Agenda February 28 PM: Medium Voltage

- SIPROTEC technical workshop
- Medium Voltage: cleverly & reliably switched
- Q&A, Conclusion
- Reception
- End of the workshop
## Highlights

<table>
<thead>
<tr>
<th>Highlight</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens’ world acclaimed expertise and technological know-how brought to your doorsteps</td>
<td></td>
</tr>
<tr>
<td>The <strong>Power</strong> Academy Lagos is part of an international network</td>
<td></td>
</tr>
<tr>
<td>The trainers undergo international train-the-trainer programs</td>
<td></td>
</tr>
<tr>
<td>The training portfolio covers every aspect of electrical conversion chain adapted to suit local requirements</td>
<td></td>
</tr>
<tr>
<td>The curriculum-based certification is locally and internationally accredited</td>
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<tr>
<td>World class facilities, Top class Training organization and special services</td>
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</tr>
</tbody>
</table>
Facilities
Training Portfolio (Energy / I&C Sectors)

### Siemens Power Academy TD (Transmission and Distribution, ~200 standard courses)

- High Voltage
- Medium Voltage
- Transformers
- Energy Automation
- Services / Power Studies / Software solutions

### Siemens Power Academy PG (Power Generation, ~x standard courses)

- Power Plants
- Instrumentation & Controls
- Oil & Gas and Industrial Applications
- Renewable Energies
Training Offer

For experienced Engineers, Technologists

**Short Term Courses (~3 to 5 Days)**
- General engineering topics on Power
- Specialized Trainings

**Short Term Certification (~10 Days)**
- Specific Topics, offered twice a year
- Involves international Trainers
- Requires deep engineering background
- Success at Assessment before and after training qualifies for certification

**Long Term Certification Program (~12 Months)**

For fresh graduates, new comers, Technicians, Artisans

- Siemens Energy program for young graduates
- Electrical Power supply and maintenance for Electricians
- Electrical engineering for oil and gas field technicians
- Electromechanics*
- Mechatronics*

* Training conducted with partners
References: Siemens- Lagos State Electricity Board

Youth Energy career program

Project Requirements

• Develop a 6 month customized training program for young graduates
  • Equip them with relevant practical skills for direct employment

Training Scope

• General Power Engineering principles
  Power systems technology, planning, studies and simulation

• Protection of electrical networks
  Principles of protection technology, Medium voltage system and equipments, engineering, selection, commission, o&m

• The Smart Grid: Energy Data Management, Control and measuring principles
  Smart grid concept, instrument transformers, energy efficiency & data management, distribution automation and SCADA systems, network communication solutions, automated power survey solutions

• Financial Grid
  supply & demand, regulation, market design, energy auditing, etc..

• Power impacts

Customer Benefits

• Ready made engineers to be employed on IPP, street lightning, Energy Survey and rural electrification projects on going in Lagos

• Quality assurance through a reliable and experienced training partner
Power Economics and IPP management

**Project Requirements**
- Bank staff to be equipped with understanding of how lenders analyze power projects (cash flow, loan documents, PPA, GPA, EPC and insurance contract) in order to conduct conveniently power project discussions
- Understand principles of power markets and especially become convenient with the Nigerian power sector reforms

**Training Scope**
- Physical grid
  - Major grids, components, reliability and operations, dynamic phenomena, stability and reliability of power systems
- Managing power projects
  - Process, tools, environmental, community, planning
- Power Economics basics & Financial Grid
  - Supply & demand, regulation, market design, pricing and tariff, low flow analysis, energy auditing, etc..
- Power impacts
  - Integration of renewable, environmental, social, financial, etc..

