Application of New Technologies for Power Transmission Systems

Power Transmission and Distribution

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Our Vision

PTD powers the planet, combining its power transmission and distribution resources to ensure an efficient supply of energy for its customers everywhere. Everything we do is focused on becoming Number One in the market and creating individualized solutions that give our customers a competitive edge. PTD’s globally networked organization, its use of ground-breaking technology, the specific industry and technological expertise of its employees and, above all, our shared dedication to work for this shared goal, create the ideal conditions for ensuring reliable power transmission and distribution around the world.
### At a glance – FY 2005

<table>
<thead>
<tr>
<th>Category</th>
<th>FY 2005 (US GAAP)*</th>
<th>FY 2004 (US GAAP)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>New orders (worldwide)</td>
<td>€ 5.3 billion</td>
<td>€ 3.9 billion</td>
</tr>
<tr>
<td>Sales (worldwide)</td>
<td>€ 4.3 billion</td>
<td>€ 3.6 billion</td>
</tr>
<tr>
<td>of which international</td>
<td>88 %</td>
<td>85 %</td>
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<tr>
<td>Employees (worldwide)</td>
<td>25,850</td>
<td>19,205</td>
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<tr>
<td>Investments as % of sales (worldwide)</td>
<td>3.0 %</td>
<td>2.4 %</td>
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<tr>
<td>R&amp;D as % of sales (worldwide)</td>
<td>2.5 %</td>
<td>2.5 %</td>
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<td>Manufacturing facilities Germany</td>
<td>12</td>
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</tr>
<tr>
<td>Manufacturing facilities outside Germany</td>
<td>44</td>
<td>32</td>
</tr>
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</table>

*as of: 30.09.2005  **as of: 30.09.2004
Pressures on Transmission Development

- Isolated Small Grids
- Higher Voltage Levels
- High Investments
- Long Distance Transmission
- Large interconnected Systems
- Least Cost Planning
- New Technologies

Power Consumption per Capita

Developing Countries  Emerging Countries  Industrialized Countries
Generation Development Economic Pressures

![Graph showing net present value over time for different energy sources.]

- **Combined cycle (700 MW, 2+1)**
- **Coal-fired steam power plant (700 MW)**
- **Hydro power plant (700 MW)**
- **Nuclear power plant (1600 MW)**

Payback times, profit, debit, and year of commercial operation are indicated on the graph.

Net Present Value (mEUR) vs. Year of commercial operation.
Transmission Lines Technology

Technologies for Transmission

- Gas insulated lines (GIL) to transit large power (2-4GW)
- Conventional underground cables (limitation 1 GW at 400 kV)
- Overhead lines (Multisystem lines, Compact lines)

Super conducting cables (2-4GW)

Fig.13: Developments in the field of overhead lines and cables
ADVANCES IN POWER ELECTRONICS

Development of power electronics for transmission systems
Solid State Circuit Breaker

Very fast Circuit Breaker (VFCB)

Short-Circuit Current Limiter using FACTS (SCCL)

SF6 Circuit Breaker – basic technology for transmission

Vacuum Circuit Breaker – basic technology for distribution
Superconductivity Applications

- Optimization of conventional systems
  - cable
    - power density
    - retrofit
  - transformer
    - energy saving
    - durability
    - safety
  - motor
    - volume
    - weight
    - revolution
    - energy saving
  - fly wheel HTSL-bearing
    - energy density
    - energy saving
    - safety

- New applications
  - magnetic energy store (SMES)
    - availability
    - protection of resources
    - environmental compatibility
  - current limiter
    - new network structure
    - protection of resources
    - energy quality

Fig. 17: Applications of Superconductivity
Summary - The Spectrum of System Dynamics

- **Very fast transients**
  - Switching voltage (disconnector etc.)
  - Lightning overvoltages

- **Transients & System interactions**
  - Power converter
  - Ferro-resonance
  - Transformerator switching
  - Grid resonances

- **Power generation and transmission**
  - Oscillation of turbine generator multi-mass systems: above approx. 300 MW (at thermic und nuclear power plants, i.e. only at „long shaft systems“)

