Power Distribution
Safety and protection for wind turbines

Perfectly coordinated components for low-voltage power distribution
Our world is changing

Global warming

- Global average temperature
- Increase of 0.76°C

Rising energy costs

- US$ per Barrel crude oil

Solutions for the more efficient use of energy must be put into action

Global greenhouse gas emissions

- 40Gt CO2e
- Industry (energy consumption) 11%
- Buildings (electricity) 13%
- Forestry 14%
- Agriculture/waste 18%
- Transportation 14%
- Industry (direct primary energy consumption) 22%
- Buildings (direct primary energy consumption) 8%
Expected changes of the energy mix – a scenario ...

- Coal
- Petroleum
- Nuclear energy
- Gas
- Wind
- Water
- Sun
- Biomass

Savings and energy efficiency

Quelle: H. Lehmann Wuppertaler Institut für Klima, Umwelt und Energie

© Siemens AG 2012. Alle Rechte vorbehalten.
Market development of the wind turbine market

Market development (worldwide)

Annual total installation in MW BTM Consult 03.2011

+16%

<table>
<thead>
<tr>
<th>Year</th>
<th>Americas</th>
<th>SEA</th>
<th>RoW</th>
<th>OECD-Pacific</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>39.404</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>46.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>53.875</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>60.475</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>72.475</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>81.350</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Increasing performance capacity and costs – higher risk

**Increase in capacity:**
- In just 20 years, the yield from wind turbines has increased 50-fold. With the current 6 MW turbines and the 10-15 MW turbines which are already in the development phase, this yield will again increase many times over.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rated power (kW)</th>
<th>Rotor diameter (m)</th>
<th>Hub height (m)</th>
<th>Annual yield (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>250</td>
<td>30</td>
<td>50</td>
<td>400,000</td>
</tr>
<tr>
<td></td>
<td>1,500</td>
<td>70</td>
<td>100</td>
<td>3,500,000</td>
</tr>
<tr>
<td></td>
<td>3,000</td>
<td>90</td>
<td>105</td>
<td>6,900,000</td>
</tr>
<tr>
<td>2012</td>
<td>6,000</td>
<td>126</td>
<td>135</td>
<td>approx. 20,000,000</td>
</tr>
</tbody>
</table>
Design of wind turbines

Main circuit

Auxiliary Circuit

Additional system components
LV products designed to ensure the electrical availability & reliability of Wind turbines

SENTRON circuit protection/monitoring devices
SENTRON Control and Switch disconnectors
SENTRON protection and measuring devices
SIVACON busbar trunking systems
Safe power distribution in the main circuit

The main circuit is responsible for the basic function of a wind turbine, i.e. the generation of electric power and the grid-compliant infeed of this power into the grid.

**Highlights**

- Comprehensive product portfolio for safe power distribution in the main circuit
- Maximum availability of the wind turbine thanks to high product quality
- Coordinated products satisfy requirements even under extreme conditions
- Reliable components support grid-compliant power quality
SIVACON 8PS busbar trunking system

Advantages compared to cables:

- Pre-installation in the factory simplifies the on-site installation process
- Only little space required, even in case of complex installations inside the nacelle
- High protection against ingress of water for vented system with IP34 and IP54 (sprinkler-suitable)
- High protection of all conductor surfaces due to non-ageing coating
- Sheet steel enclosure to reduce EMC effects to a minimum
SIVACON 8PS busbar trunking system
Advantages for protection against fires

Advantages for protection against fires:

- Significantly lower combustive energy due to sheet steel enclosure (Reduction of combustible materials acc. VdS 3523)
- Maximum short-circuit strength
- High short-circuit strength of the tap-off units
- High thermal loading capacity with regards to effects of a lightning strike
Switching and protecting the main circuit

- Effective protection of the main circuit in case of overload or short circuits
- Safe disconnection from the grid during maintenance
  - Locking mechanism against unauthorized switching-on for maximum protection of the maintenance personnel
- Communication-capability for optional connection to the electrical management system of the wind turbine
3WL air circuit breaker

- Maximum system availability thanks to the rapid replacement of devices and preventive maintenance
- Simple diagnostics for the contact condition in order to determine the service intervals
- Voltage range 690 V +/- 20% to 1,150 V and cold climate capability possible
- Modular design and same complete range of standard accessories, e.g. remote control due to motorized operating mechanism
- Externally controlled 3WL air circuit breaker for use with variable frequencies
Effective protection concept for the converter

