Siemens Power Transmission and Distribution

What we have to offer

High Voltage
Components, switchgear and turnkey projects for power transmission > 52kV (AC and DC)

Transformers
Power transformers up to 1,300 MVA and 765kV, distribution transformers with oil or cast-resin insulation

Medium Voltage
Components, switchgear and turnkey projects for power transmission ≤ 52kV (AC and DC)

Energy Automation
Integrated control systems, protection and substation automation, telecontrol systems, power quality

Services
Network planning & consulting, asset maintenance and maintenance management for grids & networks, metering services
PTD Division
High Voltage overview

Air Insulated Switchgear (AIS)
- Circuit-breakers
- Arrestors, Bushings, Coils and Instrument Transformers
- Disconnectors

Gas Insulated Switchgear (GIS)

Highly Integrated Switchgear (HIS)

Gas Insulated Lines (GIL)

Reactive Power Compensation

High Voltage Direct Current (HVDC) Installations
Products and Solutions for High Voltage
AIS – Circuit Breakers
High-Voltage Circuit-Breaker
Product Characteristics

Type 3AP1 FG up to 245 kV
- For all applications: reliable and economical
- Stored energy Spring Drive Mechanism
- Self compression arc quenching principle
- Rated voltages up to 245 kV
- Rated short circuit breaking current up to 50 kA
- Type tested to the new IEC 62271-100
- Available for one or three pole operation (FG/FI)
- Delivered more than 50,000 breakers to more than 120 countries

Type 3AP1 FI up to 300 kV
- Stored energy Spring Drive Mechanism
- Self compression arc quenching principle
- Rated voltages up to 300 kV
- Rated short circuit breaking current up to 50 kA
- Type tested to the new IEC 62271-100
High-Voltage Circuit-Breaker
Product Characteristics

Type 3AP1 DTC 72.5 up to 245 kV
- One interrupter unit per pole
- Stored energy
  Spring Drive Mechanism
- Rated voltages
  up to 245 kV
- Rated short circuit
  breaking current
  up to 63 kA
- Type tested to the
  new IEC 62271-100
- Equipped with bushing
  type current transformers
- Ambient temperature range
  from +50° C down to -55° C
  with pure SF₆

Type 3AP2 FI up to 420 kV
- Stored energy
  Spring Drive Mechanism
- Self compression arc
  quenching principle
- Rated voltages
  up to 420 kV
- Rated short circuit
  breaking current
  up to 50 kA
- Type tested to the
  new IEC 62271-100
- Easy installation and
  commissioning:
  only few subassemblies
  Transportation costs are
  minimized
Products and Solutions for High Voltage Arrestors, Bushings, Coils & Instrument Transformers

Arrester
- HV: AIS (Porcellain, Polymer) & GIS; HVDC, FACTS
- MV: Distribution & Traction Vehicles

Coils
- Air Core Dry Type Reactors
- Line Traps
- Arc Suppression Coils

Bushings
- Air Core Dry Type Reactors
- Line Traps
- Arc Suppression Coils

Instrument Transformers
- Current Transformers
- Voltage Transformers
### Products and Solutions for High Voltage
**Disconnectors & Earthing Switches** from 36 kV to 800 kV

<table>
<thead>
<tr>
<th>Type</th>
<th>Voltage Range</th>
<th>Current Capacity</th>
<th>Current Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Centre Break</strong></td>
<td>72.5 kV – 550 kV</td>
<td>1250 A – 4000 A</td>
<td>31.5 kA – 63 kA</td>
</tr>
<tr>
<td><strong>Pantograph</strong></td>
<td>123 kV – 420 kV</td>
<td>3150 A</td>
<td>50 kA</td>
</tr>
<tr>
<td><strong>Vertical Break</strong></td>
<td>123 kV – 550 kV</td>
<td>1250 A – 6300 A</td>
<td>31.5 kA – 63 kA</td>
</tr>
<tr>
<td><strong>Double Break</strong></td>
<td>36 kV – 800 kV</td>
<td>1250 A – 5000 A</td>
<td>31.5 kA – 63 kA</td>
</tr>
<tr>
<td><strong>Earthing Switch</strong></td>
<td>123 kV – 550 kV</td>
<td>1250 A – 400 A</td>
<td>31.5 kA – 63 kA</td>
</tr>
<tr>
<td><strong>Knee Type</strong></td>
<td>123 kV – 550 kV</td>
<td>1250 A – 400 A</td>
<td>31.5 kA – 63 kA</td>
</tr>
</tbody>
</table>
Products and Solutions for High voltage
Gas Insulated Switchgear (GIS)