- **Subsynchronous resonances**

- **Power oscillations**
  - Rotor oscillations of generators

\[ f_N \]
Development of Power Electronic Components for Adjustable Speed Drives

Semiconductor Trends will be driven primarily by Traction Converters due to large number of Applications and Devices
## FACTS Controllers Today
### Impact on System Network Performance

<table>
<thead>
<tr>
<th></th>
<th>FSC</th>
<th>SVC/G STATCOM</th>
<th>TCSC CSC</th>
<th>PST</th>
<th>UPFC</th>
<th>HVDC</th>
</tr>
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<tbody>
<tr>
<td>Voltage Quality</td>
<td></td>
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<tr>
<td>Load Flow Control</td>
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<tr>
<td>(Meshed System)</td>
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<tr>
<td>Transient Stability</td>
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<td>(Bulk Power System)</td>
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<tr>
<td>Oscillation Damping</td>
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<tr>
<td>(Transmission System)</td>
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</table>

- **○** low or no influence
- **●** small influence
- **●●** medium influence
- **●●●** strong influence

<table>
<thead>
<tr>
<th>FACTS Controllers</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>FSC</td>
<td>Fixed Series Compensation</td>
</tr>
<tr>
<td>SVC/SVG</td>
<td>Static Var Compensator / Generator</td>
</tr>
<tr>
<td>TCSC</td>
<td>Thyristor Controlled Series Compensation</td>
</tr>
<tr>
<td>PST</td>
<td>Phase Shifting Transformer</td>
</tr>
<tr>
<td>UPFC</td>
<td>Unified Power Flow Controller</td>
</tr>
<tr>
<td>STATCOM</td>
<td>Static Synchronous Compensator</td>
</tr>
<tr>
<td></td>
<td>Power Transmission and Distribution</td>
</tr>
</tbody>
</table>
System Transients - The Spectrum

Computer Simulation ↔ On-Site Measurements

Real-Time Simulation

Machine ↔ Grid

Frequency Transformation

Subsynchronous Resonances

Power Oscillations

Power Electronics

Control and Protection

Grid

Harmonics

Unbalances Power Oscillations

Subsynchronous Resonances

Fast Transients (VF Transients)

0 Hz 0 Hz 10 Hz 60 Hz 50 Hz 60 Hz 1 kHz 5 kHz 10 kHz 10 MHz 40 kHz 40 MHz
Tasks of Reactive Power Compensation

Power-Flow Control

Series Compensation

Parallel Compensation

Voltage Control

Section of a Transmission Line
FACTS Applications in Power Systems

Radial System - Improvement of Power Quality:
- SVC
  - Voltage Control
  - Power Oscillation Damping
- TCSC
  - Load Flow Control
  - Power Oscillation Damping
  - SSR Mitigation
- GPFC
  - Load Flow Control
  - Power Oscillation Damping

Meshed System - Power Flow Control:
- FSC / TPSC
  - Increase of Transmission Capacity
- TCSC
  - Load Flow Control
  - Power Oscillation Damping
  - SSR Mitigation

Option for Combinations

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Power Transmission and Distribution
TPSC (Thyristor Protected Series Capacitor)

1. series capacitor
2. thyristor valve as fast bypass - device
3. current limiting reactor
4. MOV
5. bypass circuit breaker
6. bypass damping reactor
7. platform disconnects with grounding switch
8. bypass disconnect
Advanced Power Transmission Solutions
Light Triggered Thyristor Valves
Shunt Compensation by SVC
Technical Main Features

Direct Light Triggered Thyristor:
- Reduced Valve Components
- No auxiliary Energy or logic Circuits at High Potential
- Better di/dt Capability
- Integrating the break-over Protection against Overvoltage

2 Years or more period for Maintenance requiring shut-off

System Reliability 99% or better due to redundant Components and proven Technology.

Use of Siemens Standard Industrial Controller Hardware
Simatic TDC for Valve Control and Protection Function ensures long-term Availability of Spare Part Supply
FACTS - Application of Series Compensation

- Increase of Transmission Capacity
- Damping of Power Oscillations
- Loadflow Control
- Mitigation of SSR

Fixed Series Compensation:

- Increase of Transmission Capacity

Controlled Series Compensation:

- Damping of Power Oscillations
- Loadflow Control
- Mitigation of SSR
TPSC - Thyristor Protected Series Compensation

Vincent/USA
Benefits of TPSC: High Availability after Fault Clearing - Standard FSC with Arresters needs up to 8 h to cool down.