- Protection of the power semiconductors against uncontrolled failure due to short circuit and overload
- High operational reliability due to super-quick disconnection characteristic
- Increased system availability thanks to optional fuse monitoring and integration into superordinate communication systems of the wind turbine
SITOR semiconductor fuses

- Effective protection of the sensitive power semiconductor with SITOR semiconductor fuses
- Super-quick disconnect characteristic of SITOR semiconductor fuses
- Increased system availability thanks to optional fuse monitoring
- Flexible installation thanks to a range of designs and mounting options
Safe power supply for the auxiliary circuits

Electrical equipment guarantees the vital functions of the wind turbine, e.g. pitch and yaw control systems and ventilation or hydraulic systems. Equipment of this kind must be fitted with coordinated components in order to ensure effective protection against overvoltages, overloads and short circuits.

Highlights

- A safe power supply guarantees maximum functionality
- Reliable protection against over-voltage, overload and short circuits
- Interruption-free operation thanks to a comprehensive protection concept for electrical operating mechanisms
- Products certified worldwide for the standard-compliant installation of protection concepts
High infeed protection for the auxiliary circuits

- Optimal overload and short circuit protection by the 3VL molded-case circuit breaker and the 3NP1 fuse switch disconnector.
3VL molded-case circuit breaker
3NP1 fuse switch disconnector

- A safe and requirement-based power supply for the control and auxiliary circuits
- Flexible adaptation to the required tripping characteristic
- High current carrying capacity with associated low derating
- Increased system transparency thanks to integration into the communication systems of the wind turbine
Perfect protection for auxiliary circuits

- Effective line protection and protection of electrical equipment against overload and short circuits with miniature circuit breakers
- Optimized personal safety and fire protection against dangerous residual currents with UC sensitive RCCBs

1. 5SM2 RC unit for personal safety and protection against electrically ignited blazes
2. 5SY miniature circuit breaker, 4-pole
3. 5ST3 remote-controlled operating mechanism for remote switching of the MCB
4. 5ST3 undervoltage releases protect downstream loads in the circuit against risks from undervoltage
5. 5ST3 auxiliary switches and 5ST3 fault signal contacts for displaying switching state or protective tripping
Miniature circuit breakers
RCCBs

- Maximum safety thanks to line protection against overload and short circuits
- UC-sensitive residual current operated circuit breaker for maximum personal safety
- Increased system availability thanks to remote reconnection with the assistance of motorized operating mechanisms
- Early detection and signaling of residual currents prevents system downtimes
Requirement-based motor protection concepts

A modular system consisting of standard components is available to switch, protect and start the various electrical operating mechanisms. The components are perfectly coordinated and can be combined with ease.

Highlights

- Extensive modular system for controlling, protecting and monitoring the operating mechanisms
- Integrated soft starting and speed-variable operation for requirement-based control
- Diverse diagnostics functions and integration of these into the wind turbine’s communication systems
- Use of SITOR semiconductor fuses to achieve type 2 co-ordination
## Motor protection concepts

<table>
<thead>
<tr>
<th>Circuit diagram</th>
<th>Product combination</th>
<th>Application</th>
<th>Function</th>
</tr>
</thead>
</table>
| ![Circuit diagram 1](image1.png) | ![Motor-protective circuit breaker](image2.png) | Single-phase small loads, e. g. fans in control cabinets | - Miniature circuit breaker with motor protection characteristic C for protection against overload and short circuits  
- Insta contactor for normal switching duty |
| ![Circuit diagram 2](image3.png) | ![Miniature circuit breaker with motor protection characteristic C](image4.png) | Pump motors, e. g. for cooling water or gear oil without requirements for speed-variable operation | - Motor-protective circuit breaker for protection against short circuits  
- Alternative cost-effective solution: fused motor starter combination, especially for use for motor feeders  
- SIRIUS contactors for normal switching duty  
- Overload relays for protection against overloading of the motor |
### Motor protection concepts

<table>
<thead>
<tr>
<th>Circuit diagram</th>
<th>Product combination</th>
<th>Application</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Circuit diagram 1" /></td>
<td><img src="image2" alt="Product combination 1" /></td>
<td>Motors which are operated with soft starters, e.g. service crane</td>
<td>- Motor-protective circuit breaker with overload relay function for protection against short circuit and overload in just one device</td>
</tr>
</tbody>
</table>
| ![Circuit diagram 2](image3) | ![Product combination 2](image4) | Protection of motors which are operated with soft starters, e.g. service crane when there are special requirements in order to achieve type 2 coordination | - Switch disconnector with fuses for semiconductor and line protection through SITOR semiconductor fuse in order to achieve type 2 coordination  
- Door-coupling rotary operating mechanism allows isolation outside the control cabinet for maintenance purposes  
- Soft starter for the soft, protective starting of motors  
- Overload relay for overload protection of the motor  |