**Customer Benefits**
- **Flexibility**: customized in-house training
- **Quality assurance**
References: Siemens- Shell Nigeria

Protection training for O&G networks

**Project Requirements**
- Engineers to gain understanding of typical O&G electrical networks.
- Trainees should gain understanding of typical protection schemes used in O&G networks and become convenient with fault interpretation procedures in order to **reduce down-time**

**Training Scope**
- **Typical O&G electrical network**
  load flow, short circuit, motor start, voltage & frequency stability, protection settings coordination, and protection trip reports
- **DIGSI 4 Operating and Evaluation Software**
- **General Principles of numerical relaying**
  over current protection, distance protection, differential protection, motor and generator protection, busbar protection
- **Measuring supervision and fault analysis using SIGRA**
- **Hands-on training with relays**
- **Relays secondary testing**

**Customer Benefits**
- **Cost advantages** and **Quality assurance in a local environment**
- **Flexibility:** It is much more easier to send 36 engineers to Lagos at once.
Table of content

1. Introduction
2. Switching Devices, types and their selection
3. Technical data of MV Switchgears
4. More Technical Information for MV Switchgears
5. Circuit Breakers – functions and types
6. Types of MV switchgears:
   (i). MV Air-Insulated Switchgears (AIS);
   (ii). MV Vacuum Switchgears;
   (iii). MV Gas-Insulated Switchgears (GIS).

7. Global MV Production Locations and Examples of Industrial applications.
1. Introduction:

According to international rules, there are only two voltage levels:

- Low-voltage: up to and including 1kV AC (or 1,500 V DC)
- High-voltage: above 1kV AC (or 1,500 V DC).

The term “medium-voltage” has come to be used for the voltages required for regional power distribution that are part of the high-voltage range from 1kV AC up to and including 52kV AC.

Most operating voltages in the medium-voltage systems are in the 3kV AC to 40.5 kV AC range. The table in the next slide however shows the nomenclatures according to IEC.

High operating voltages (and therefore low currents) are preferred for power transmission in order to minimize losses.

In some countries, majority of medium-voltage systems in public power supplies are operated in the 10kV to 30kV range. In Nigeria, 11kV to 33kV.
# Voltage levels according to IEC

## Nomenclatures used to represent different voltage levels

<table>
<thead>
<tr>
<th>System</th>
<th>Nominal voltage ((V_r)) kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV</td>
<td>(V_r \leq 1)</td>
</tr>
<tr>
<td>MV</td>
<td>(1 &lt; V_r \leq 35)</td>
</tr>
<tr>
<td>HV</td>
<td>(35 &lt; V_r \leq 230)</td>
</tr>
<tr>
<td>EHV</td>
<td>(230 &lt; V_r \leq 800)</td>
</tr>
<tr>
<td>UHV</td>
<td>(V_m = 1050) or (1200)</td>
</tr>
</tbody>
</table>

(Practiced in USA)
Voltage levels from the power plant to the consumer

1. Medium voltage
2. High voltage
3. Low voltage
2. Switching devices

What are switching devices?

Switching devices are devices used to close (make) or open (break) electrical circuits. In other words, they are **gears used for switching** i.e. **switchgears**. The process of making and/or breaking the electrical circuit may be associated with the stress of

- No-load switching;
- Breaking of operating currents;
- Breaking of short-circuit currents.
Types of Switching Devices and what they do:

Circuit breakers
Can make and break all currents within the scope of their ratings, from small inductive and capacitive load currents up to the full short-circuit current, and this under all fault conditions in the power supply system, such as earth faults, phase opposition, etc.

Switches
Can switch currents up to their rated normal current and make on existing short-circuits (up to their rated short-circuit making current).

Disconnectors (Isolators)
May exclusively be switched on no-load. Cannot switch on and off load currents. Cannot switch off short-circuit currents. Their function is to “isolate” downstream devices so they can be worked on.

Switch-disconnectors (load-break switches)
The combination of a switch and a disconnector, or a switch with isolating distance.
Contactors

Load breaking devices with limited short-circuit making or breaking capacity. They are used for high switching rates.

Earthing switches

To earth isolated circuits.

Make-proof earthing switches (earthing switches with making capacity):

Used for the safe earthing of circuits, even if voltage is present, i.e. also in the event that the circuit to be earthed was accidentally not isolated.

Non-switching devices

Fuses (HBC or HRC)

Consist of a fuse-base and a fuse-link. With the fuse-base, an isolating distance can be established when the fuse link is pulled out in de-energized condition (like in a disconnector). The fuse-link is used for one single breaking of a short-circuit current. Fuses have current-limiting properties. They are not used for operational switching.
Surge arresters

Used to discharge loads caused by lightning strikes (external over-voltages) or switching operations and earth faults (internal over-voltages) to earth. They protect the connected equipment against impermissibly high voltages.