60 s after the 1st fault the valve temperature rise is 2.2 K.

5 cycles fault clearing time.
Thyristor-Controlled Series Capacitor (TCSC)
Kayenta Substation, USA
TCSC - The Impedance Curve

Impedance = Capacitor Voltage / Line Current

"High Impedance Sensitivity" Area

Active Damping by means of $\alpha$?

"Low Impedance Sensitivity" Area

"High Impedance Sensitivity" Area
TPSC versus TCSC - Benefits for active Damping

impedance as function of firing angle

- **L = 2.1 mH (TPSC)**
- **L = 12 mH (TCSC)**

**TPSC:** “Increased Sensitivity”

**TCSC:** “Low Sensitivity”
Poste Montagnais 476Mvar FSC @ 735kV, Canada
Sera de Mesa 107Mvar TCSC @ 500kV, Brazil
Vincent 401Mvar TPSC @ 500kV, USA
Var Technology
Shunt compensation

**MSC / MSR**

- Mechanical Switched Capacitors / Reactors
  - Switchgear
  - Capacitors
  - Reactors
  - 52 < kV < 1000
  - 50 < Mvar < 500

**SVC**

- Static Var Compensator
  - Thyristor Valve(s)
  - Control & Protection
  - Transformer
  - Capacitors
  - Reactors
  - 52 < kV < 1000
  - 50 < Mvar < 800

**STATCOM**

- Static Compensator
  - GTO/IGBT Valves
  - Control & Protection
  - Transformer
  - DC Capacitors
  - 52 < kV < 1000
  - 50 < Mvar < 800

SIEMENS
Static Var Compensator (SVC)
Typical SVC Configuration

1. Step-down transformer
2. LV bus bar
3. Thyristor controlled reactor
4. Thyristor switched capacitor
5. Fixed filter circuit
6. Control
Static Var Compensator (SVC)
Common Configurations

TCR, FC

TCR, TSC, FC

TSR, TSC
Shunt Compensation by SVC
Funil SVC, Brazil, Container Building - 3-D-View

Advantages:
- Reduced Installation Time
- Relocatable
- Pre-Tested in Factory, Reduced Commissioning
### Shunt Compensation

#### Statcom versus SVC - Basic differences - Summary

<table>
<thead>
<tr>
<th>Issue</th>
<th>Statcom</th>
<th>SVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>V/I characteristic</td>
<td>good undervoltage performance</td>
<td>good overvoltage performance</td>
</tr>
<tr>
<td></td>
<td>Current source</td>
<td>Impedance</td>
</tr>
<tr>
<td>Control range</td>
<td>Symmetrical otherwise Hybrid solutions</td>
<td>freely adjustable to any range by TCR/TSR/TSC branches</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Modularity</td>
<td>Same converter usable for various applications (STATCOM, UPFC, CSC, B2B etc)</td>
<td>TCR/TSR/TSC branches used in SVC and TCSC/TPSC</td>
</tr>
<tr>
<td></td>
<td>Redundancy no degraded mode</td>
<td>Redundancy</td>
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<tr>
<td></td>
<td></td>
<td>Degraded mode operation</td>
</tr>
<tr>
<td>Response time</td>
<td>1 to 2 cycle</td>
<td>2 to 3 cycle</td>
</tr>
<tr>
<td>Transient behaviour</td>
<td>Self protecting at critical system faults</td>
<td>Available before, during and after critical system conditions</td>
</tr>
<tr>
<td>Space requirements</td>
<td>40 to 50 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Availability</td>
<td>96 to 98 %</td>
<td>&gt; 99 %</td>
</tr>
<tr>
<td>Investment costs</td>
<td>120 to 150 %</td>
<td>100 %</td>
</tr>
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</table>
Var Technology
Statcom versus SVC - V / I characteristic