© Siemens AG 2012. All rights reserved.  
Industry Sector – HUSUM 2012
## Motor Protection Concepts

<table>
<thead>
<tr>
<th>Circuit Diagram</th>
<th>Product Combination</th>
<th>Application</th>
<th>Function</th>
</tr>
</thead>
</table>
| ![Circuit Diagram](image1.png) | ![Product Combination](image2.png) | Speed-variable operation of e.g. cooling fan motors which are control-led in accordance with the ambient temperatures inside the nacelle | - SITOR semiconductor fuse for the cost-effective protection of the power semiconductors of the frequency converter  
- Achieving type 2 coordination  
- Contactor for normal switching duty  
- Frequency converter for gene-rating variable motor speeds. The protective function against over-load is covered by the frequency converter |
| ![Circuit Diagram](image3.png) | ![Product Combination](image4.png) | Control of e.g. soft-starting yaw operating mechanisms                                                           | - Compact feeders combine a circuit breaker, solid-state overload relay and contactor in just one device  
- Low variance of devices thanks to wide setting ranges  
- Soft starter for the soft, protective starting of motors |
### Motor protection concepts

<table>
<thead>
<tr>
<th>Circuit diagram</th>
<th>Product combination</th>
<th>Application</th>
<th>Function</th>
</tr>
</thead>
</table>
| ![Circuit Diagram](image) | ![Product Combination](image) | It is important that motors can be put back into operation as quickly as possible following a fault, especially in the case of motors which relate to safety functions | - Repair switch for manual isolation, e.g. for maintenance purposes or for the emergency-stop function  
- SITOR semiconductor fuse to protect the semiconductor of the high-quality frequency converter against short circuits. Achieving type 2 coordination. Rapid putting back into operation following a fault by replacing the fuse  
- Decentralized frequency converter for generating variable motor speed. The protective function against overload is covered by the frequency converter. The device is suitable for use in harsh ambient conditions |

© Siemens AG 2012. All rights reserved.
Industry Sector – HUSUM 2012
Optimal cabinet air conditioning and lighting

The control cabinet air conditioning ensures constant operating temperatures in all control cabinets, no matter what the weather.

The control cabinet lighting offers maintenance staff optimal visibility for maintenance and repair work.

Highlights

- Operation-compatible climate in the control cabinet in every type of weather
- Effective protection against overheating and mold formation
- Wide-ranging portfolio of air-conditioning equipment for the most varied requirements
- Optimal visibility thanks to compact cabinet lights
Safe disconnection from the network during maintenance

The high-quality switch disconnectors for safe and reliable disconnection from the network.

**Highlights**

- Reliable protection of maintenance staff against unauthorized reconnection
- Safe disconnection of the auxiliary circuits and loads from the network
- Further options, e.g. as an EMERGENCY-STOP switch for increased safety in hazardous situations
Lightning/overvoltage protection

- Owing to their exposed locations, wind turbines are subject to a highended risk of being struck by lightning.
- Therefore they require extensive lightening- and overvoltage protection matching the respective type of turbine.
- The necessary risk assessment must be based on the maximum risk possible (risk level I) in accordance with IEC 62305/IEC61400-24.
- It must take account of the possible lightning paths, e. g. from the rotor blade, hub and the nacelle via the tower down to the foundation.
- In addition to the lightning partial currents which can be expected, switching surges must also be taken into consideration.
Protection against lightning and overvoltage

By using our graded portfolio, you can protect not only the supply circuit equipment, but also the data lines.

**Highlights**

- Prevention of system failures through graded lightning and overvoltage protection
- High level of protection thanks to remote signaling of the device condition and simple replacement of the modules
- Control technology protection thanks to overvoltage protection for data lines
## Risk zones (LPZ) in wind turbines

<table>
<thead>
<tr>
<th>LPZ</th>
<th>Area</th>
<th>Risk</th>
<th>Wind turbine parts affected</th>
</tr>
</thead>
</table>
| 0a  | Area at risk of a direct lightning strike | Lightning | - Rotor blades  
- Building 400/690 V power supply/transformer station |
| 0b  | Protection area in which the system is not exposed to a direct lightning strike | High-energy unattenuated electro-magnetic fields | - Nacelle  
- Externally attached sensors (wind speed/direction; climate)  
- Hazard lights (aviation lights) |
| 1   | Inside the nacelle/tower | Transients triggered by: electromagnetic fields, switching operations (SEMP) | - Protection devices and switchgear  
- Generator  
- Converter  
- Motorized operating mechanisms/frequency converter  
- Air conditioning systems |
| 2   | Shielded components inside the nacelle or tower | Lower-energy transients triggered by: Switching operations (SEMP) Electrostatic discharge (ESD) | - Control components (e.g. pitch)  
- Communication components |
# Graded portfolio for overvoltage protection – from medium voltage to data networks

