HVDC Protection
What are the special features of HVDC Protection Systems? (1)

The protection cannot prevent system faults but it can avoid or limit the damage caused by short circuits and provide good strategies to recover reliably and fast after AC and DC faults.
What are the special features of HVDC Protection Systems? (2)
What are the special features of HVDC Protection Systems? (3)

Protection must be

- **Fast**
  - e.g. detection time of DC line faults < 5 ms
  - DC protection with very high reliable design

- **Reliable**
  - (no additional upper back up levels like AC protection systems)

- **Fail-Safe**
  - no false trips e.g. check of measuring signals before trip initiation

- **Selective**
  - Strategies to stay in operation e.g. after loss of a filter bank

- **Independent**
  - Main and back up functions with independent measuring channels
HVDC Protection Functions

Protection Zones
1 Station, 1 Pole

1 AC Busbar Protection (incl. Connection Protections)
2 AC-Line Protection
3 AC-Filter Sub Bank Protection
4 Converter Transformer Protection
5 Converter Protection
6 DC-Busbar Protection
7 DC-Filter Protection
8 Electrode Line Protection
9 DC-Line Protection
HVDC Protection Functions

Protection Zones

1 Station, 1 Pole

1 AC Busbar Protection (incl. Connection Protections)
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to other Pole
HVDC Protection Functions

50/51C: DC Overcurrent Protection
- Short Circuits at Rectifier / Inverter and Overload Failures
- \( \text{Max (} I_{\text{acY}}, I_{\text{acD}}) > \delta \)
- \( \rightarrow \) ESOF, Open AC Circuit Breaker (4 stages)
**HVDC Protection Functions**

87CBY, 87CBD: Bridge Differential
- Each 6p-G separate detected: commutation failure, firing malfunction, Conv. DC faults
- MAX (lacY, lacD) - lacY > delta or MAX (lacY, lacD) – lacD > delta
- 1st stage: Id reduction to 0.3 Idref
- 2nd stage: ESOF and Open AC Circuit Breaker
**HVDC Protection Functions**

87CSY, 87CSD: Short Circuit Protection
- Valve short circuit
- $I_{acY} - \text{MIN} (IdH, IdN) > \delta$ or $I_{acD} - \text{MIN} (IdH, IdN) > \delta$
- Short Circuit at Rectifier: Block VBE, ESOF, Open AC Circuit Breaker
- Short Circuit at Inverter: ESOF, Open AC Circuit Breaker
**87CG: Group Differential Protection**

- All DC faults that are bypassing the inverter
- MAX (IdH,IdN) – MAX (IacD,IacY) > Delta
- ESOF, Open AC Circuit Breaker, Open HSNBS
HVDC Protection Functions

87DCM: DC Differential Protection
- Ground faults anywhere in the converter
- $I_{dH} - I_{dN} > \Delta$
- ESOF, Open AC Circuit Breaker, Block firing pulses at rectifier
HVDC Protection Functions

Converter Protection

One System Shown

**59/37DC: Open Converter Protection / DC Overvoltage Protection**
- When rectifier tries to operate against open dc line or a blocked inverter
- \( U_{dL} > \text{thres.} \)
- Block request
HVDC Protection Functions

27DC: DC Undervoltage Protection
- High voltage faults to neutral or ground
- \(U_dL < \text{thres}\)
- ESOF, Open AC Circuit Breaker
- Must be co-ordinated with DC Line Fault Recovery Sequence

Converter Protection

One System Shown
HVDC Protection Functions

81-50Hz/100Hz: Fundamental Frequency Protection

- Commutation failures at inverter side, Single phase faults at the AC side
- \( \text{IdL(50Hz)} > \text{thres} \), \( \text{IdL(100Hz)} > \text{thres} \)
- 1st stage: \( \rightarrow \) Current reduction to 0.3 \( \text{Idref} \)
- 2nd stage: \( \rightarrow \) Block pole
- must be co-ordinated with fault back-up clearing time
**81-I/U: Remote Station Fault Protection**

**AC-DC Conductor Contact Protection**

- Inadverted Pulse Block of Inverter, AC line contact to DC line
- IdL (50Hz) > Thres1 & IdL > Thres2, UdL (50Hz) > Thres 3 & IdL (50Hz) > Thres4
- Forced Retard (Alpha:120°), Block Pole after 50Hz comp. clearing
HVDC Protection Functions

Converter Protection

One System Shown

50/51C: DC Overcurrent Protection
87CBY, 87CBD: Bridge Differential
87CSY, 87CSD: Short Circuit Protection
87CG: Group Differential Protection
87DCM: DC Differential Protection
59/37DC: Open Converter Protection / DC Overvoltage Protection
27DC: DC Undervoltage Protection
81-50Hz, 81-100Hz: Fundamental Frequency Protection
81-I/U: Remote Station Fault Protection / AC-DC Conductor Contact Protection
HVDC Protection Functions

Protection Zones

1 Station, 1 Pole

1 AC Busbar Protection (incl. Connection Protections)
2 AC-Line Protection
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9 DC-Line Protection
HVDC Protection Functions