Rated short-circuit breaking current (kA)

Voltage (kV)

8DR1
8DQ1
HIS 8DQ1
8DN9
HIS 8DN8
8DN8

80 72.5 63 50 40 25 0
123 145 300 362 420 550 800
Gas Insulated Switchgear (GIS)
8DN8.2 switchgear

- Rated voltage: up to 145 kV
- Rated frequency: 50 / 60 Hz
- Rated power frequency withstand voltage (1 min): up to 275 kV
- Rated lightning impulse withstand voltage (1,2/50 µs): up to 650 kV
- Rated busbar current: up to 3150 A
- Rated feeder current: up to 3150 A
- Rated breaking current: up to 40 kA
- Rated short-time current: up to 40 kA
- Leakage rate per year and gas compartment: < 0.5 %
- Bay width: 800 mm
- Bay height: 2850 mm
- Bay depth: 3500 mm
- Bay weight: 3 t
Gas Insulated Switchgear (GIS)

**8DN9 switchgear**

- Rated voltage: up to 245 kV
- Rated frequency: 50 / 60 Hz
- Rated power frequency withstand voltage (1 min): up to 460 kV
- Rated lightning impulse withstand voltage (1,2/50 µs): up to 1050 kV
- Rated busbar current: up to 3150 A
- Rated feeder current: up to 3150 A
- Rated breaking current: up to 50 kA
- Rated short-time current: up to 50 kA
- Leakage rate per year and gas compartment: < 0.5 %
- Bay width: 1500 mm
- Bay height: 3500 mm
- Bay depth: 4700 mm
- Bay weight: 5 t
Products and Solutions for High voltage
Highly Integrated Switchgear (HIS)

- Compact
- Low cost
- Modular
- Suitable for in- and outdoor use

<table>
<thead>
<tr>
<th>Savings HIS*</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Site price</td>
<td>60 %</td>
</tr>
<tr>
<td>Civil works</td>
<td>20 %</td>
</tr>
<tr>
<td>Secondary cables</td>
<td>35 %</td>
</tr>
<tr>
<td>Steel structures</td>
<td>30 %</td>
</tr>
<tr>
<td>Earthing</td>
<td>70 %</td>
</tr>
<tr>
<td>Erection, tests,</td>
<td>70 %</td>
</tr>
<tr>
<td>commissioning</td>
<td></td>
</tr>
</tbody>
</table>

* compared to air insulated switchgear
Domaine d’utilisation des installations moyenne tension

Niveau de production et Réseau de Transport

Niveau de distribution primaire

Niveau de distribution secondaire

Basse tension
Medium Voltage: Overview

Primary distribution switchgear
- Gas-insulated (SF6)
  - NX PLUS C
  - NX PLUS
  - 8DA/8DB
- Air-insulated
  - NX AIR
  - NX AIR M
  - NX AIR P
  - SIMOPRIME

Secondary distribution switchgear
- Gas-insulated (SF6)
  - 8DH10
  - 8DJ10/8DJ20
- Air-insulated
  - SIMOSEC

Components
- Vacuum tubes
- Vacuum circuit-breakers
- Vacuum contactors
- Other Components

MV DC-Multifunctional Link
- SIPLINK
Medium Voltage Products for Primary Distribution

