transmitted to the remote station via HVDC Telecontrol.
- With HVDC Telecontrol out of service the ESOF at rectifier shuts it down as normally done by ESOF and the inverters blocks on “Remote Station Fault Detection”.
- With HVDC Telecontrol out of service the ESOF at inverter fires bypass pair and the rectifier blocks on “Undervoltage Detection”. Inverter then blocks at I_d = 0.
- On completion the ESOF takes the faulty station into STANDBY status and the remote station into BLOCKED status.

SIEMENS

Fast Switch Off Sequence (FASOF)

ESOF at Rectifier

Initiated by:

1) Transformer secondary voltage monitoring
2) Ambient temperature current limitation monitoring

- Ramp down I_{cap} to I_{min} with 1pu / 500ms.
- At $I_{cap} = I_{min}$, force retard α to ~ 100° and send block request to inverter via Telecontrol.
- If I_d ~ 0 for 50ms, force retard α to about 160 deg.
- If I_d ~ 0 for 100 ms, block firing pulses and disable control

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Fast Switch Off Sequence (FASOF)

ESOF at Inverter

Initiated by:

1) Transformer secondary voltage monitoring
2) Ambient temperature current limitation monitoring

- Ramp down I_{cap} to I_{min} with 1pu / 500ms.
- At $I_{cap} = I_{min}$, send block request to rectifier via Telecontrol.
- Inverter recieves block request from rectifier when rectifier has blocked.
- If $I_d \sim 0$ for 500ms, force retard α to about 160 deg, block firing pulses and disable control.
- If Telecontrol is faulty fire bypass pair at $I_{cap} = I_{min}$ and when $I_d \sim 0$ for 500ms, force retard α to about 160 deg. Block firing pulses and disable control.

DC Line Fault Recovery Sequence

- Located in the Pole Controls and works in tandem with DC Line Protection
- Purpose is to recover from DC line fault in a shortest possible time
- On detection of fault the DC Line Protection sends a signal to Pole Control
- Pole Control then initiates force retard and the DC line is de-ionized
- After a de-ionization period, which can be set by the operator, the pole control attempts to restart the transmission
- The DC line fault signals are exchanged between stations via telecom, so DFRS is processed even if own station fails to detect DC line fault
- Up to four restart attempts can be made as per following table

# Restart Attempt	Deionization time	DC Line Voltage (reduced voltage, default setting)	DC Line Voltage (full voltage, selectableby operator)	Block HVDC
1	150 ms	350kV (1.00 pu)	350kV (1.00 pu)	-
2	200 ms	250kV (0.715 pu)	350kV (1.00 pu)	-
3	200 ms	250kV (0.715 pu)	350kV (1.00 pu)	-
4	250 ms	250kV (0.715 pu)	350kV (1.00 pu)	-
5	n.a.	n.a.	n.a.	✓

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DFRS at Rectifier

- Disable DC under-voltage protection and end of current failure detection to prevent inadvertent blocking / fault indication.
- Set DC voltage for the rectifier VDCOL to zero during de-ionisation time to initiate the transient current controls for recovery from AC and DC system faults.
- Maintain counter for restart attempts, corresponding de-ionization times etc.
- Enable detection of unsuccessful restart attempts, which cannot be detected by the DC Protection due to a bolted DC fault. This type of fault is detected by the Pole Control if the DC voltage is still below 20 % 150 ms after restart.
- FR rectifier to 100°, if I_d ~ 0 switch limit to 160°
- Start protection initiated converter block sequence, if the number of DC line faults exceed preset number

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DFRS at Inverter

- Increase counter for restart attempts which provides a reduced DC voltage command if the number of DC line faults for selection of reduced voltage is reached.
- Set extinction actual value to 0 to shift the converter controller in direction of 120°. This ensures that the DC voltage does not exceed the reduced voltage level if restart with reduced voltage is selected.
- Enable detection of unsuccessful restart attempts, which cannot be detected by the DC Protection due to a bolted DC fault. This type of faults is detected by the Pole Control if the DC voltage is still below 20% 150 ms after restart.

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Power Reversal

The power direction of a pole can be changed if it is in BLOCKED status.

Deblocking the HVDC in reverse power direction is only possible if the waiting time of e.g. 5 minutes after blocking the pole is elapsed and AC Filters are available for deblock

Automatic power reversal sequences are provided in Round Power mode or without Round Power.

Converter

Tap Changer Control

Tap Changer Control Functions / Modes

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Tap Changer Functions

- Tap Changer Monitoring
- Tap Changer Mode Selection Logic
- Tap Changer Raise / Lower Logic, including Inhibit Raise and Back-up Lower functions
- Tap Changer Running Time Supervision
- Tap Changer Position and Status Supervision
- Tap Changer Control Modes

Tap Changer Control Modes

- Tap Changer Firing Angle Control (= Angle Control Mode at Rectifier)
- Tap Changer Extinction Angle Control (= Angle Control Mode at Inverter)
- Tap Changer U_{di0} Control Mode (automatically active as long as BLOCKED status
- Tap Changer Manual Mode
- Tap Changer Start Position Mode

Tap Changer Control Monitoring

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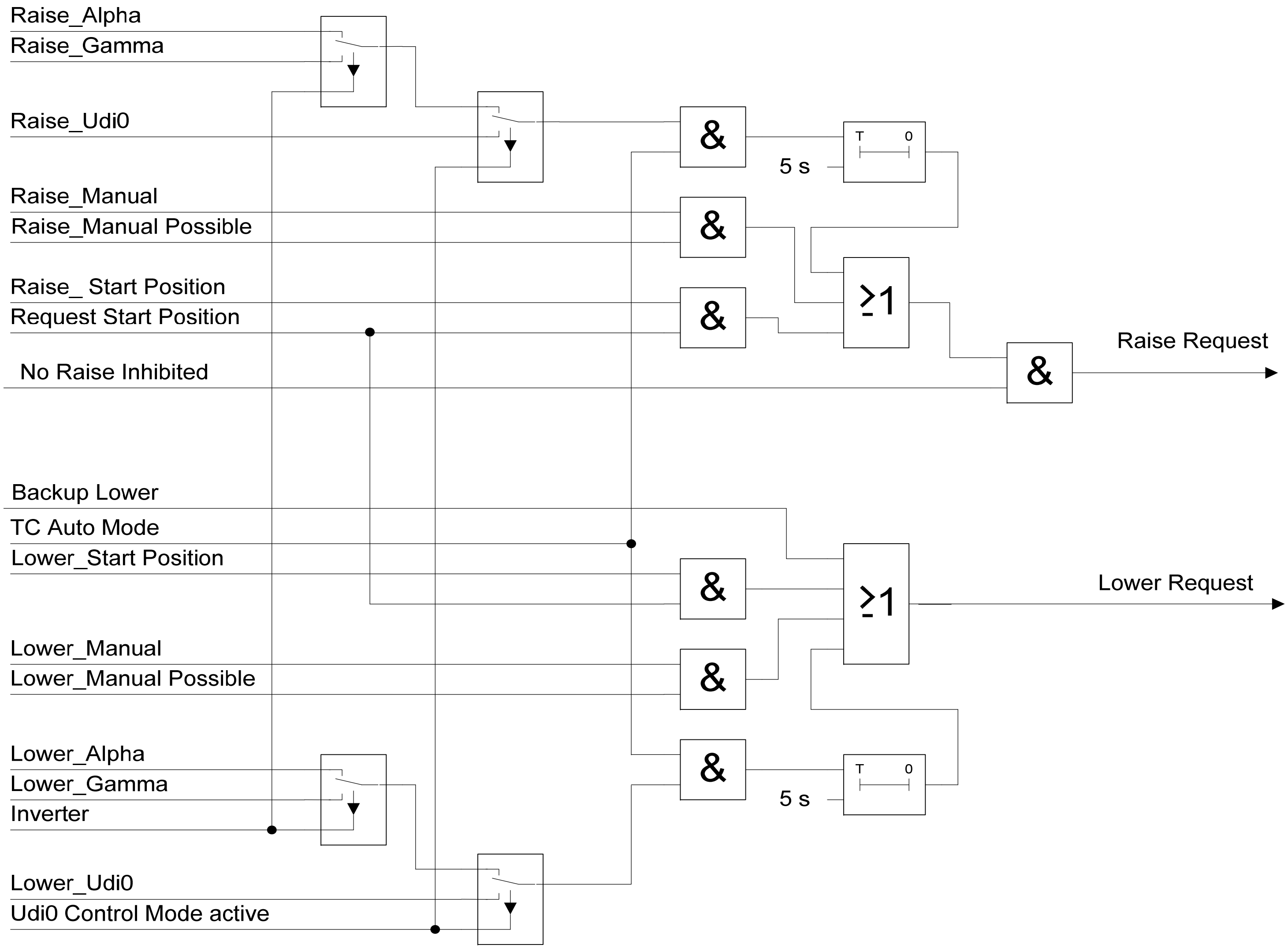
The Tap Changer Monitoring function gets all check back signals from the Tap Changers of each phase like:

- Tap Changer Position
  (Pole 3: BCD coded in six bits per phase, Pole 2: analog signal)
- Tap Changer Running Signal
- Tap Changer Faulty Signal
- Tap Changer in local control at the tap changer
- Tap Changer Loss of one AC Input
- Tap Changer Control Voltage Fault

Tap Changer Control
Positions and Operating Range

	Pole 2			Pole 3		
ΔuPrim [%]	Step No.	"TC raise"	"TC lower"	Step No.	"TC raise"	"TC lower"
30.00	1	Lower Limit				
28.75	2					
27.50	3			1	Lower Limit	
26.25	4			2		
⋮	⋮			⋮		
1.25	24			22		
0	25			23		
-1.25	26			24		
⋮	⋮			⋮		
-7.50	31			29		
-8.75	32			30		
-10.00	33	Upper Limit		31		
-11.25				32		
-12.50				33	Upper Limit	

Tap Changer Control
Raise / Lower Request Logic



Tap Changer Control
Raise / Lower Request Logic

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- Supervision of minimum and maximum tap positions and the voltage on the secondary side of the converter transformer U_{di0}.
- As soon as the transformer is energized, the U_{di0}-Monitoring calculates the U_{di0} voltage to enable supervising of the voltage on the secondary side of the converter transformer
- E.g. at 1.013 pu a further “Raise Command”*) is inhibited
- E.g. at 1.026 pu a “Back-up Lower”*) is initiated
- To avoid Tap Changer Fault indication a “Raise Command” is inhibited if the Tap Changer is already in its maximum position and vice versa a “Lower Command” is not allowed if the Tap Changer is in the lowest position.