From the foregoing, it can be seen that switchgears are used either to de-energize equipment to allow work to be done or to discharge excessive voltages or to clear faults downstream. While some can combine some of these functions, others cannot.

For industrial applications, a number of switchgear line-up may be combined in one housing or cubicle and the entire structure is still called switchgear or switchgear assembly.
Typical Feeder Configuration in a Switchgear

- Busbar
- Bus disconnector
- Circuit breaker
- Current transformer
- Feeder disconnector
- Earthing switch
- PLC-Filter
- Voltage transformer
- Surge arrestor
### Switching in Power Systems - Characteristics of Switching Devices (Overview)

<table>
<thead>
<tr>
<th></th>
<th>Making of</th>
<th>Breaking of</th>
<th>Isolating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small current</td>
<td>Load current</td>
<td>Short circuit current</td>
</tr>
<tr>
<td><strong>Circuit breaker</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Isolator/disconnector</strong></td>
<td>✓</td>
<td>(✓)</td>
<td>(✓)</td>
</tr>
<tr>
<td><strong>Fuse</strong></td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Selection of switching devices

Switching devices are selected both according to their ratings and according to the switching duties to be performed, which also includes the switching rates.

1. Selection according to ratings:

The system conditions, that is, the properties of the primary circuit, determine the required parameters. The most important of these are:

- **Rated voltage**: The upper limit of the system voltage the device is designed for. Since all high-voltage switching devices are zero-current interrupters – except for some fuses – the system voltage is the most important dimensioning criterion. It determines the dielectric stress of the switching device by means of the transient recovery voltage and the recovery voltage, especially while switching off.

- **Rated insulation level**: The dielectric strength from phase to earth, between phases and across the open contact gap, or across the isolating distance. The dielectric strength is the capability of an electrical component to withstand all voltages with a specific time sequence up to the magnitude of the corresponding withstand voltages.
These can be operating voltages or higher-frequency voltages caused by switching operations, earth faults (internal over-voltages) or lightning strikes (external over-voltages). The dielectric strength is verified by a lightning impulse withstand voltage test with the standard impulse wave of 1.2/50 µs and a power frequency withstand voltage test (50 Hz/1min).

- **Rated normal current:**

  The current that the main circuit of a device can continuously carry under defined conditions. The temperature increase of components – especially contacts – must not exceed defined values. Permissible temperature increases always refer to the ambient air temperature. If a device is mounted in an enclosure, it may be advisable to load it below its full rated current, depending on the quality of heat dissipation.

- **Rated peak withstand current:**

  The peak value of the major loop of the short-circuit current during a compensation process after the beginning of the current flow, which the device can carry in closed state.
It is a measure for the electro-dynamic (mechanical) load of an electrical component. For devices with full making capacity, this value is not relevant (see next item).

- **Rated short-circuit making current:**
  The peak value of the making current in case of short-circuit at the terminals of the switching device. This stress is greater than that of the rated peak withstand current because dynamic forces may work against the contact movement.

- **Rated breaking current:**
  The load breaking current in normal operation. For devices with full breaking capacity and without a critical current range, this value is not relevant (see previous item).

- **Rated short-circuit breaking current:**
  The rms value of the breaking current in case of short-circuit at the terminals of the switching device.
The switching devices and all other equipment must be selected for the system data available at the place of installation. This system data defines the ratings of the components.

<table>
<thead>
<tr>
<th>Component designation</th>
<th>Rated insulation level</th>
<th>Rated voltage</th>
<th>Rated normal current</th>
<th>Rated peak withstand current</th>
<th>Rated breaking current</th>
<th>Rated short-circuit breaking current</th>
<th>Rated short-circuit making current</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Switching devices</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circuit-breaker</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Switch</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>1)</td>
<td>■</td>
</tr>
<tr>
<td>Switch-disconnector</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Disconnector</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Earthing switch</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Make-proof earthing switch</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Contactor</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>1)</td>
<td>1)</td>
</tr>
<tr>
<td><strong>Non-switching components</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuse link</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Fuse-base</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Surge arrester</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>2)</td>
<td>3)</td>
</tr>
</tbody>
</table>

■ Influence on selection of component  
— No influence on selection of component

1) Limited short-circuit making capacity  
2) Rated discharge current of arresters  
3) Short-circuit current strength in case of overload of arresters
2. Selection according to endurance and switching rates:

If several devices satisfy the electrical requirements and no additional criteria have to be taken into account, the required switching rate can be used as an additional selection criterion.