SF$_6$-Insulated Switchgear

### 8DA
- Type-tested, single-phase encapsulation, metal-clad
- Proved design, Single Busbar
- Modular design with standard enclosures allows single- and double phase applications
- More than 15 years of operating experience

### 8DB
- Type-tested, single-phase encapsulation, metal-clad
- Proved design, Double Busbar
- Modular design with standard enclosures
- Busbars and busbar-disconnectors in separate gas compartments
- More than 15 years of operating experience

#### Delivery Program

<table>
<thead>
<tr>
<th>8DA</th>
<th>8DB</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 40.5 kV</td>
<td>up to 40 kA</td>
</tr>
<tr>
<td>up to 4000 A</td>
<td>up to 40.5 kV</td>
</tr>
<tr>
<td>up to 40 kA</td>
<td>up to 4000 A</td>
</tr>
</tbody>
</table>
**Medium Voltage Products for Primary Distribution**  
**Air-Insulated Switchgear (AIS)**

### NX AIR
- Type-tested, IEC 62271-200, metal-clad, loss of service continuity category: LSC 2B, partition class: PM, internal arc classification: IAC A FLR ≤40 kA, 1s
- Single- and double busbar (back/back, front/front)
- Vacuum circuit-breaker withdrawable
- Vacuum contactor withdrawable
- Max. renewed availability by modular design
- Selective shutdown by bushing type transformers and pressure resistant compartments
- Max. operating safety by self-explanatory logical operating elements
- Maintenance intervals > 10 years

### NX AIR M
- Type-tested, IEC 62271-200, metal-clad, loss of service continuity category: LSC 2B, partition class: PM, internal arc classification: IAC A FLR ≤25 kA, 1s
- Single- and Double Busbar (back/back, front/front)
- Vacuum circuit-breaker withdrawable
- Max. renewed availability by modular design
- Selective shutdown by bushing type transformers and pressure resistant compartments
- Max. operating safety by self-explanatory logical operating elements
- Maintenance intervals > 10 years

<table>
<thead>
<tr>
<th>Delivery Program</th>
<th>Delivery Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 12 kV</td>
<td>up to 25 kA</td>
</tr>
<tr>
<td>up to 40 kA</td>
<td>up to 2500 A</td>
</tr>
<tr>
<td>up to 2500 A</td>
<td>up to 2500 A</td>
</tr>
</tbody>
</table>
Medium Voltage Products for Secondary Distribution

SF₆-Insulated Switchgear

8DJ10
- Type-tested
- Independent of climate
- Maintenance-free
- Block-type construction, for 3-6 bays
- Hermetically-sealed welded switch-gear enclosures
- Compact and clear design
- No sealings
- Highest Quality Level
- Shortest Delivery Periods
- Smallest floor space for substations

8DJ20
- Type-tested
- Independent of climate
- Maintenance-free
- Block-type construction, for 1-5 bays
- Hermetically-sealed welded switch-gear enclosures
- Compact and clear design
- No sealings
- Highest Quality Level
- Shortest Delivery Periods

Delivery Program
- up to 24 kV  up to 25 kA  up to 630 A

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Power Transmission and Distribution
Independent power producers (wind generators, solar plants)

Large-scale industry with in-plant generation

Manufacturing, trade, small industry without in-plant generation

City

Large-scale power plant

Consumers with sensitive processes

Hospital

New Switching Technologies for Distribution Systems Improves Cost-Effectiveness, Availability and Power Quality
High reliability

Excellent field experience with more than 2 million vacuum interrupters

Tailormade development

Wide product range for any application

For use in

LV and MV circuit-breakers, load-break switches and contactors

Autoreclosers

Transformer Tap Changers

<table>
<thead>
<tr>
<th>Delivery Program</th>
<th>up to 65 kA</th>
<th>up to 2500 A</th>
</tr>
</thead>
<tbody>
<tr>
<td>690 up to 1300 V</td>
<td>up to 65 kA</td>
<td>up to 2500 A</td>
</tr>
<tr>
<td>7.2 up to 40.5 kV</td>
<td>up to 72 kA</td>
<td>up to 6300 A</td>
</tr>
</tbody>
</table>
• Power transformers