*) Values for Pole 3 (U_{di0N}: 1pu = 194,0 kV)

Tap Changer Raise → Increases Reduces secondary voltage U_{di0}

Tap Changer Lower → Reduces secondary voltage U_{di0}

Tapchanger Control
Start Position Control

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- Prior to transformer energization, the Tap Changers are set to the start position (Tap 1 for Hayward and for Benmore converter station)
- The start position considers both minimum over-voltage stress on the converter valves and minimized inrush current to the converter transformer
- To accomplish this, the "Request start position" is given by the start sequence during transition from STOPPED to STANDBY status (before switching on the AC line circuit breaker)
- The request is also given by the stop sequence during transition from BLOCKED to STANDBY status (before switching off the AC line circuit breaker) to prepare the Tap Changer for restart
- In manual Tap Changer mode this operation can be initiated from the Operator Level.

Tapchanger Control
Runtime Supervision

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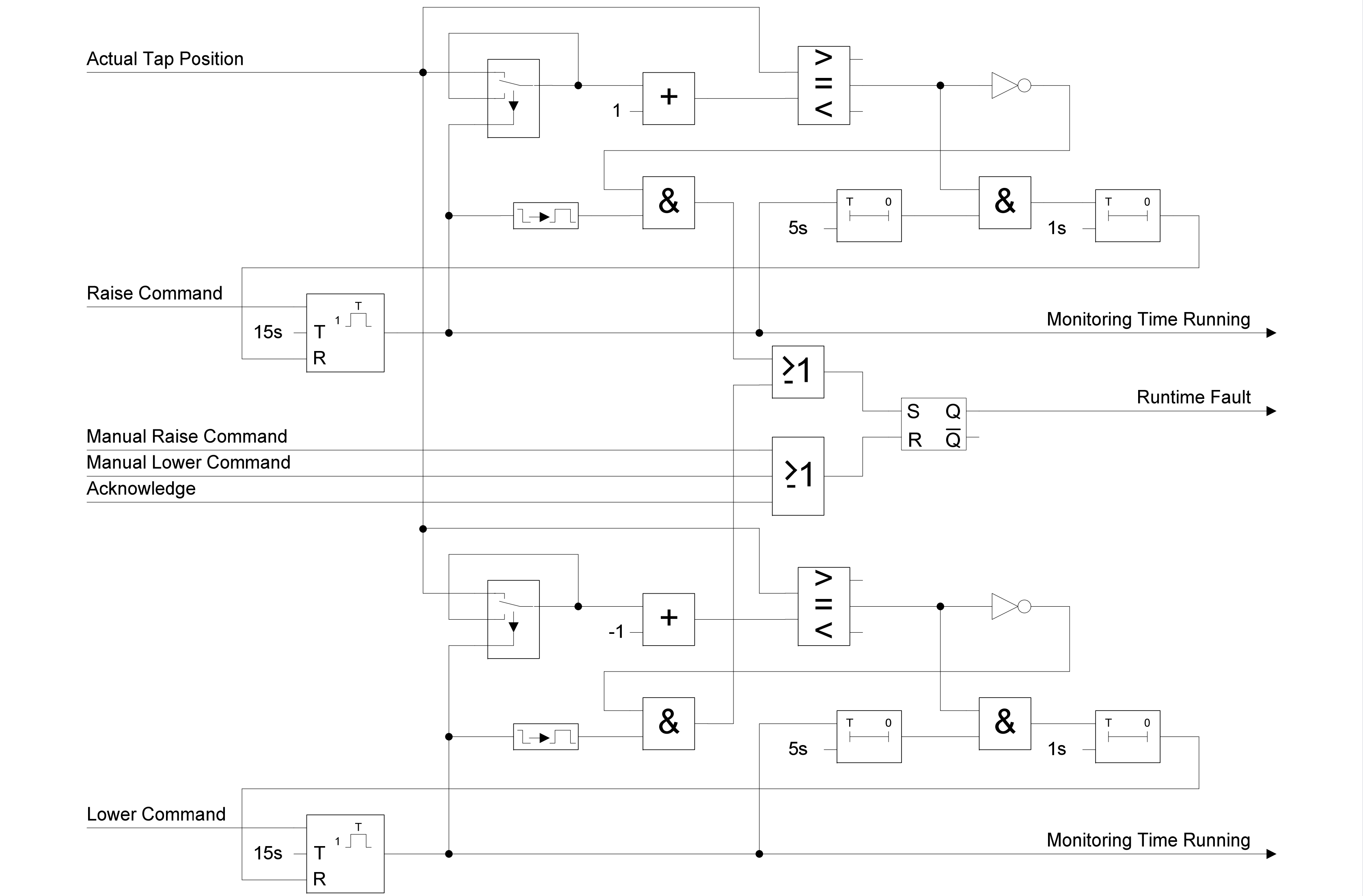


DC Filter Switching Sequences

DC Filter Switching

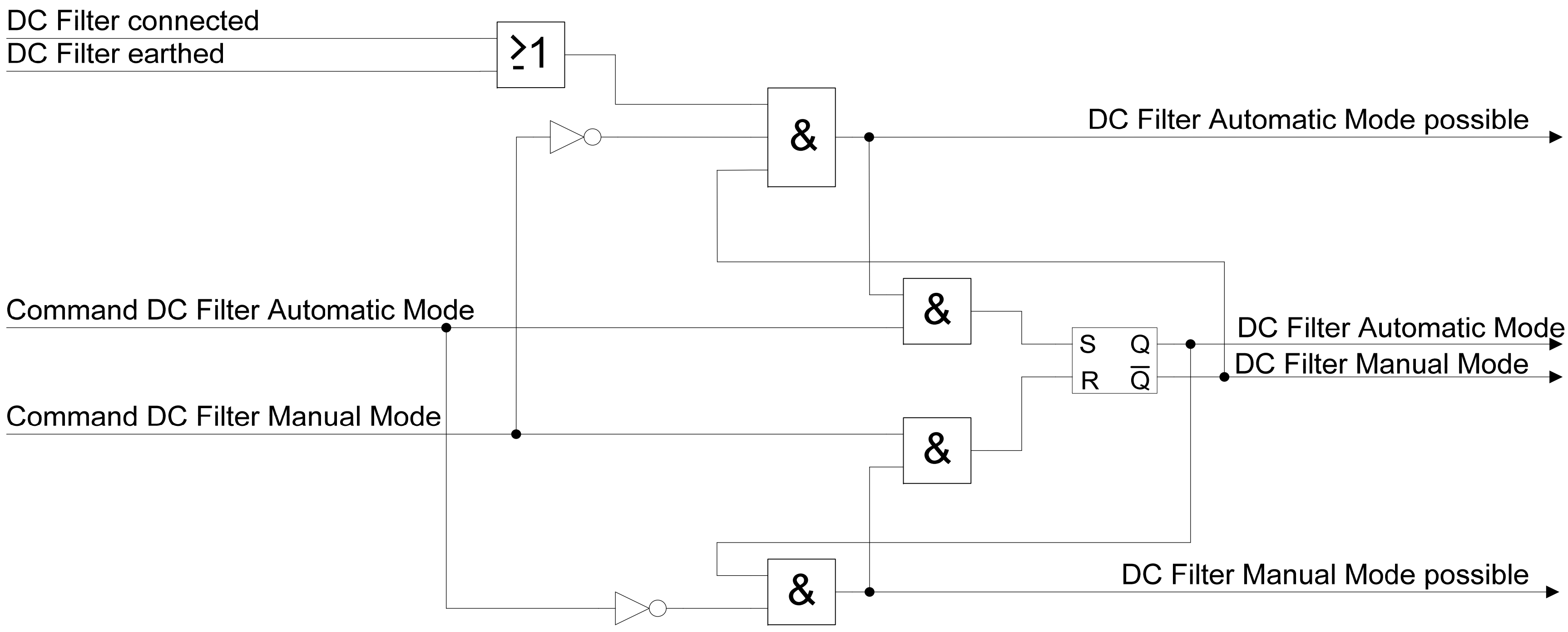
The HVDC system provides a DC Filter for each pole of each converter station, which are controlled from the respective Pole Control. DC Filter control includes:

- Check-back Supervision
  - LV DC Filter earthing switch (On, Off, Fault and Local Control Indication)
  - LV DC Filter disconnector (On, Off, Fault and Local Control Indication)
  - HV DC Filter earthing switch (On, Off)
  - HV DC Filter disconnector (On, Off, Fault and Local Control Indication)