<table>
<thead>
<tr>
<th>Energy</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protection of the main circuit</strong></td>
<td>Protection of data and measuring systems</td>
</tr>
<tr>
<td>Special arrester versions for use in close proximity to the generator and the converter. They are leakage current-free and insensitive to operational voltage peaks.</td>
<td>Surge protection devices for the protection of analog signal circuits and the lines of digital status signals. Special arresters for resistance-based temperature measuring systems (e.g. Pt100) are available.</td>
</tr>
<tr>
<td><strong>Protection of auxiliary circuits</strong></td>
<td>Protection of communication interfaces</td>
</tr>
<tr>
<td>Suitable surge protection devices for a range of mains types and applications.</td>
<td>Suitable surge protection devices for all common fieldbus systems, such as Profibus, CAN, CANopen and DeviceNet. Suitable arresters with RJ11, RJ12, RJ45 sockets for the protection of phone and ISDN systems.</td>
</tr>
<tr>
<td><strong>Protection of sensitive loads</strong></td>
<td>Protection for Industrial Ethernet</td>
</tr>
<tr>
<td>Surge protection devices with ultra strong voltage limitation for the protection of sensitive loads, such as UPS systems, measuring instruments and the power supply lines of controls.</td>
<td>Surge protection devices for communication systems based on Gigabit Ethernet, such as Profinet, EtherCAT, EtherNet/IP and EthernetPOWERLINK.</td>
</tr>
<tr>
<td><strong>Protection of medium-voltage systems</strong></td>
<td>Protection for serial interfaces</td>
</tr>
<tr>
<td>3EK4 and 3K7 surge arresters offer the best protection against overvoltages in medium-voltage distribution grids up to a maximum system voltage of 72.5 kV.</td>
<td>Surge protection devices for serial interfaces RS232 and RS485 with the correct Sub-D9 connection.</td>
</tr>
</tbody>
</table>

© Siemens AG 2012. Alle Rechte vorbehalten.

Industry Sector – HUSUM 2012
High system transparency with measuring devices

- Increased system transparency thanks to measuring, providing and communicating of consumption data and electrical characteristics
- Measuring of the current quality of the main circuit
- Measuring of the internal consumption of the control and auxiliary circuits within the wind turbine
- Integration into the communication systems of the wind turbine
- Recording of measured data and querying via the wind park control rooms
7KM PAC measuring devices

- Early information about critical system states increases safety
- Graphical LCD, intuitive operation with text display in ten languages and 4 control keys
- Expandable due to optional communication modules for integration into superordinate communication systems
- Connection to the wind park control rooms
- Comfortable configuration software included in scope of delivery
Optimal availability thanks to communication

Integrated communication makes diagnostics and control an easier process and increases the availability of wind turbines.

**Highlights**

- Optimal system transparency thanks to communication-capable products
- Increased system availability thanks to preventive maintenance and diagnostics functions
- Flexible adaptation to requirements thanks to graded communication classes
- Fully informed thanks to intelligent measurement technology
Flexible adaptation through graded communication classes

**Basic functions:**

- Forwarding of data to other systems via bus system
  - PROFIBUS
  - Modbus
  - Ethernet
- Measurement function in the circuit breaker
- Further processing of measured values and diagnostics/status signals in process control systems
Flexible adaptation through graded communication classes

Configuration examples:

1. **Forwarding of status signals** via a configurable CubicleBus digital output module, e.g.:
   - Ready-to-close status
   - Connected position
   - Limit violation signal (e.g. temperature, current ...)
   - Reason for tripping signal (e.g. short circuit, overload ...)

2. **Collection of switching state data** (e.g. ACB, SPD, LS, RCM) via DI to 7KM PAC4200 and forwarding the status information to PN (use of 7KM PAC in addition to the main measurement function)
Comprehensive and competent product offering

We offer the world’s most comprehensive portfolio of electrical and electronic drive solutions, automation and communication components and power distribution systems for wind turbines. In addition to this, we also offer fire detection and fire extinguishing systems.