• Distribution transformers with oil or cast-resin insulation
Siemens Transformers at all Levels of Transmission and Distribution

- Generator transformer
- Shunt reactor
- HVDC
- Phase angle regulator
- System interconnecting transformer
- Special purpose transformers for industrial application
- Oil-immersed distribution transformer
- Voltage regulator
- GEAFOL cast-resin transformer
- Traction transformer

TLM
Siemens Transformer Life Management (condition assessment, life-extension, on-site-services, monitoring, ...)

Siemens Transformers at all Levels of Transmission and Distribution
Ratings from 10 MVA up to 1.100 MVA / 1200 kV

Three-phase and single-phase
Distribution Transformers

GEAFOL

- Cast-resin distribution transformers
- Ratings from 50 kVA up to 40 MVA
- Possibility for on-line tapchanger
- Static converter transformers
Distribution Transformers

Oil-immersed

- Ratings from 50 up to 4,000 kVA
  (TUNORMA and TUMETIC)
PTD Division
Energy Automation

- Information and network control technology
- Protection and substation automation, telecontrol systems, power quality
Energy Automation
Strong products and brands on all levels

Energy Market Mgmt.
- EMM
- FDWH
- PROPHET Solutions
- AMIS
- ...

Communications & networking
- PLC
- Modems
- ...

Tools
- SICAM TOOLBOX
- IMM
- DIGSI...

System control centers
- Spectrum PowerCC
- SINAUT Spectrum

Station control & automation
- SICAM PAS
- SAT 1703 / SAT 230

RTU’s
- SAT 1703
- SICAM eRTU / miniRTU
- TG 805 / TG 5700

Protection/Power Quality/Bay Control
- SIPROTEC
- REYROLLE
- BC 1703 ACP
- SIMEAS

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LE BUT DE LA PROTECTION SELECTIVE EST:
- Assurer la continuité de service du réseau d'énergie, par élimination de l’élément défaillant et de lui seul
- Eviter des dégâts au niveau des équipements affectés par les défauts (câbles, transformateurs...)
LE SYSTÈME DE PROTECTION =

TI/TP + Relais + Disjoncteur

Sélectif, rapide, fiable
SIPROTEC 4 - What does it mean?

SIPROTEC 4 is a family of numerical Protection, Control- and Automation Devices from SIEMENS
<table>
<thead>
<tr>
<th>Protection Type</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>O/C protection</td>
<td>7SJ6</td>
</tr>
<tr>
<td>Distance protection</td>
<td>7SA6</td>
</tr>
<tr>
<td>Line differential protection</td>
<td>7SD5 / 7SD6</td>
</tr>
<tr>
<td>Transformer diff. protection</td>
<td>7UT6</td>
</tr>
<tr>
<td>Generator protection</td>
<td>7UM6</td>
</tr>
<tr>
<td>Station protection</td>
<td>7SS52</td>
</tr>
</tbody>
</table>
SIPROTEC 4

O/C protection
7SJ6
Time-overcurrent protection

Criteria for fault: overcurrent

Criteria for selectivity: time
Time-overcurrent protection Characteristics

Tripping characteristic of a two stage time-overcurrent protection device - definite time

![Diagram](image-url)
Time-overcurrent protection Characteristics

Tripping characteristic of a time-overcurrent protection device - inverse time

Characteristics:
- IEC
- ANSI
- user defined
Time-overcurrent protection Application

As main protection

Used as:

1. Line protection
   Selectivity by time-grading

2. Motor protection
   with short circuit- and overload protection, start protection, start inhibit

3. Transformer protection
   for network transformers with short circuit- and overload protection, Inrush-stabilisation
Time-overcurrent protection Application

Main protection as line protection

Advantage: simple device, only current transformers are necessary
Disadvantage: near infeed higher tripping time
Reverse Interlocking Application