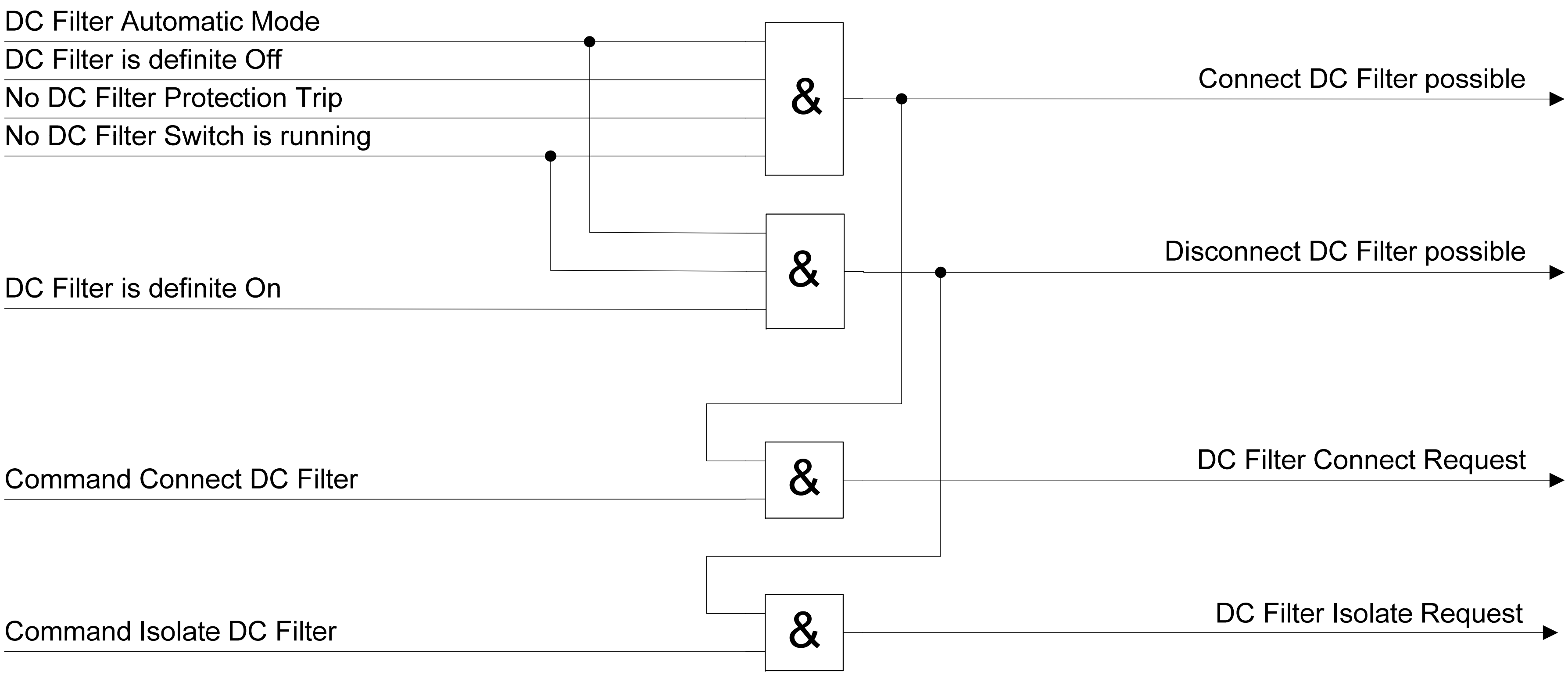
- DC Filter Mode Selection
  - Automatic Mode
  - Manual Mode

- DC Filter Connect / Isolate Sequence

DC Filter Mode Selection



DC Filter Connect / Isolate Logic



DC Filter Sequence

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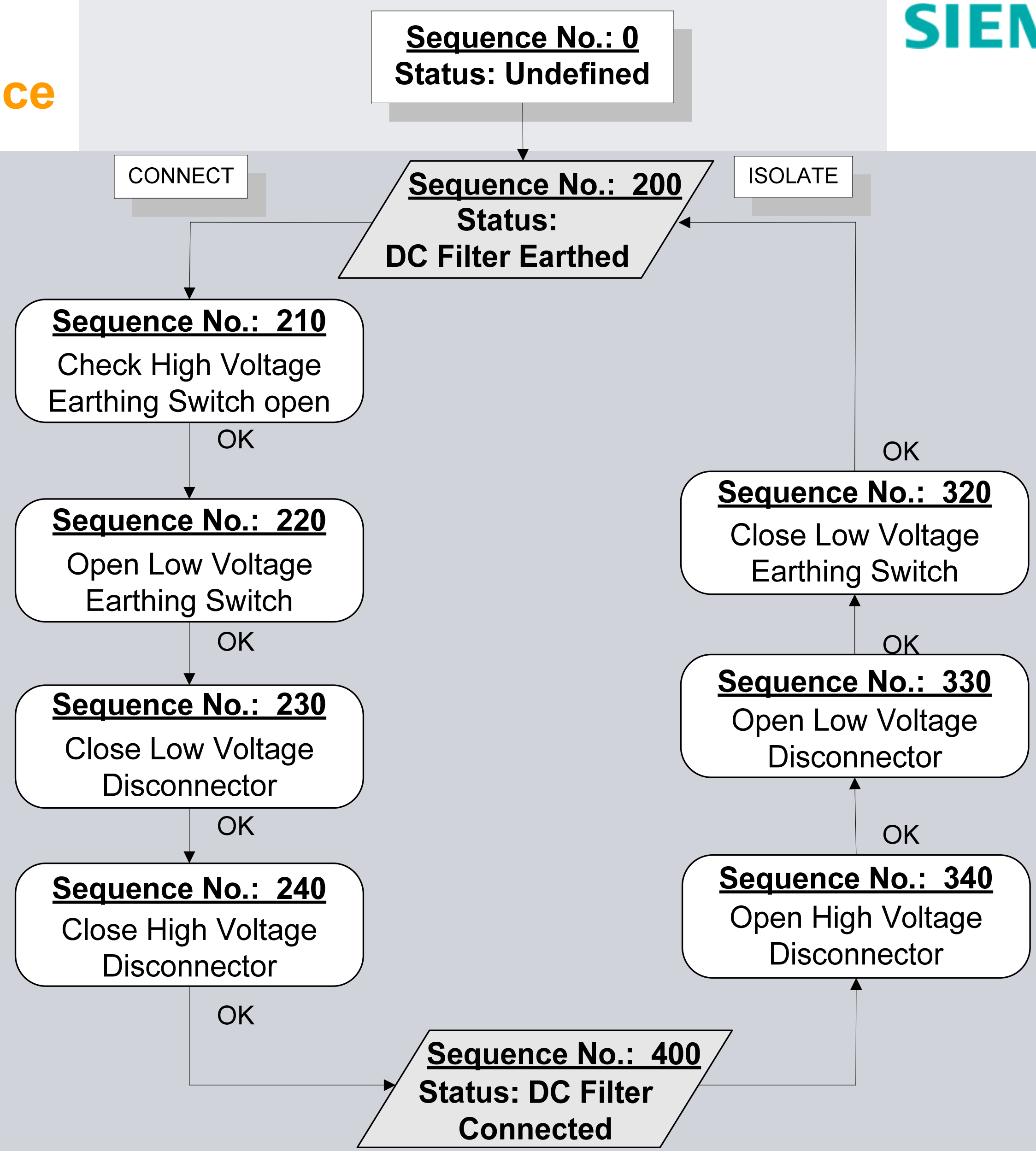

Switchgear Interlocking

Switchgear Interlocking Concept

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Interlocking Valve Hall & DC Filter areas

Interlocking functions are programmed in BCU and provided to Pole Control via PRE-RELEASE signal

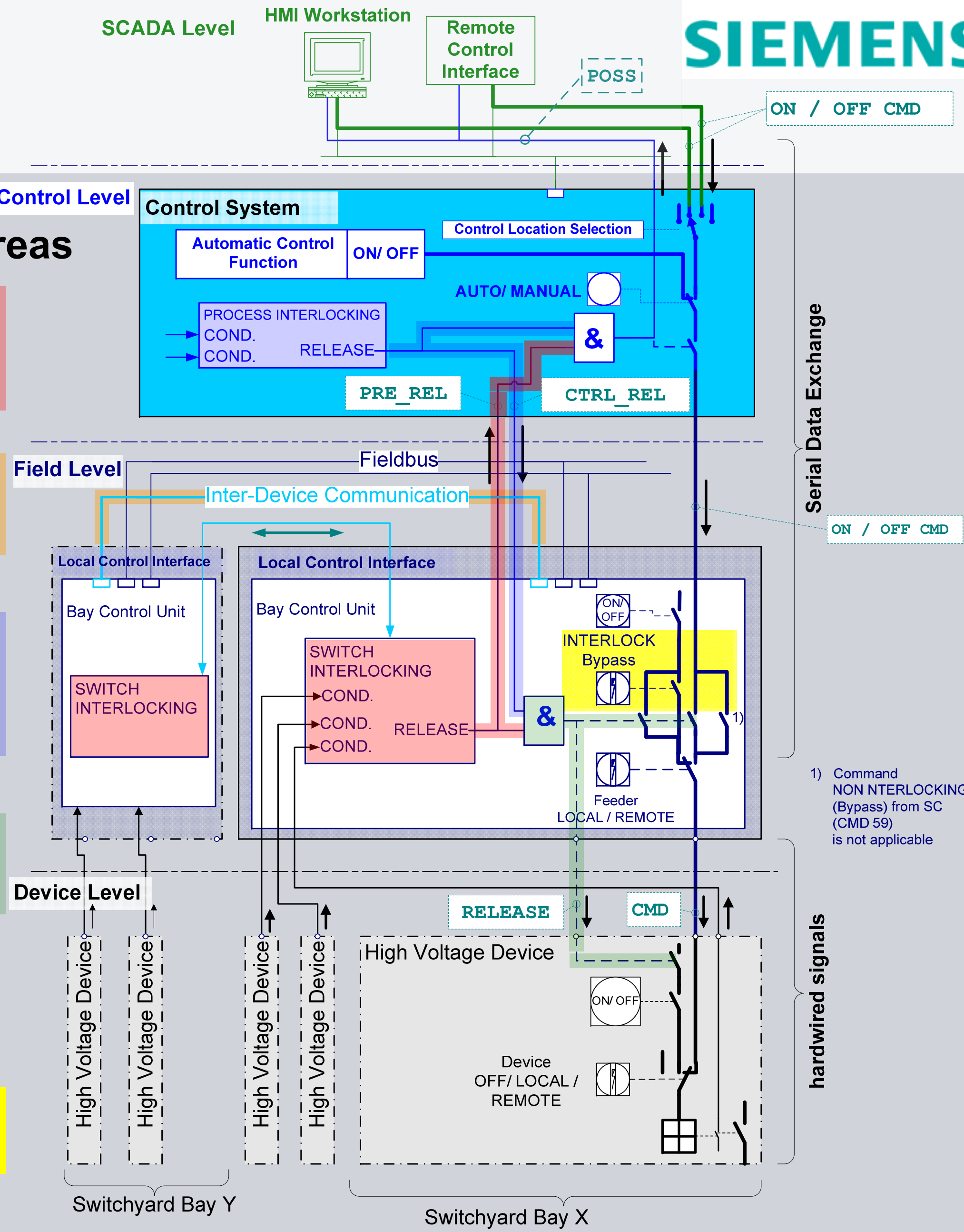
BCU inter-device communication allows realization of interlocks over bay borders

Pole Control provides overall interlocks to BCU via RELEASE signal e.g. interlocking with opp. station, pole deblocked etc.