DC bus bar Protection

87HV: HV DC Busbar Differential Protection (F to G or N)

87LV: Neutral DC Busbar Differential Protect. (F to G or HV)

87DCB: DC Differential Back-Up Protection (Earth F at DC Bus or Pole Equipment)
HVDC Protection Functions

Protection Zones

1 Station, 1 Pole

1 AC Busbar Protection (incl. Connection Protections)
2 AC-Line Protection
3 AC-Filter Sub Bank Protection
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to other Pole
HVDC Protection Functions

DC-Line Protection

- **WFPDL**: Wavefront Protection (DC Line F to G)
- **27dUdt**: Undervoltage Sensing Protection (27du/dt), DC Line F to G or N
- **87DCL**: DC Line Differential Protection (DC Line F to G)

WFPDL: absolute change of current in a fix time

27dUdt: Rate of change of voltage

87DCL: absolute change of voltage in a fix time

Diagram showing current and voltage relationships with symbols for different components.
HVDC Protection Functions

Protection Zones
1 Station, 1 Pole

1 AC Busbar Protection (incl. Connection Protections)
2 AC-Line Protection
3 AC-Filter Sub Bank Protection
4 Converter Transformer Protection
5 Converter Protection
6 DC-Busbar Protection
7 DC-Filter Protection
8 Electrode Line Protection
9 DC-Line Protection

Diagram showing various protection zones and their components, including symbols and labels for current and voltage indicators.
HVDC Protection Functions

Electrode Line Protection

76 SG: Station Ground Overcurrent Protection
76 EL: Electrode Overcurrent Protection
60 EL: Electrode Current Balance Protection (Earth F at EL)
87 EB: Electrode Bus Differential Protect. (Earth F to Electr.Bus)
59 EL: Electrode Overvoltage Protection (Open E Line)
(in add. Pulse Echo Monitoring System, PEMO)
HVDC Protection Functions

**Electrode Line Protection**

- **76 SG:** Station Ground Overcurrent Protection
- **76EL:** Electrode Overcurrent Protection
- **60EL:** Electrode Current Balance Protection
- **87EB:** DC Line Transversal Differential Protection (DC L F to G and CE F in MR-Operation)
- **59 EL:** Electrode Overvoltage Protection (Open E Line) (in add. Pulse Echo Monitoring System)

Diagram:

- **UdL:**
- **IdCH:**
- **IdLN:**
- **IdSG:**
- **IdEE1:**
- **IdEE2:**
- **UdN:**
- **other pole:**

**Siemens**
HVDC Protection Functions

Protection Zones
1 Station, 1 Pole

1. AC Busbar Protection (incl. Connection Protections)
2. AC-Line Protection
3. AC-Filter Sub Bank Protection
4. Converter Transformer Protection
5. Converter Protection
6. DC-Busbar Protection
7. DC-Filter Protection
8. Electrode Line Protection
9. DC-Line Protection
HVDC Protection Functions

DC-Filter Protection

51C1DF: C1 Differential Overcurrent Protection (SC, faults to N,G)
60/61DF: Capacitor C1 Unbalance Supervision (F within Cap. Unit)
51 DF: Inverse Overcurrent Time Protection (Excess. harm. Curr.)
87DF: DC Filter Differential Protection (F to G or N in the P Zone)
HVDC Protection Functions

Protection Zones

1 Station, 1 Pole

1 AC Busbar Protection (incl. Connection Protections)
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5 Converter Protection
6 DC-Busbar Protection
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9 DC-Line Protection

to other Pole
HVDC Protection Functions

AC-Filter
Sub Bank Protection

Main Protection
SIEMENS

Back-up Protection
SIPROTEC

87ACFB
50/51ACF

50/51ACFR
50/51ACFL

60/61ACFC1

50/51ACFZS:
Zero Sequence Protection

C1
T1
T2
L1
R1
L2
C2
R2
T41
T42
T3

50/51ACF:
Inverse Overcurrent-Time Protection

49/59ACF:
Capacitor Overload Protection

87ACF:
Differential Protection

60/61ACFC1:
C1 Capacitor Unbalance Supervision

50/51ACR:
Overload Protection for Resistor

50/51ACL:
Overload Protection for Reactor

50/51ACFZS:
Zero Sequence Protection
HVDC Protection Functions

AC Busbar Protection

67: AC Directional overcurrent Relay
87BB: Busbar differential Protection relay

AC Grid

67 Bus bar Back-up

AC Busbar

87BB Bus bar Main

AC Filter 1
AC Filter n
AC Shunt

AC Filter 1..................................AC Filter n
HVDC Protection Functions

AC Line Protection

21 Distance Relay
87L Line differential Protection
50 BF overcurrent breaker failure relay
DTT direct transfer trip

Main 1 Protection
87L 21 50BF DTT (7SD522)

Main 2 Protection
87L 21 50BF DTT (7SD522)

Optical link to substation (7SD522)
HVDC Protection Functions

Converter Transformer Protection

- 87T Differential Protection
- 87N Restricted Earth Fault Protection
- 50/51T Overcurrent Protection
- 50N (SBEF) Standby Earth Fault Protection

Diagram showing connections and protection functions.