1. Outgoing protection initiates and blocks the infeed protection stage within 50 ms

2. Infeed protection gives a trip after 50 ms since no outgoing feeder has picked up and blocked the infeed protection
O/C protection with motor protection

7SJ61

- Over current protection (Phase/Earth)
- Inrush Blocking
- Motor Protection
- Overload Protection
- Unbalanced Load Protection
- Auto reclosure
- Trip Circuit Supervision
- Breaker Failure Protection
- Lock out

4 CT inputs
Distance protection
Why impedance protection?

**Situation:** Meshed network and two infeeds
**Directional overcurrent time relays**

```
0.6s  0.3s  0.6s  0.3s  0.6s
```

non-selective trip
Localization of short-circuits by means of an impedance measurement:

- fault on the protected line $Z_1$

- fault outside the protected line $Z_2$

**selectivity**
Distance measurement (principle)

6 loops: 3 phase-phase loops and 3 phase-ground loops

phase-phase-loop: \[ U_{L1-L2} = Z_L (I_{L1} - I_{L2}) \]

The same applies to the remaining loops

\[ Z_L = R_L + j X_L \]
\[ Z_E = R_E + j X_E \]
Distance measurement (principle)

The same applies to the remaining loops

Phase-ground-loop:

\[ U_{L1} = I_{L1} \cdot (R_L + jX_L) - I_E \cdot (R_E + jX_E) \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( U_{L1} )</td>
<td>Measured voltage</td>
</tr>
<tr>
<td>( I_{L1} )</td>
<td>Measured current</td>
</tr>
<tr>
<td>( I_E )</td>
<td>Measured current</td>
</tr>
</tbody>
</table>

\[ Z_L = R_L + jX_L \]

\[ Z_E = R_E + jX_E \]
Numerical filtered phasor measurement

1. Fast operation ⇒ Use short data window
2. High accuracy ⇒ High selectivity
3. Signal distortion does not cause delay or maloperation
Fourier analysis of measured values

Sampled measuring values

\[ i_{(k-n+i)} \]

Resulting phasor

\[ I_{(k)} = I_{S(k)} + j \cdot I_{C(k)} \]

\[ j \cdot I_{C(k)} \]

\[ I_{S(k)} \]

\[ \phi \]

\[ \sin \frac{2\pi \cdot i}{n} \]

\[ \cos \frac{2\pi \cdot i}{n} \]
Load and short-circuit impedances

Distance relay operating characteristic

Fault area

Phase - Phase Fault

\[ R_R \approx R_F / 2 \]

Phase - Earth Fault

\[ R_R \approx R_F / (1 + R_E/R_L) \]

Minimum Load Impedance:
Minimum voltage \( 0.9 \) Un
Maximum current \( 1.1 \) In
Maximum angle \( \pm 30^\circ \)
Graded distance zones

Grading rules:

\[
\begin{align*}
Z_1 &= 0.85 \, Z_{AB} \\
Z_2 &= 0.85 \, (Z_{AB} + 0.85 \, Z_{BC}) \\
Z_3 &= 0.85 \, (Z_{AB} + 0.85 \, (Z_{BC} + 0.85 \, Z_{CD}))
\end{align*}
\]

Safety margin is 15%:
- line error
- CT, VT error
- measuring error
Determination of fault direction

Fault location

Where is the fault?

current / voltage diagram

impedance diagram

The impedance also shows the direction, but ....
Fault detection techniques

Over-current fault detection

- Voltage dependant over-current fault detection
- Voltage and angle dependant over-current fault detection

Impedance fault detection

Not in 7SA522
Impedance zones of digital relays

Distance zones
Inclined with line angle $\phi$
Angle $\alpha$ prevents overreach of Z1 on faults with fault resistance that are fed from both line ends

Fault detection
no fault detection polygon: the largest zone determines the fault detection characteristic
simple setting of load encroachment area with $R_{\min}$ and $\varphi_{\text{Load}}$
Zone grading chart, radial feeder

Grading according to the recommendation with the safety margin of 15%.