BCU integrates RELEASE from Pole Control to COMMAND RELEASE for device

➔ **BCU & Pole Control interlocks are applicable for operation at all levels, from device up to HMI**

“INTERLOCK Bypass” function available at BCU control panel



Switchgear Interlocking Concept
Interlocking Signals Provided by Pole Control

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Typical RELEASE signals provided by Pole Control

=11D04-Q9	(=11D04-Q51/OFF Λ =11D04-Q53/OFF)[1] Λ (AC side not Earthed P3)[4] Λ (Valve Hall not Earthed P3)[4] Λ (P3 PULSES BLOCKED > 3s Λ =31D01-Q8/OFF)[3]	BCU Other BCU Other BCU Control

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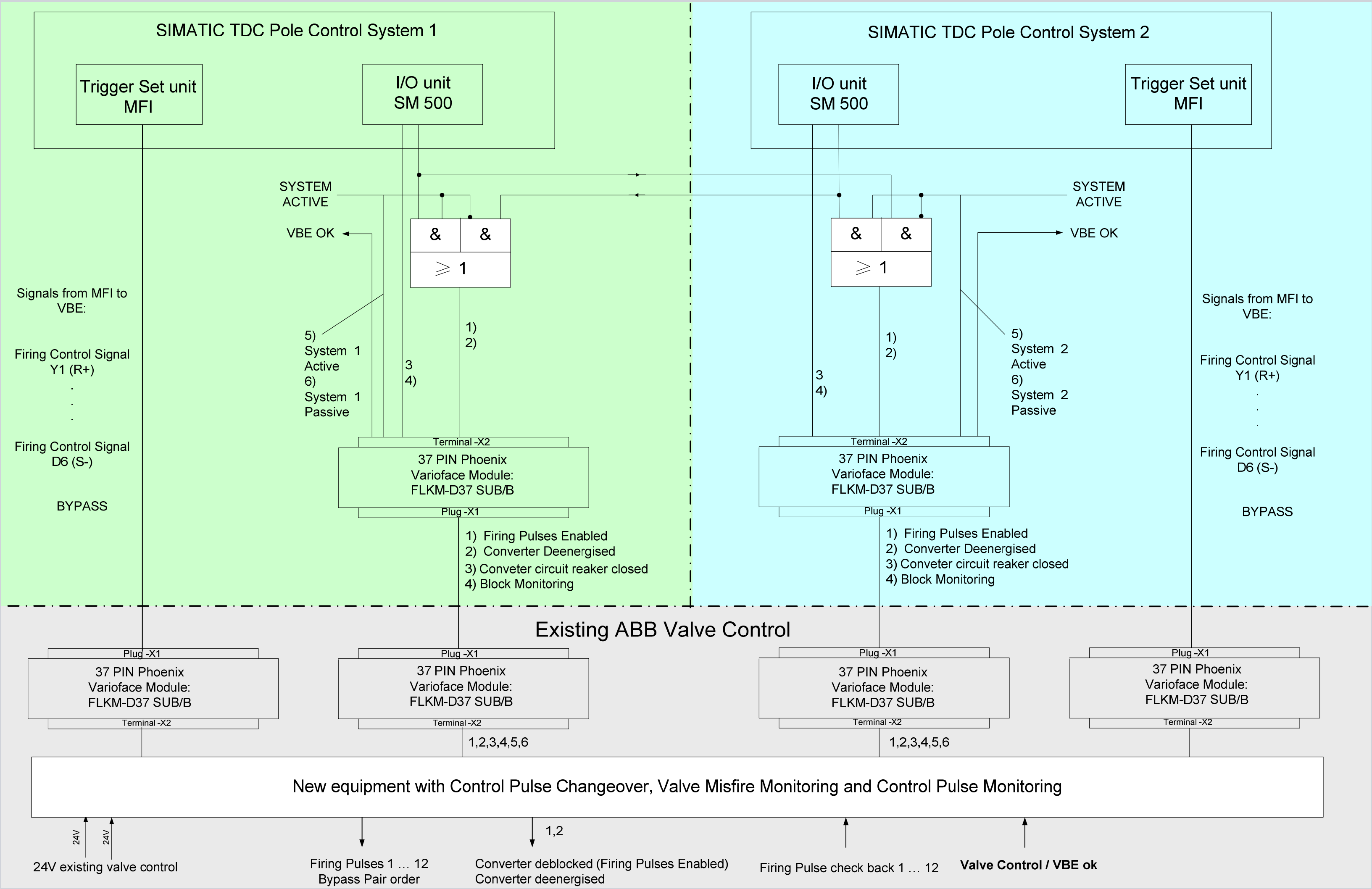
Interface
Pole Control System
and existing Pole 2 VBE

Interface with Pole Control Systems



Overview Signal exchange between Pole Control System and existing Pole 2 VBE

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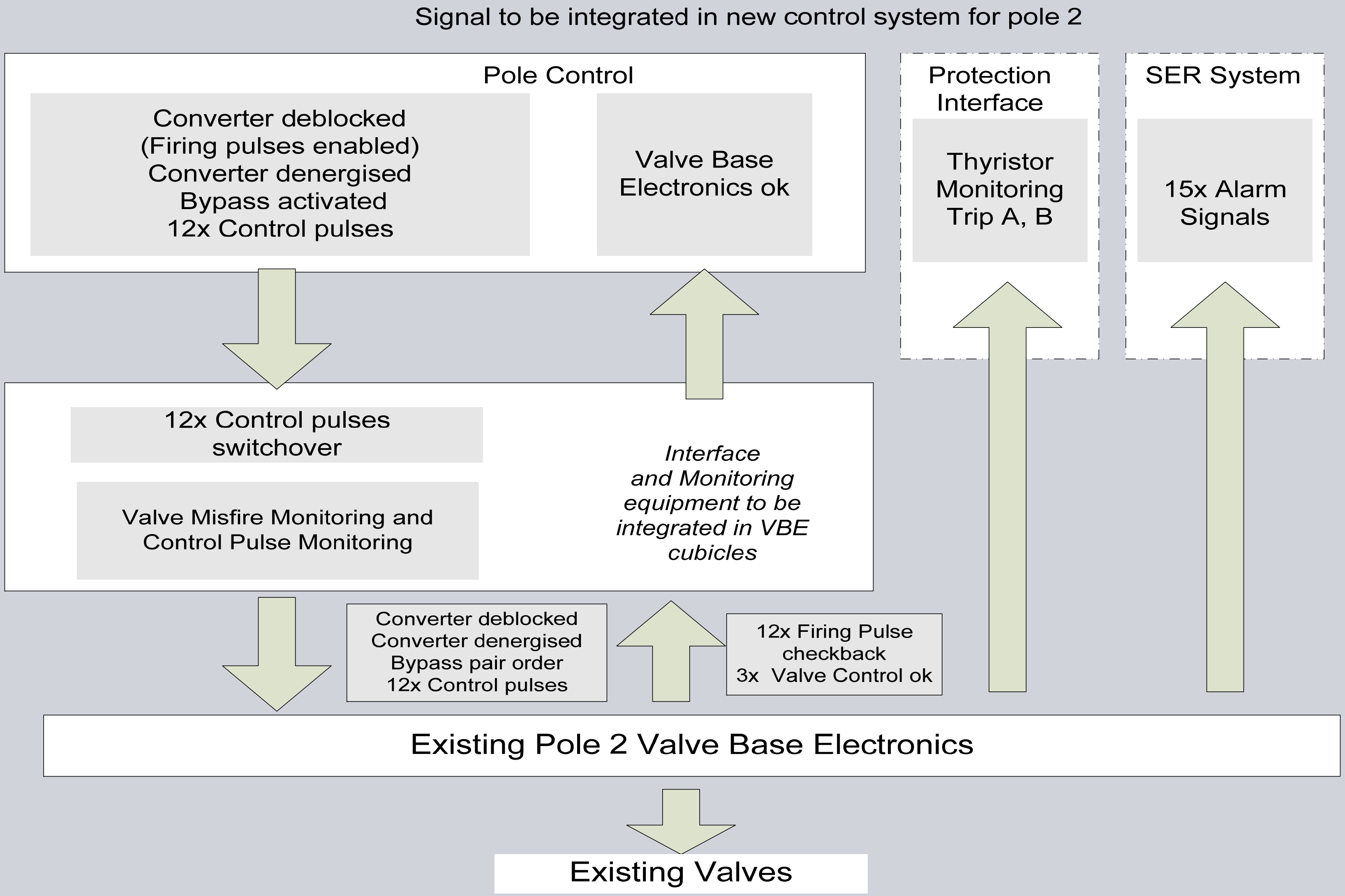