**Highlights**

- The widest portfolio for automation and power distribution in wind turbines
- Coordinated TIA and TIP system architectures
- Close proximity to customers thanks to a worldwide presence
- Many years of proven experience in the industry
Comprehensive and competent product offering

1. Wind Turbine Generator
   - Automation/SCADA/HMI
   - Busbar trunking systems
   - Protection devices
   - Electrical operating mechanisms
   - Generator/Converter
   - Camera surveillance

2. Medium-voltage transformer

3. Medium-voltage switchgear
   - Circuit breakers
   - Control panel
   - Busbar trunking systems

4. Control room
   - Automation
   - Monitoring
   - Controlling

5. Infeed meter

6. Operation and service
   - Preventative maintenance
   - Reconstruction

7. Transformer station and high-voltage transmission lines
8DJH 36 –
Prepared for all requirements
8DJH 36 –
Prepared for all requirements
Windfarms secure the energy supply in the future
One switchgear for all requirements

8DJH 36 is a gas-insulated modular switchgear with high reliability for your distribution applications up to 36kV and 630A.
8DJH 36 is a gas-insulated switchgear with a compact design which fits in the tower of wind turbines.

8DJH 36 climatic independence enables worldwide application.
8DJH 36 is the newest chapter of a long story of success
8DJH 36 is the newest chapter of a long story of success

More than **30 years ago**, Siemens laid the foundation for the gas-insulated medium-voltage switchgear 8DJH 36. It is the logical and consequent extension of the very successful 8DJH switchgear.

Practical experience of more than **750,000 installed feeders** in the secondary distribution level.

More than **120,000 installed switchgear panels** in primary distribution.
8DJH 36 advantages

- Compactness
- Personal safety
- Maintenance-free design
- Climatic independence
- Modular construction
8DJH 36 – today’s answer to the questions of tomorrow
Main applications for 8DJH 36

- **Wind farm**
  - 8DJH 36 – Compact design enables installation in the tower of wind turbines
- **Hydroelectric power plant**
  - 8DJH 36 – Climatic independence leads to a longer service life
- **Solar power plant**
  - 8DJH 36 – Climatic independence enables worldwide application
- **Stadium**
  - 8DJH 36 – Highest quality standards ensure availability
- **Public power supply**
  - 8DJH 36 – Reliability reduces downtimes
- **Sewage plant**
  - 8DJH 36 – Responsible utilization of resources protects the environment
- **Industry**
  - 8DJH 36 – Maintenance-free design reduces operational costs
8DJH 36 is the ideal solution for today’s and tomorrow’s requirements in power distribution.
Overview

Applications:
- substations
- customer transfer substations
- distribution and switching substations

Users:
- power supply bureau
- public utilities
- public buildings (e.g. high-rise buildings, railway stations, hospitals)
- Industrial plants
Gas-insulated switchgear: our values

- Reliable
- Security of operation
- Compact
- Environmentally responsible
- Climate-independent
- Personal safety
- Maintenance-free

© Siemens AG 2012. Alle Rechte vorbehalten.

Industry Sector – HUSUM 2012
Technical Features

- Up to 36 kV, 20 kA/ 3 s
- Busbar 630 A, feeders up to 630 A
- Factory assembled, type tested switchgear acc. to IEC 62271-200
- Metal-enclosed
- Single busbar
- Gas-insulated, sealed for life
- Flexible due to extension option and block formation
- Individual panels and block versions
Main Power Circuit

Technical Concepts for Switchgears
Main Power Circuit
Overview

Generator → Main power circuit (Converter...) → Transformer → 20 kV

SG

Infeed panel
Transformer
## Generator & Converter: Concepts

### Fixed Rotor Speed

- **Directly coupled induction (asynchronous) generator**

### Variable Rotor Speed

- **Doubly fed induction generator (DFIG)**
- **Induction generator with full inverter system**
- **Synchronous generator with full inverter system**
Doubly fed induction generator (DFIG)

Examples

2 Contactors 3RT14, each 690 A * 1.8 (Derating) = 1.200 A  →  1,6 MW – Turbine
3 Contactors 3RT14, each 690 A * 2.5 (Derating) = 1.700 A  →  2,4 MW – Turbine
3 Contactors 3TF69, each 910 A * 2.5 (Derating) = 2.300 A  →  3,0 MW – Turbine

Contactors are used parallel at 690V and AC1
Full inverter system

Examples

3 Contactors 3RT14, each 690 A * 2.5 (Derating) = 1.700 A → 1.2 MW per Converter module
3 Contactors 3TF69, each 910 A * 2.5 (Derating) = 2.300 A → 1.6 MW per Converter module

Contactors are used parallel at 690V, AC1

[Details see at slide before (DFIG)]