\[
Z_1 = 0.85 \, Z_{AB}
\]
\[
Z_2 = 0.85 \, (Z_{AB} + 0.85 \, Z_{BC})
\]
\[
Z_3 = 0.85 \, [Z_{AB} + 0.85 \, (Z_{BC} + 0.85 \, Z_{CD})]
\]
Ring feeder: with grading against opposite end

The same grading from both sides
Line differential protection

7SD61 / 7SD52
Kirchhoff: \[ I_1 + I_2 + I_3 + I_4 + I_5 = 0 \]
Trip Characteristic

Internal Fault
Trip Characteristic

\[ I_D = |I_X + I_Y| \quad I_R = |I_X| + |I_Y| \]

\[ I_D = |(+1) + (+1)| = 2 \quad I_R = |+1| + |+1| = 2 \]
Trip Characteristic

- **Ideal internal fault**: $\text{Idiff} = I_1$, $\text{Istab} = I_1$
  - Fault is on fault line

- **External fault**: $\text{Idiff} = 0$, $\text{Istab} = |I_1| + |I_2| + ... + |I_n|$
  - Fault is not on fault line

- **Security for CT deviations**

The diagram illustrates the relationship between $\text{Idiff}$ and $\text{Istab}$ for internal and external faults, showing the fault line where the conditions for ideal internal fault are met.
Differential Current due to CT-Saturation

Differential Current may cause maloperation in case of CT-saturation
Current transformer saturation

Saturation during steady-state current

Saturation during offset current
Line differential protection

- Current Comparison Protection for all applications for cables and overhead lines
- Two up to six line ends
- Handles transformers in the protected zone (integrated vector group matching)
- Direct connection to communication networks
- Communication via copper and ISDN networks
- Fault Locator
- Fast tripping (less than 15 ms)
- Automatic reclosure
SIPROTEC 4 Line differential protection

Configurations

over 3 line ends
No restrictions for communication

- Communication with …
  - direct FO connection up to 100 km
  - digital communication network (G703, X21)
  - ISDN-connection
  - 2 or 3 wire pilot wire (twisted, screened)
Topography detection, example

Ring topology

Partial current summation

I_1 + I_2

I_3 + I_1

I_1 + I_2

I_3 + I_1

I_1 + I_2

I_3 + I_1

connection to other devices
7SD52 V4.3  Line protection

Universal line protection for HV and EHV applications

- Line differential protection and distance protection in one device
- Comprehensive function mix for 2-6 line end applications
- Any combination of DIF and DIS, as main or backup protection
- Emergency / backup protection as additional backup level
- Full control functionality (graphic display)
Multifunctional Protection for Transformers and Generators 7UT6
Measuring Preprocessing, Example for CT Matching (Part 1)

$I_P1 = 500\text{A}$ (load current)

$I_P2 = 1833\text{A}$ (load current)

$S_N = 100\text{MVA}$

$U_{N1} = 110\text{kV}$

$U_{N2} = 30\text{kV}$

$1000/5\text{A}$

$2000/5\text{A}$

$winding 1$ $winding 2$

$I_{N, Trafo} = 525\text{A}$

$I_{N, Trafo} = 1924\text{A}$

$I_{N, Trafo} = 525\text{A}$

$I_{N, Trafo} = 1924\text{A}$

$I_{S1} = 2.5\text{A}$

$I_{S2} = 4.58\text{A}$

measured secondary currents

$I_{Diff} = ?$

$I_{Stab} = ?$
Method of Vector Group Determination

\[ I_{L1,S2} = I_{L1} - I_{L2} \]

Vector group is \( Y_d 11 \)
SICAM PAS
System with IEC61850 and further services

100 Mbit/s switched and redundant Ethernet ring

Station unit
SICAM PCC

62.5µ or 50µ FO

DIGSI 4
Web-Monitor

Stand by connection

max. 6 devices per switch

Ethernet-Switch

Ethernet patch-cable

Goose Message

Info report