Firing Control Pulse Switchover

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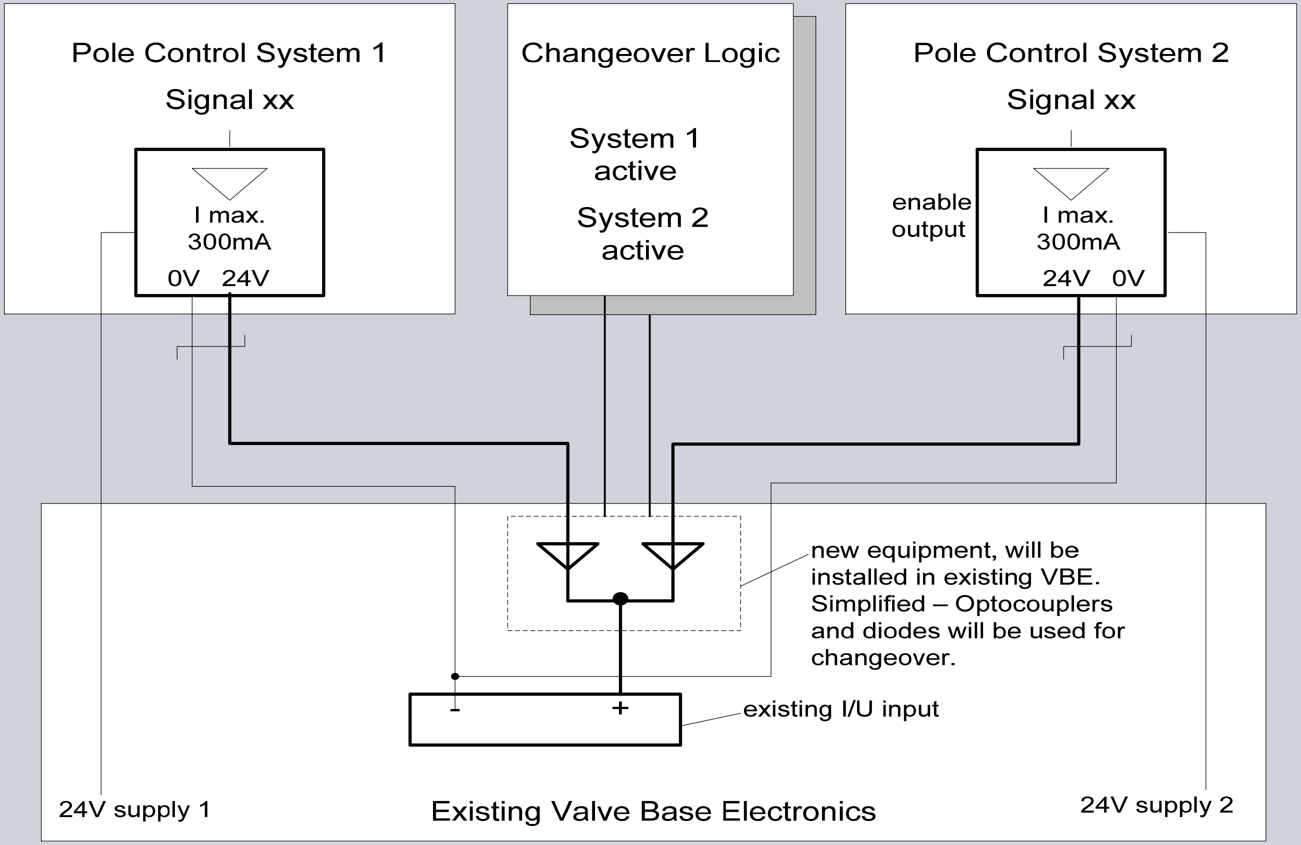
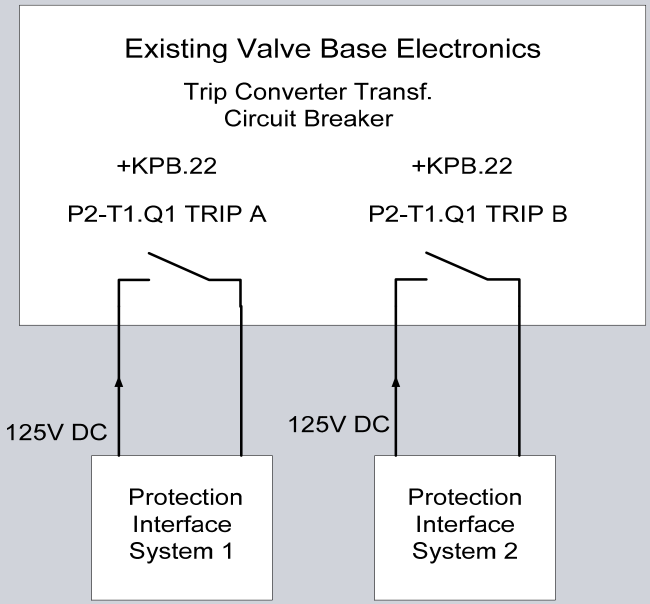
Redundancy changeover principle - Signal exchange valid for:

Converter deblocked
Converter de-energised
Bypass pair order
12x Firing pulses

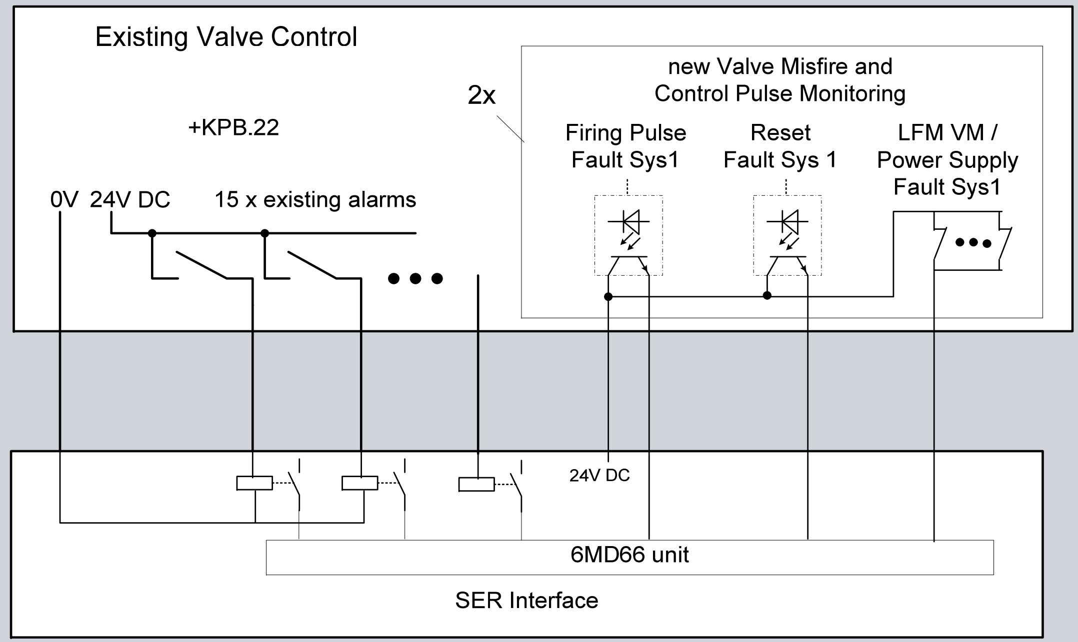


Interface design

Converter Trip Signals



SER Signals



Interface design of TFR Signals

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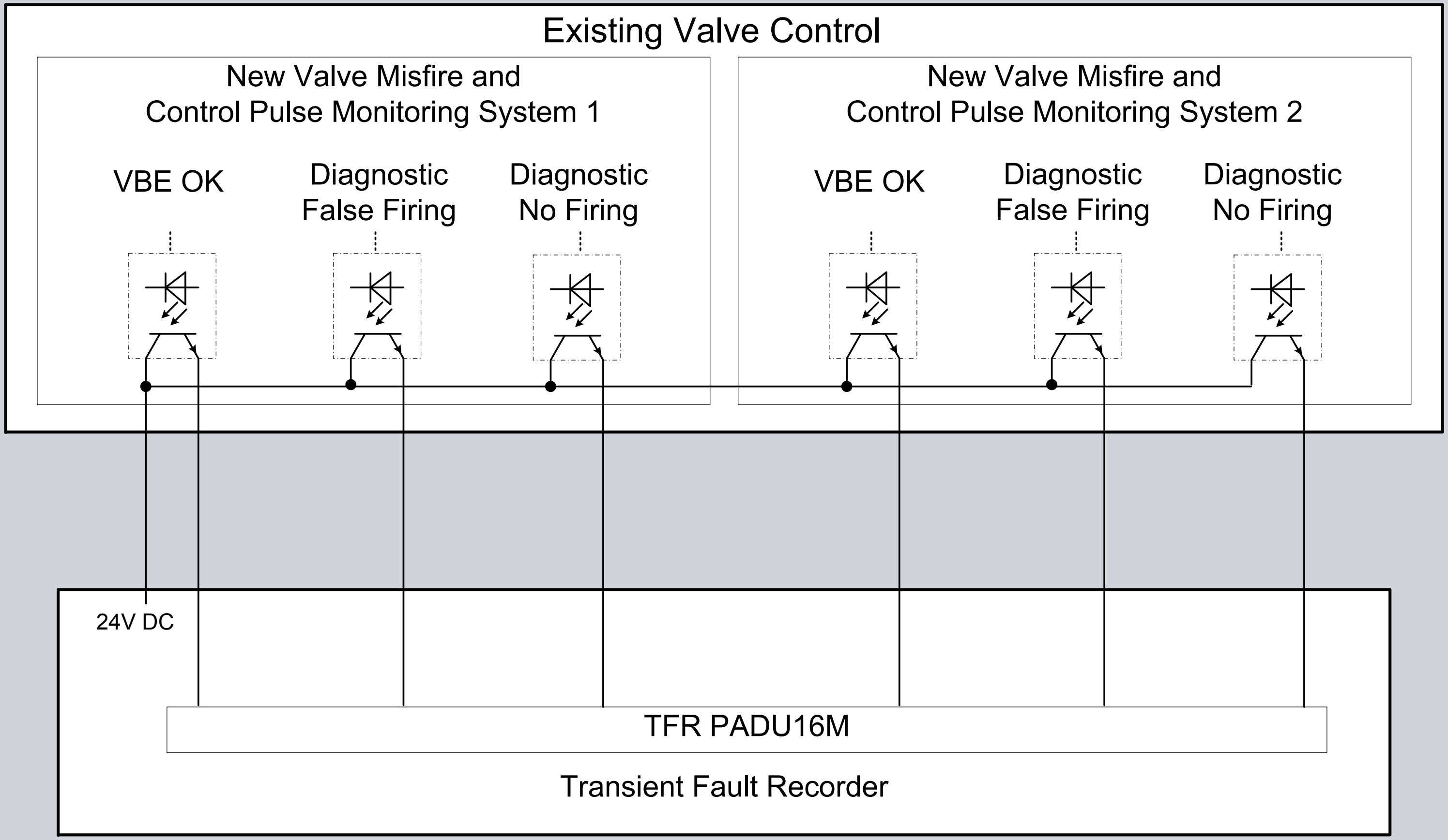

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Leading in HVDC Technology

New Zealand
Inter Island HVDC Project Pole 3

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Training Pole Control
Part 3 - Maintenance

E_B1_0341_App3_XDC

Disclaimer

Slides are for training purpose only, they are prepared on a general basis and may not in all cases cover all project specific aspects. Project specifics will also be shown in the direct on site training and in the manuals. The manuals also contain important safety instructions which need to be studied before beginning of the maintenance and inspection activities.

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Contents

- Installation of Application Software
- Maintenance
- Troubleshooting

Repair Instructions

DANGER

Dangerous voltages are present in the equipment which will cause death, serious injury or property damage.
It is especially important that the warning information in all of the relevant Operating Instructions is strictly observed.