- **Operating area STATCOM**
  - Continuous and transient

- **Operating characteristic SVC**
  - Continuous and transient

**Design point cap**

**Design point ind**

- **U_{ref} = 1.035 pu**
- **Slope = 3%**

**Operating area**

- **V_{Base} = 115 kV = 1.0 pu**
- **I_{Base} = 150 MVar = 1.0 pu**

**V_{prim} (pu)**

<table>
<thead>
<tr>
<th>V_{prim} (pu)</th>
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<tbody>
<tr>
<td>1.5</td>
</tr>
<tr>
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<td>0.5</td>
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<td>1.0</td>
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**I_{prim} (pu)**

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<td>1.0</td>
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<td>1.5</td>
</tr>
</tbody>
</table>

**SVC Design point**

**SVC Design point cont operation**

**SVC Design point transient operation**

**12 cycles SVC**

**2 cycles SVC**
Var Technology
Statcom versus SVC - Operating losses (Thy / GTO)
Shunt Compensation
Statcom versus SVC - Conclusion

**Advantages SVC:**
- More reliable (typically >99%) due to less complicated Converter technology and built-in redundancy
- Free design for inductive and capacitive control range
- Reduced losses because of line-commutated Converter
- Overload capability

**Advantages Statcom:**
- Faster response (1 cycle) due to voltage-sourced Converter technology
- Reduced footprint
- Possibility to build UPFC
- VAR output linear with network voltage

**Conclusion:**
For 90 to 95% of Shunt Compensation in high-voltage transmission system speed of conventional SVC is acceptable and footprint size not critical. Because of lower investment and operation cost, SVC will remain the preferred and dominant technical solution.
Converter Technology Trends
Statcom / UPFC - mid term Future (10 years)

Semiconductors used in high-end medium voltage drive converters offer excellent basis (mass market)

Taking into account overall cost, performance and availability (no. of different manufacturer): IGCT most promising semiconductor device

Competing Converter Topologies:

1.) 3-level Converters using series connection of devices and optimised pulse patterns

vs.
2.) Cascaded (“chain-link”) Converters with simplified magnetics but UPFC function or Statcom back-to-back difficult to accomplish

vs.
3.) 3-level Converters using parallel connection of Converter Modules
Siemens – Beta Experience
Adelanto 0/+388Mvar SVC, USA
SCCL from Siemens - The Solution of the 21st Century

- Applications
- Conclusions
SCCL - The New Solution

Low Impedance for Best Load Flow

Fast Increase of Coupling Impedance

Impedance $X$

SCC Limitation
**SCCL - The better Alternative:**
- No Risk of Voltage Collapse
- Reactive Power remains balanced
- No Impact on Grid Load Flow
- Increase of First Swing Stability
- **Dynamic Add-Ons** for SSR & Power Oscillation Damping

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**Only Current Limiting Reactor ?**
- Voltage Drop - needs Compensation
- Mechanically or Thyristor Switched Capacitor
System designed for 3 Infeeds

Bus 1

Existing

Bus 2

115 kV

Existing

3 ~

3 ~
SCCL - Examples of Applications

System designed for 3 Infeeds

Bus 1

115 kV

Bus 2

Existing

Expansion
SCCL - Examples of Applications

System designed for 3 Infeeds

Bus 1

Existing

Bus 2

115 kV

Existing

Expansion

Excess of allowed SCC Levels

Power Transmission and Distribution
SCCL - Examples of Applications

System now designed for 4 Infeeds

Bus 1

3 ~ Existing

115 kV

Bus 2

3 ~ Existing

3 ~ Expansion

SCC Limitation

Enables Connection of additional Generation on the 115 kV System
SCCL - Designed for maximal Availability

Not with Siemens Technology:
- High Power LTT Thyristor - 110 kA peak, self cooling
- Protection with SIMATIC-TDC - a standard in HVDC, FACTS and Drives
- Measurements - redundant (optically powered) transducers
- no auxiliary power supplies on the platform needed

The Operation Principle:
- Fail safe - thyristor will be shorted in case of malfunction
- Backup by wafer-integrated over-voltage protection
- Fast switch on - instead of delayed switch off
- Redundant number of thyristors
- Minimal steady state losses (reactor)
- Minimal Maintenance - 10 h per year (0.1 %)

SCCL: designed for harsh Environment & Multiple Fault Contingencies
GIL - Gas-Insulated Transmission Line
Arrangement in a Tunnel