WARNING

Hazardous voltages are present in this electrical equipment during operation.
Non-observance of the safety instructions can result in severe personal injury or property damage.
It is especially important that the warning information in all of the relevant Operating Instructions is strictly observed.

CAUTION

This panel contains components which can be destroyed by electrostatic discharge.
Prior to touching any electronics board, your body must be electrically discharged. This can be simply done by touching a conductive, grounded object immediately beforehand (e.g. bare metal cabinet components, socket protective conductor contact).

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Reference Documents

The following documents should be available and known by the maintenance personal

- Pole Control, System Information Manual, Doc.-No. E_B2_0341_XDC
- Pole Control, Maintenance Manual, Doc.-No. E_B4_0341_XDC
- Pole Control, C&P Hardware Drawings, Doc.-No. E_C2_0341_XDC
- Bipole Control, System Information Manual, Doc.-No. E_B2_0322_XDC
- Bipole Control, Maintenance Manual, Doc.-No. E_B4_0322_XDC
- Bipole Control, C&P Hardware Drawings, Doc.-No. E_C2_0322_XDC
- Single line diagram, Layout Drawing, Doc.-No. E_C1_0801_HAY
- Single line diagram, Layout Drawing, Doc.-No. E_C1_0801_BEN

Installation of Application Software

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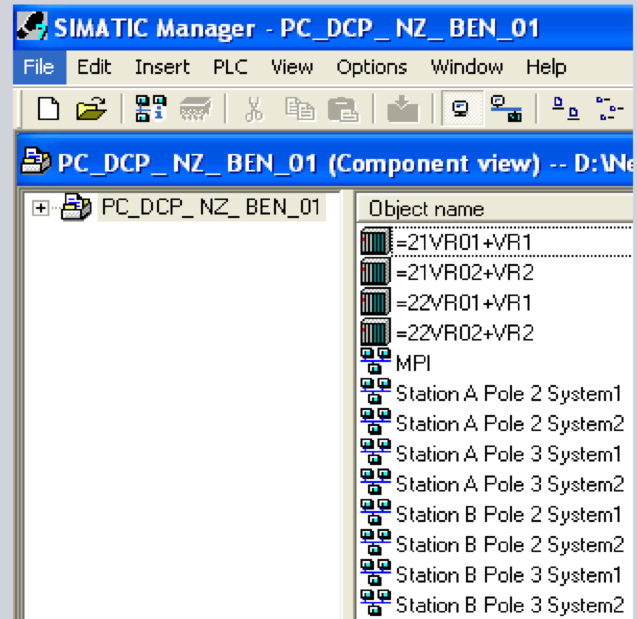
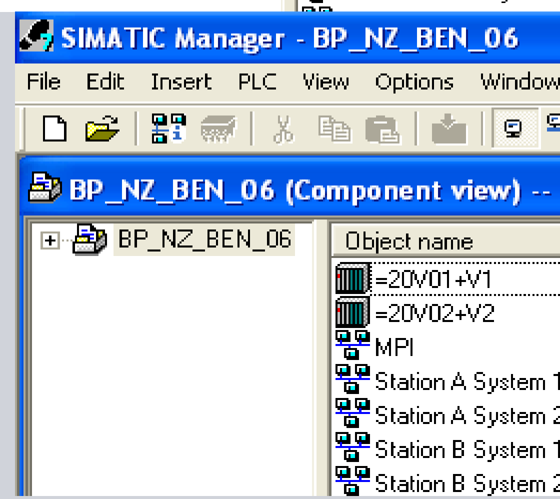
Installation of Application Software

SIMATIC TDC Engineering PC

- Master Software – One Master for both Stations
  - Copy Simatic TDC-Station at the Simatic Manager and rename for Pole 3 and Pole2 system 1
- Loading of System Parameter Files into the Application Software - PaGeTDC program
- SER Parameter – Pole dependent SER -Messages
  - Copy Pole 3 and Pole2 system 1 Simatic TDC-Station at the Simatic Manager and rename to Pole 3 and Pole2 system 2 (Pole Control only)
- Parameter Files – System dependent Parameter

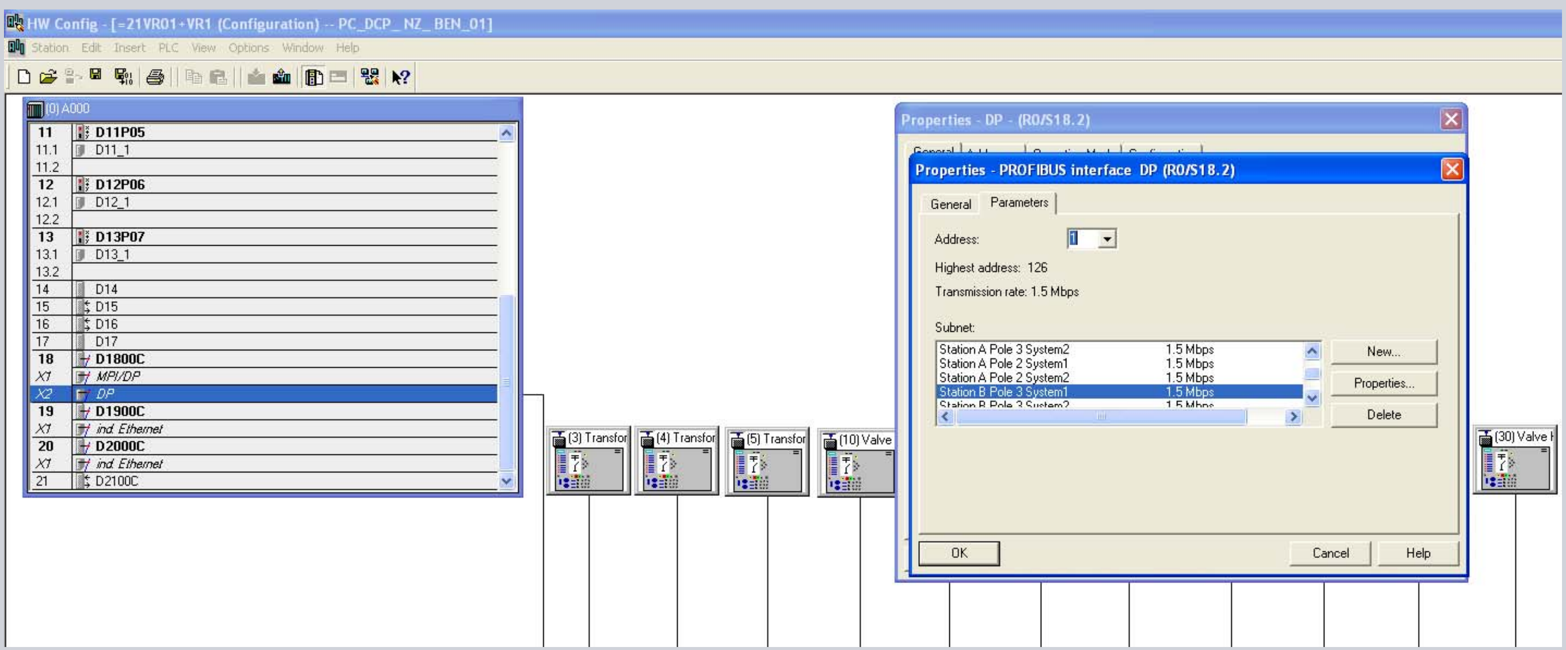




Hardware Configuration

MPI/DP	- Address, Subnet
PROFIBUS	- Address, Subnet
Ethernet LAN1	- Subnet, IP Address, Subnet Mask, Router Address
Ethernet LAN2	- Subnet, IP Address, Subnet Mask, Router Address

=> Save and Compile HW Config



Compilation EPROMs for CPU modules CPU551

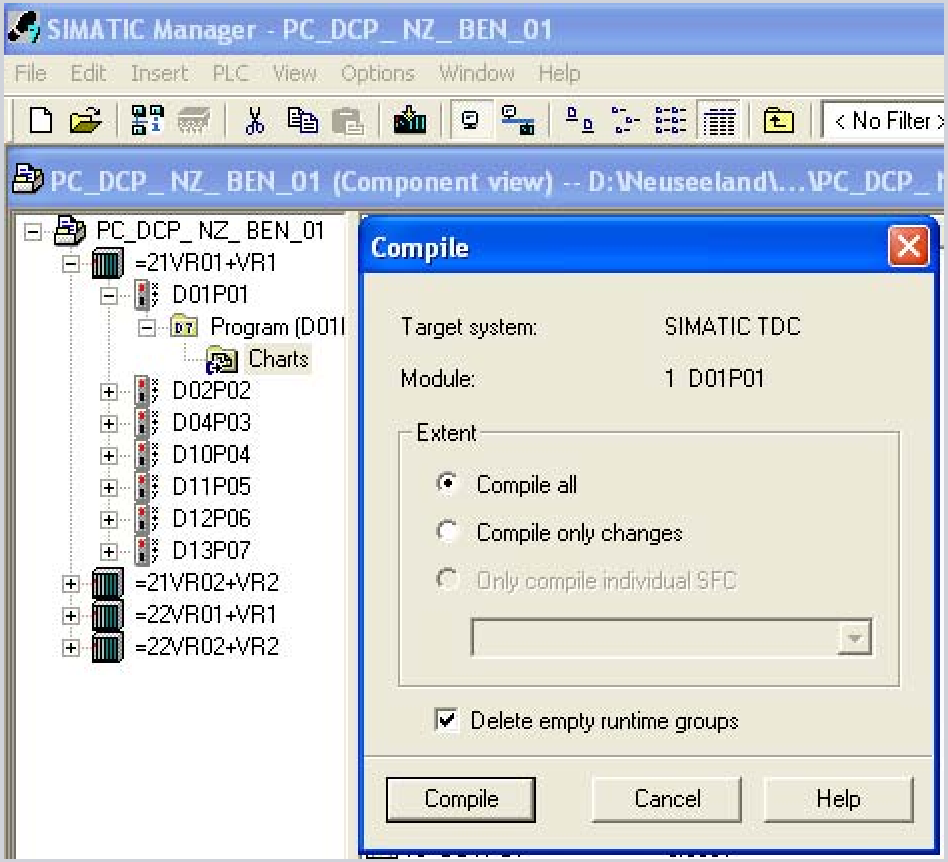
Compilation of a single CPU module

Highlight “charts” of the corresponding CPU module in the left part of the SIMATIC Manager window and select the menu:

Edit -> Compile

with the option “Compile all”

Repeat for all CPU-Modules



Programming EPROMs for CPU modules CPU551

Programming of a single CPU module

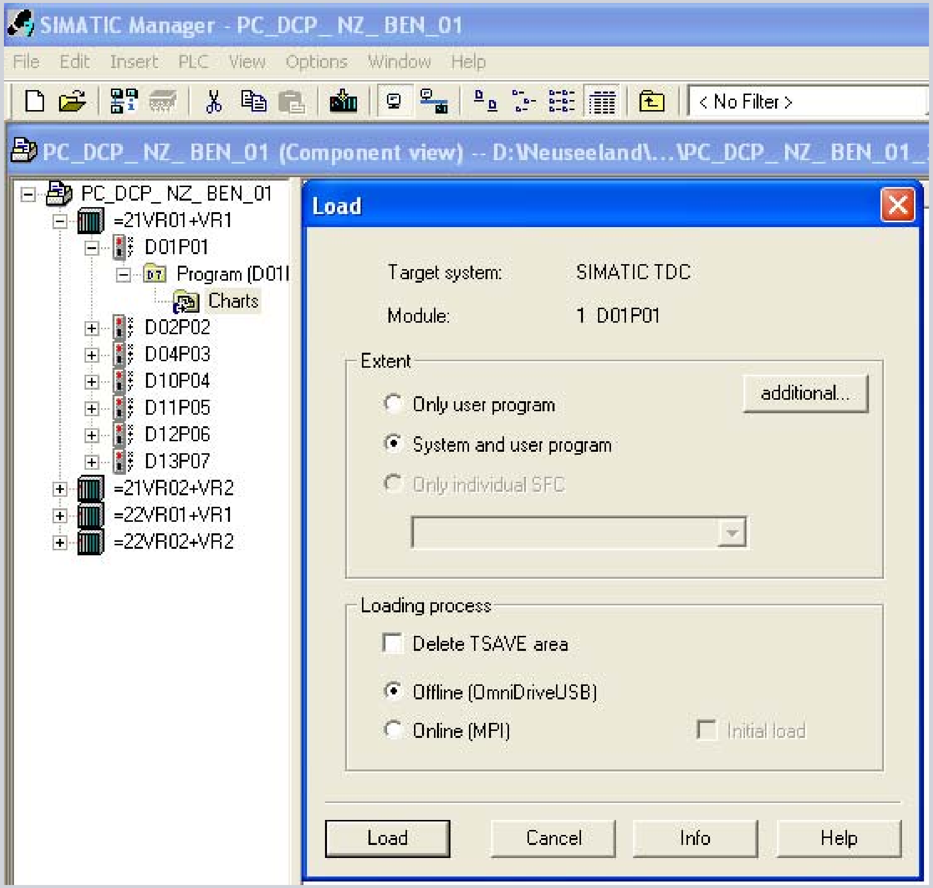
Highlight “charts” of the corresponding CPU module in the left part of the IMATIC Manager window and selection of the menu:

PLC -> Download

with the options:

System and user program

Offline (OmniDriveUSB)



Repeat for all CPU-Modules

Troubleshooting Instructions

System Failure Diagnostics of SIMATIC TDC

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LED display on each SIMATIC TDC processor module CPU551

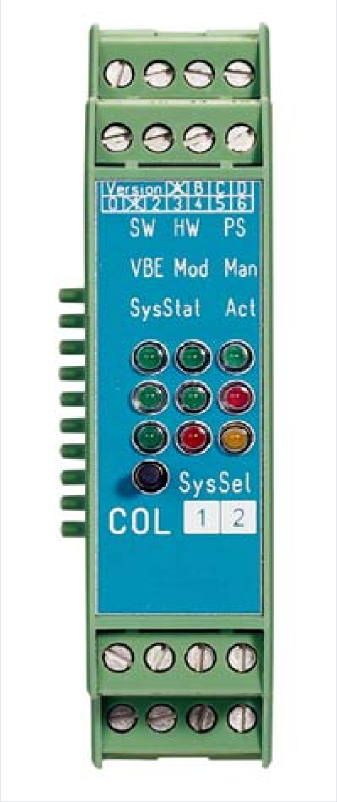
5 x 7 dot LED Display Indication	Meaning	Description	Can be deleted using Button S1
1... 21 (steady)	Configured number of the CPU module in normal operation.	User program running	no
0	Initialization error: User program is not running	Diagnostics should start at the CPU module which first displays the “0” fault message. ▪Flashing "0": Fault on this module ▪Steady "0": Fault on another module	no
b	Monitoring error: User program is running	Low-priority error during the initialization, which permits standard operation to start, and which is detected by the background processing, e.g.: ▪missing, discharged back-up battery ▪program memory not inserted ▪fan failure ▪Invalid floating value (Replacement value is used)	yes
C	Communications error: User program is running	Erroneous communications configuring or connection	no
d	User stop: User program is not running	▪Steady "d": Module is in STOP; Selection in the menu "Target system/operating status"; data is not being downloaded. ▪Flashing "d": Download is running in STOP (this is faster than downloading in RUN, which runs in the background).	no

System Failure Diagnostics of SIMATIC TDC

5 x 7 dot LED Display Indication	Meaning	Description	Can be deleted using Button S1
E	Task administration error: User program is running	The following errors are possible: ▪Cycle error: A task was not able to be completed within the task sampling time. ▪Task back-up: If the task is not marked as a task to run with the highest priority and it must re-started. ▪No free local buffer: The data buffer is no longer enabled. The task start is bypassed. ▪Software watchdog: If the basic sampling time is not processed four times, one after the other. The basic clock cycle timer is re-initialized with the configured basic sampling time and processing is continued.	yes
H	System error: User program is not running	Hardware or software problems which cause the program to crash. ▪Flashing "H": Fault/error on this module ▪Steady "H": Fault/error on another module	no
X	User error	User program running Diagnostics event, defined by the user using the USF function block.	yes
T	Trip	Trip by one (or more) protection functions at this particular CPU.	no
W	Warning	Warning detected by one (or more) software monitoring functions at this particular CPU.	no

Troubleshooting Instructions for Hardware

- LED Status COL
  - Green “OK” LED’s differentiate between faults of:
  - SW = Software ok (green LED)
  - HW = Hardware ok (green LED)
  - PS = Power Supply ok (green LED)
  - VBE = Corresponding Valve Base Electronics system ok (green LED)
  - Mod = Correct function of the COL module (green LED)
  - Man = Manual Mode (red LED)
  - SysStat = System Status ok / fault (green and red LED)
  - Act = System active (yellow LED)



- TDC subrack
  - Power supply disturbed: Green LED “POWER” is off
  - Fan disturbed: Red LED “FAN FAIL” is on
  - Red LED “SYS FAIL” is on

Troubleshooting Instructions for Hardware

- TDM Bus failure
  The LED H5 or H6 of the TDC subunit MFI is red instead of green
- Control Bus failure
  The LED H1, H2, H3 or H4 of the TDC subunit MFI is red instead of green
- Logic Function Module -D41…-D44 fault: Green LED “Module OK” not lit
- PROFIBUS OLM -U141 failure:
  - Green LED “System” not lit or flashes red.
  - Yellow LED “CH1” / “CH2” not lit or flashes / lights red
- PROFIBUS RS485 Repeater -U121 or -U122 failure:
  - Green LED “DC 24 V” not lit.
  - No indication of bus activity on segment 1 or 2 by yellow LED.

Energizing Control Cubicle

MCB Switching sequence MCB

- Switch On sequence:

  Start with -F10, -F12,-F13

  60sec time to switch on

  -F31 to -F331, otherwise

  initialisation fault will be caused.

  The setting of the "Software OK"