2 systems 420/550 kV
Tunnel diameter 3 m
Installed length:
30 km; up to now all in service without any failure
**Example of a GIL Connection: Wehr, Germany**

**Commissioning:** 1975, Tube length 4 km

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Specification</th>
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<tbody>
<tr>
<td>1</td>
<td>600 MVA Transformer</td>
<td>Rated Voltage 420 kV</td>
</tr>
<tr>
<td>2</td>
<td>Encapsulated Surge Arrestors</td>
<td>Rated Impulse</td>
</tr>
<tr>
<td>3</td>
<td>Transfer Switching units</td>
<td>Withstand Voltage 1640 kV</td>
</tr>
<tr>
<td>4</td>
<td>GIL Connection</td>
<td>Rated Current 2000/2500 A</td>
</tr>
<tr>
<td>5</td>
<td>Open Air Surge Arrestor</td>
<td>Rated Short-Time Current 53 kA</td>
</tr>
<tr>
<td>6</td>
<td>Overheadline</td>
<td></td>
</tr>
</tbody>
</table>

**Example of a GIL Connection:** Wehr, Germany

**Commissioning:** 1975, Tube length 4 km

- 600 MVA Transformer
- Encapsulated Surge Arrestors
- Transfer Switching units
- GIL Connection
- Open Air Surge Arrestor
- Overheadline

---

*Image of a GIL Connection: Wehr, Germany*

Commissioning: 1975, Tube length 4 km
Example of a GIL Connection: Bowmanville, Canada
Commissioning: 1985-87 Tube length 2.5 km

Rated Voltage: 550 kV
Rated Impulse Withstand Voltage: 1550 kV
Rated Current: 4000 / 6300 / 8000 A
Rated Short-Time Current: 100 kA
Technical Data of the Standard Design

- Rated voltage: 420 / 550 kV
- Impulse withstand voltage: 1425 / 1600 kV
- Rated current: 3150 / 4000 A
- Rated short-time current: 63 kA / 3 s
- Rated transmission load: 2000 / 3800 MVA
- Overload capability (typical): 200 %
- Insulation gas: N₂/SF₆ mixture at 7 bar

Designed and tested according to IEC 61640 „HV gas-insulated transmission lines for rated voltages of 72.5 kV and above”
Straight Unit

- for straight sections up to 120 m length
- bending radius up to 400 m possible

1 enclosure
2 inner conductor
3 conical insulator
4 support insulator
5a male sliding contact
5b female sliding contact
Angle Unit

- for directional changes
- flexible angle from 4° to 90°

1. enclosure
2. inner conductor
3a. male sliding contact
3b. female sliding contact
4. conical insulator
5. support insulator
Disconnecter Unit

- separation of gas compartments
- connection point for sectional commissioning of the GIL
- location of the decentralised monitoring units

1. enclosure
2. inner conductor
3a. male sliding contact
3b. female sliding contact
4. conical insulator
5. support insulator
Compensation Unit

- Compensation of the thermal expansion of the enclosure
- Flexible connectors are leading the current
Directly Buried GIL
Laying Process
Directly Buried GIL
System Components

| L1   | distance between fixpoints | 100 - 150 m |
| L2   | distance between shafts    | 1000 - 1500 m |

Shaft with disconnection and compensator unit

Angle unit
Single line drawing

1. GIL construction unit, straight
2. GIL construction unit, bend $R > 400\ m$
3. Axial compensator
4. Disconnecting housing with gastight insulators and surveillance system
5. Support with fixed point
6. Support with sliding bearing
7. Angle unit
Laying and Commissioning in the Tunnel

1. Delivery and supply of prefabricated elements
2. Mounting and welding
3. Threading of the GIL in the tunnel
4. High voltage test
Cost structure GIL Madrid, Spain

- Insulators: 2.2%
- Order Processing Berlin: 3.2%
- Pipes, components: 6.5%
- Logistics, transport: 41.4%
- Engineering, PM: 2.5%
- Gas, steel, surge arresters: 5.2%
- Construction site (tech.): 7.4%
- Civil works: 19%
- Installation personnel: 12.7%
- Civil works: 7.4%
HVDC Applications