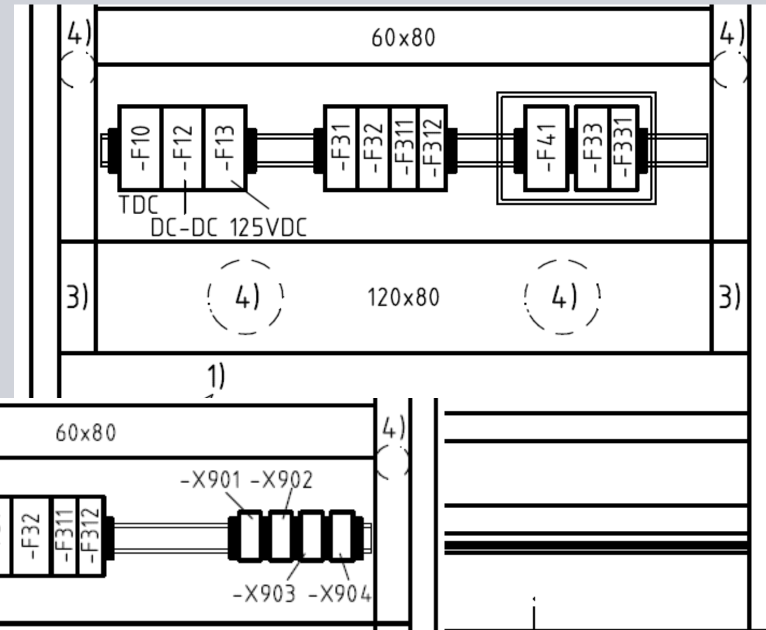
  status takes at least 3 minutes

- Switch Off sequence

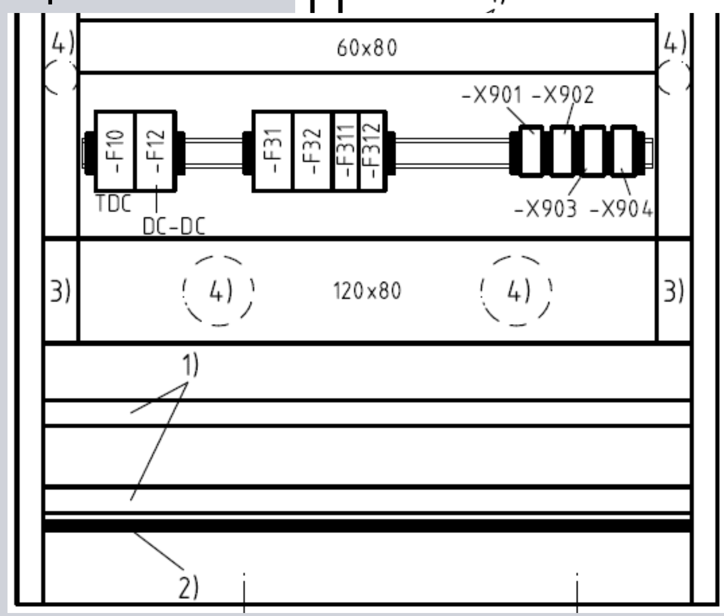
  In reversed order

  -F331 to -F10

Pole Control



Bipole Control



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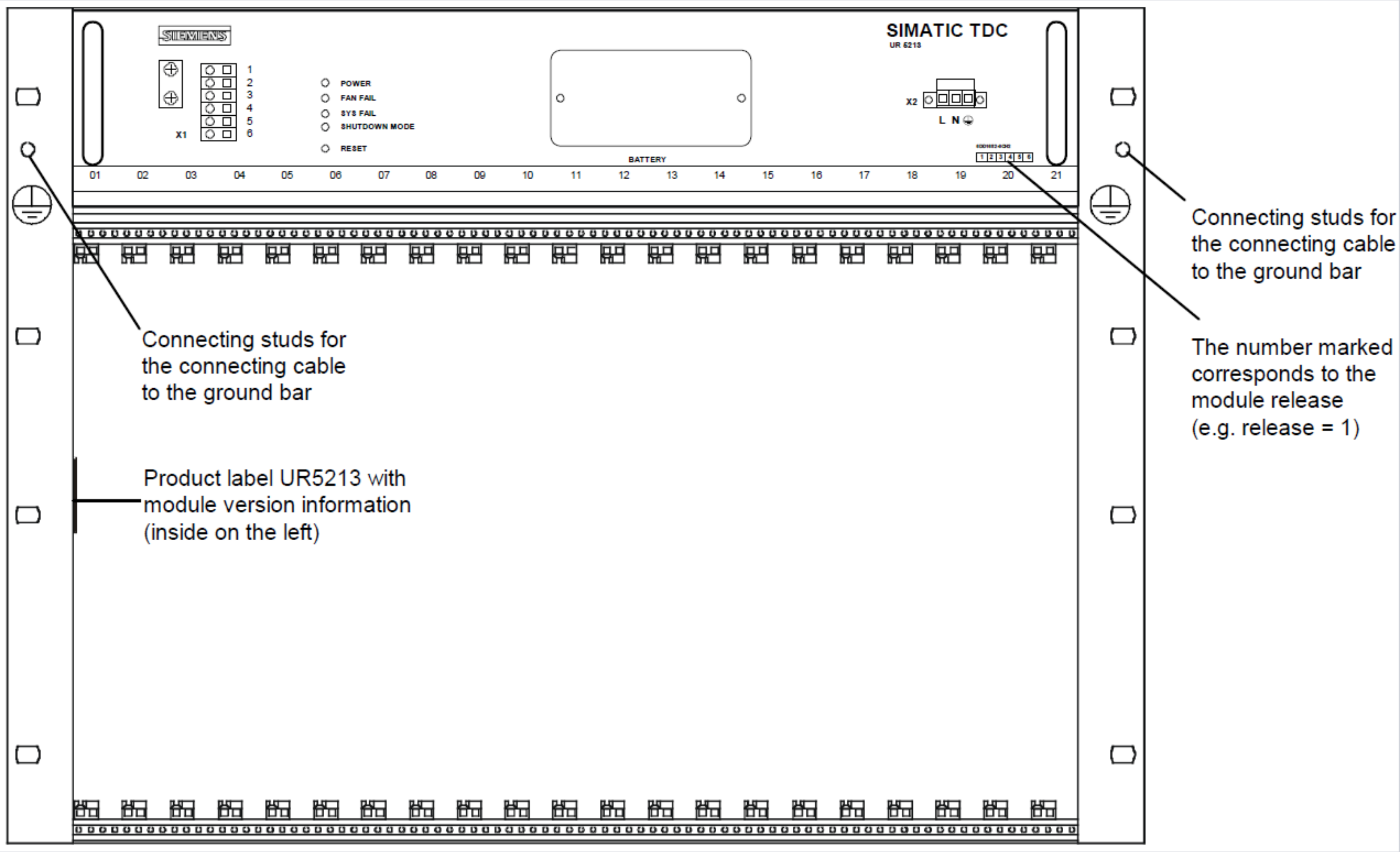
Set-up of Modules for the SIMATIC TDC Subrack

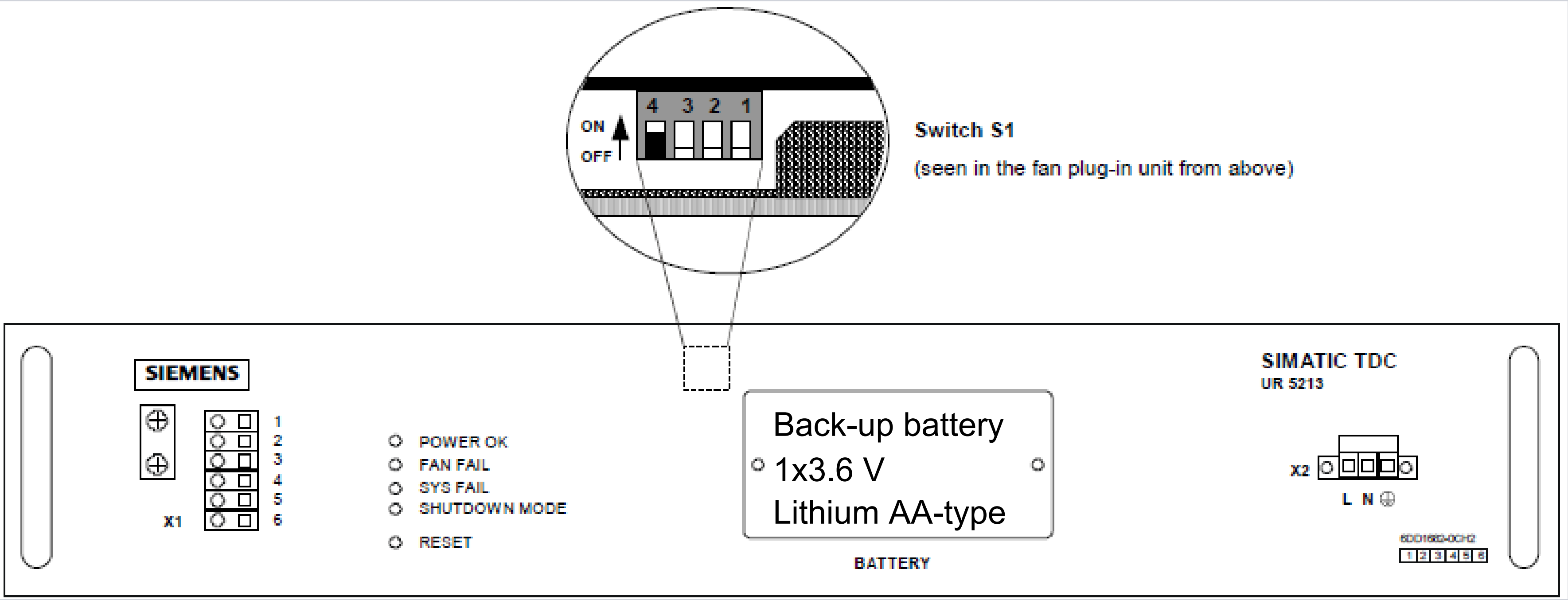
Order number	Description (Firmware)	Set-up
6DD1600-0BA1	CPU module CPU551	dongle “CY7C344B” into the plug socket using the appropriate tool. If applicable, plug in the MFI Multi function interface or the ICH optical communication subunit.
6DD1640-0AH0	SM500 signal module	No special set-up necessary.
6DD1661-0AD1	CP50M1 communication module	DIP-switch settings according factory setting (refer to E_B4_300_04-01_XDC chapter 6.1.5).
6DD1661-0AE1	CP51M1 communication module	DIP-switch settings according factory setting (refer to E_B4_300_04-01_XDC chapter 6.3.5).
6DD7050-0AA70	MFI multi function interface	No special set-up necessary.
6DD7050-0AA30	ICH optical communication subunit	No special set-up necessary.
14.131000	SM128V VMEbus interface card	Settings of mini switches at the front plate according to Hardware Drawings:
6DD1682-0DA1	Slot cover SR51	No special set-up necessary.

TDC Subrack



SIMATIC TDC
UR 5213
POWER
FAN FAIL
SYS FAIL
SHUTDOWN MODE
RESET
BATTERY
X1
X2
L N
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21
Connecting studs for the connecting cable to the ground bar
Product label UR5213 with module version information (inside on the left)
Connecting studs for the connecting cable to the ground bar
The number marked corresponds to the module release (e.g. release = 1)

Operator control and display elements



Replacing the back-up battery is possible during operation of SIMATIC TDC but it is recommended to replace the battery during maintenance period only

One Lithium AA-type 3.6 V battery
(Ord.-No.: 6ES7971-0BA00)

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Operator control and display elements

Terminal X1: 3 floating 230V signaling relays (3 x 2 contacts)

SHUTDOWN MODE:

The system shutdown mode can be selected using the switch position, when either one fan fails or two fans .

The used operating mode is indicated on the front panel with the LED shutdown mode.

LED: The four LED's display the subrack status.

RESET: All of the modules are re-started when the recessed button is pressed.

BATTERY: Compartment for buffer battery (1 accumulator lithium, type AA)

Terminal X2: Line supply connector

Front panel: Switch S1 (seen in the fan plug-in unit from above)

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Status and fault displays

LED	Display	Subrack status
POWER (green or red)	Green bright	Fault-free operation
	Red bright	Fault (also refer to voltage monitoring)
FAN FAIL (red)	Dark	Fault-free operation
	Bright	Fault (at least one fan has failed)
SYSFAIL (red)	Dark	Fault-free operation
	Bright	System was stopped
Shutdown mode (yellow)	Bright	Disconnection if two fans have failed (corresponds to the OFF switch position of the switch S1.4)
	Blinking	Disconnection if one fan has failed (corresponds to the ON switch position of the switch S1.4)

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Leading in HVDC Technology