Long Distance

AC - DC line - AC
System 1          System 2

Sea Cable

AC - DC cable - AC
System 1          System 2

Back-to-Back

AC - AC
System 1          System 2
HVDC Long Distance Transmission Systems

**Monopolar**
- Terminal A
- Transmission Line
- Terminal B

**Bipolar**
- Terminal A
- Pole 1
- Pole 2
- Transmission Line
- Terminal B
Bipolar System: Operating Modes

- Bipolar
- Monopolar, ground return one DC line pole
- Monopolar, metallic return
- Monopolar, ground return two DC line poles
HVDC Long Distance Transmission Systems

Multi Terminal

Terminals in Parallel

Terminals in Series
Bipolar HVDC Terminal

1. AC Switchyard
2. AC Filters, Capacitor Bank
3. Converter Transformers
4. Thyristor Valves
5. Smoothing Reactors and DC Filters
6. DC Switchyard

AC Switchyard

Controls, Protection, Monitoring

To/from other terminal

System 1

System 2

Pole 1

Pole 2

AC

DC filter

AC filter
HVDC Back-to-Back Station

1. AC Switchyard
2. AC Filters, Capacitor Bank
3. Converter Transformers
4. Thyristor Valves
5. Smoothing Reactors
Thyristor Valves
133kV Valve in Commercial Operation

Mechanically tailored to replace a 133kV mercury arc valve
Converter Transformer: Tian - Guang

Tian - Guang

HVDC Bipolar Long Distance Transmission

$P_N = 2 \times 900 \text{ MW}, \ V_{DC} = \pm 500 \text{ kV}$
Decentralized Control and Protection System

- GPS: Master Clock System
- HMI: Human Machine Interface
- SER: Sequence of Events Recording System
- TFR: Transient Fault Recording System
- DA: Data Acquisition Unit

Control & Protection Level:
- Station Control System
- Control & Protection System
- Measuring System

Field/Process Level:
- I/O Unit
- AC Filter Switch
- Valves

Redundancy is not shown.

LAN 100 MBit/s.

Fiber Optic Field Bus.

Opposite Station

Dispatch Centre

Remote Control Interface

Inter Station Communication

Remote Control Interface

Fiber Optic Field Bus

TFR

Measuring System

HMI

SER

Opposite Station
Basic HVDC Control Functions

- **Tap Changer Control**
- **Converter Control**
  - Inverter: Ud-Control
  - Rectifier: Id-Control
- **ACF**
  - AC Filter
- **Reactive Power Control**
- **AC System A**
  - Ud: DC Voltage
- **AC System B**
  - Tap Changer Control
  - Id: DC Current
  - ACF: AC Filter

**Icons**:
- Orange: Converter Control
- Blue: Reactive Power Control
- Light Green: Tap Changer Control
Hybrid-Optical DC Current Measuring

duplicated sensor head

Shunt

Analog/Digital

Optical Signal fibre
Win-TDC/SIMATIC TDC - Modules

- All Control and DC Protection systems use the high-performance control system SIMATIC TDC (Less Spare Parts!)
- Systems are used worldwide in various applications
- Estimated product life cycle of more than 25 years
- Flexible interface systems make Win-TDC also the solution for HVDC Control and Protection refurbishment projects
<table>
<thead>
<tr>
<th>Customer:</th>
<th>China National Technical Import &amp; Export Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project name:</td>
<td>(CNTIC)</td>
</tr>
</tbody>
</table>
| Location: | Gesha  
| | Gezhouba  
| | (Central China)  
| | Nan Qiao  |
| Power rating: | (40 km from Shanghai) |
| Voltage level: | 1200 MW, bipolar  
| | ± 500 kV DC, 525/230 kV,  
| | 50/50 Hz  
| | Long-distance transmission,  
| | about 1000 km  
| | 5.5 kV  
| Nos. of thyristors: | 5760  
| | May 06 | PTD HVS | Power Transmission and Distribution |
Guizhou - Guangdong, China, 2004

<table>
<thead>
<tr>
<th>Customer:</th>
<th>State Power South Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project name:</td>
<td>Guizhou - Guangdong</td>
</tr>
<tr>
<td>Location:</td>
<td>Guizhou Province and Guangzhou near Hongkong</td>
</tr>
<tr>
<td>Type of Plant:</td>
<td>Long-distance transmission</td>
</tr>
<tr>
<td>Power Rating:</td>
<td>3000 MW, bipolar</td>
</tr>
<tr>
<td>Transmission dist.:</td>
<td>980km</td>
</tr>
<tr>
<td>Voltage levels:</td>
<td>± 500 kV DC, 525 kV 50Hz</td>
</tr>
<tr>
<td>Thyristor voltage:</td>
<td>8 kV (LTT) 3744</td>
</tr>
<tr>
<td>Nos. of thyristors</td>
<td></td>
</tr>
</tbody>
</table>

Additional details:
- ±500 kV DC, ±500 kV AC, ±500 kV hybrid bipolar transmission
- Power: 3000 MW
- Distance: 980 km
- Voltage levels: ±500 kV DC, ±525 kV AC
- Frequency: 50 Hz
- Thyristor voltage: 8 kV (LTT), 3744
Guizhou – Guangdong #2 HVDC Project, China

<table>
<thead>
<tr>
<th>Customer:</th>
<th>China Southern Power Grid Co.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project name:</td>
<td>Guizhou – Guangdong #2</td>
</tr>
<tr>
<td>Location:</td>
<td>Guizhou Province &amp; Guangzhou near Hong Kong</td>
</tr>
<tr>
<td>Type of Plant:</td>
<td>Long-Distance Transmission</td>
</tr>
<tr>
<td>Power Rating:</td>
<td>3000 MW, bipolar</td>
</tr>
<tr>
<td>Transmission dist.:</td>
<td>980km</td>
</tr>
<tr>
<td>Voltage levels:</td>
<td>±500kV DC, 525kV 50Hz</td>
</tr>
</tbody>
</table>

Contact Signed in May 2005
Moyle, Northern Ireland, 2001

World's first HVDC Submarine Cable Link with Direct Light Triggered Thyristor in Commercial Operation
Neptune RTS, USA, 2007

Customer: Neptune RTS
End User: Long Island Power Authority (LIPA)
Location: New Jersey: Sayreville
Long Island: Duffy Avenue
Project Development:
NTP-Date: 06/2005
PAC: 07/2007
Supplier: Consortium
Siemens / Pirelli
Type of Plant: Sea Cable
Power rating: 600/660 MW Monopolar
Transmission dist.: 82 km DC Sea Cable
23 km Land Cable
Trans Bay Cable Project, USA

Customer: Babcock & Brown
Project name: Trans Bay Cable
Location: San Francisco Bay Area
Project Status: Project Development, NTP late 05/early 06
Project Team: Exclusivity Agreement B&B, Siemens, Pirelli
Type of Plant: Long Distance Sea Cable
Power rating: 400…600 MW monopolar
Transmission dist.: App. 55 miles
Lamar, Colorado, USA, 2004
Back to Back – Conventional HVDC Transformers

**System 1**

Power & Voltage Control
Fault Current Blocking

**System 2**

Filters

**B2B - Rating:**

\[ 130 \leq \text{kV} \leq 550 \]
\[ 300 \leq \text{MW} < 1200 \]

Typically for asynchronous Systems
Lamar Colorado-Xcel Energy - 210 MW BtB Station
BTB- an Option with 2 AC Transformers

BTB With Transformers on both Sides
BTB (AC Transformers)- Conclusion & Summary of Benefits

- **Conventional AC Transformers** are used
  - Higher Reliability (no DC Stress, no Tapchanger)
  - Shorter Delivery Time
  - Reduced Costs

- **AC Filters** can be installed at the valve side of the transformer
  - Reduced Transformer Rating

- **Triple-tuned AC Filters** reduce the Number of Switchgear and Protection Equipment

- **Light triggered Thyristors** provide increased Reliability and improved Performance

- **Using a standard design & pre-assembled Solution** for Valves, Controls and Protection reduces site work, Erection and Commissioning Time

**BTB (AC Transformers) - the new Solution**
Intelligent Solutions for Power Transmission

with HVDC & FACTS from Siemens

Thank You for your Attention!