The respective device standards distinguish between classes of mechanical (M) and electrical (E) endurance, whereby they can also be used together on the same switching device: e.g., a switching device can have both mechanical class M1 and electrical class E3.
3. Technical data of Medium-Voltage Switchgear (Assembly)

Most medium-voltage switchgears are indoor units and are selected not as isolated units but as switchgear assembly. The major influences and stress values that a switchgear assembly is subjected to result from the task and its rank in the distribution system. These influencing factors and stresses determine the selection parameters and ratings of the switchgear.

a) **Rated voltage and frequency:**

The system voltage and frequency determine these values for the switchgear, switching devices and other installed components. The maximum system voltage at the upper tolerance limit is the deciding factor.

**Assigned configuration criteria w.r.t. voltage for switchgear are:**

- Rated voltage $U_r$ (kV); frequency $f$ (Hz);
- Rated insulation level [Short-duration power-frequency withstand voltage $U_d$ (kV); Lightning impulse withstand voltage $U_p$ (kV)];
- Rated primary voltage of VTs (kV).
b) **Short-circuit current:**

The short-circuit current is characterized by the electrical values of peak withstand current $I_p$ (peak value of the initial symmetrical short-circuit current) and sustained short-circuit current $I_k$. The required short-circuit current level in the system is predetermined by the dynamic response of the loads and the power quality to be obtained. This in turn determines the making and breaking capacity and the withstand capability of the switching devices and the switchgear assembly as a whole.

**Assigned configuration criteria w.r.t. short-circuit current for switchgears are:**

| Main and earthing circuits | \- Rated peak withstand current $I_p$
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Rated short-time withstand current $I_{k}$</td>
</tr>
</tbody>
</table>
| Switching devices          | \- Rated short-circuit making current $I_{ma}$
|                            | \- Rated short-circuit breaking current $I_{sc}$ |
| Current transformers       | \- Rated peak withstand current $I_{k-dyn}$
|                            | \- Rated short-time thermal current $I_{th}$ |
c) Normal current and load flow:

The normal current refers to current paths of the incoming feeders, bus-bar(s) and outgoing consumer feeders. Since the incoming currents into the bus-bar(s) are distributed, depending on the number of outgoing feeders, there may be different current ratings for bus-bar(s) and feeders.

Reserves must be planned for when dimensioning the switchgear:

- In accordance with the ambient air temperature;
- For planned overload;
- For temporary overload during faults.

**Assigned configuration criteria w.r.t normal current and load flow are:**

- Rated current of bus-bar(s) and feeders;
- Number of cables per phase in the panel (parallel cables);
- Current transformer (CT) ratings.
4. More technical information for MV Switchgear

a) Loss of service continuity category (LSC):

<table>
<thead>
<tr>
<th>Loss of service continuity category</th>
<th>When an accessible compartment of the switchgear is opened ...</th>
<th>Type of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSC 1</td>
<td>the busbar and therefore the complete switchgear must be isolated.</td>
<td>No partitions within the panel; no panel separation walls to adjacent panels.</td>
</tr>
<tr>
<td>LSC 2 LSC 2A</td>
<td>the incoming cable must be isolated. The busbar and the adjacent switchgear panels can remain in operation.</td>
<td>Panel separation walls and isolating distance with partition to the busbar.</td>
</tr>
<tr>
<td>LSC 2B</td>
<td>the incoming cable, the busbar and the adjacent switchgear panels can remain in operation.</td>
<td>Panel separation walls and isolating distance with partition to the busbar and to the cable.</td>
</tr>
</tbody>
</table>
b) Accessibility of compartments:

<table>
<thead>
<tr>
<th>Type of accessibility to a compartment</th>
<th>Access features</th>
<th>Type of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interlock-controlled</td>
<td>Opening for normal operation and maintenance, e.g., fuse replacement</td>
<td>Access is controlled by the construction of the switchgear, i.e., integrated interlocks prevent impermissible opening.</td>
</tr>
<tr>
<td>Procedure-based</td>
<td>Opening for normal operation or maintenance, e.g., fuse replacement</td>
<td>Access control via a suitable procedure (work instruction of the operator) combined with a locking device (lock).</td>
</tr>
<tr>
<td>Tool-based</td>
<td>Opening not for normal operation and maintenance, e.g., cable testing</td>
<td>Access only with tool for opening; special access procedure (instruction of the operator).</td>
</tr>
<tr>
<td>Not accessible</td>
<td>Opening not possible not intended for operator; opening can destroy the compartment. This applies generally to the gas-filled compartments of gas-insulated switchgear. Because the switchgear is maintenance-free and climate-independent, access is neither required nor possible.</td>
<td></td>
</tr>
</tbody>
</table>
C) Internal arc classification according to IEC 62271-200:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAC</td>
<td>Internal Arc Classification</td>
</tr>
<tr>
<td>A</td>
<td>Distance between the indicators 300 mm, i.e., installation in rooms with access for authorized personnel; closed electrical service location.</td>
</tr>
<tr>
<td>FLR</td>
<td>Access from the front (F), from the sides (L = Lateral) and from the rear (R).</td>
</tr>
<tr>
<td>I</td>
<td>Test current = Rated short-circuit breaking current (in kA)</td>
</tr>
<tr>
<td>t</td>
<td>Arc duration (in s)</td>
</tr>
</tbody>
</table>
d) Other information

Other information apart from the technical data are:

- Physical dimensions: Width; Height; Depth;
- Type of construction: Extendable or Non-extendable;
- Bus-bar system: Single Bus-bar or Double bus-bar;
- Insulation i.e. Insulating medium;
- Type of interrupter (if circuit breaker);
- Fixed-mounting, Withdrawable or Truck-type;
- Any special features etc.
An Example of Rated Technical Information for an MV Switchgear:

<table>
<thead>
<tr>
<th>Rated Technical data of NXAIR</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>kV</td>
<td>7.2</td>
</tr>
<tr>
<td>Frequency</td>
<td>Hz</td>
<td>50/60</td>
</tr>
<tr>
<td>Short-duration power-frequency withstand voltage</td>
<td>kV</td>
<td>20(^1)</td>
</tr>
<tr>
<td>Lightning impulse withstand voltage</td>
<td>kV</td>
<td>60</td>
</tr>
<tr>
<td>Short-circuit breaking current; max.</td>
<td>kA</td>
<td>40</td>
</tr>
<tr>
<td>Short-time withstand current; 3s, max.</td>
<td>kA</td>
<td>40</td>
</tr>
<tr>
<td>Short-circuit making current; max.</td>
<td>kA</td>
<td>100/104(^2)</td>
</tr>
<tr>
<td>Peak withstand current; max.</td>
<td>kA</td>
<td>100/104(^2)</td>
</tr>
<tr>
<td>Normal current of the busbar; max.</td>
<td>A</td>
<td>4000</td>
</tr>
<tr>
<td>Normal current of the feeders; max.</td>
<td>A</td>
<td>4000</td>
</tr>
<tr>
<td>Width</td>
<td>mm</td>
<td>435(^3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>Depth</td>
<td>mm</td>
<td>1350</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1400(^3)</td>
</tr>
<tr>
<td>Height</td>
<td>mm</td>
<td>2300</td>
</tr>
</tbody>
</table>

1) For GOST standard 32 or 42 kV optional  
2) Values for 60 Hz  
3) Contactor panel
5. Circuit Breakers – functions and types

Functions of a Circuit Breaker in an electrical Network:

- Circuit Breakers are like electromechanical switches with a making and breaking capacity such that they can withstand the stresses which arise when equipment and parts of an installation are switched on and off under normal and abnormal conditions for example a short circuit.
- They prevent damage to other parts of equipment like transformers, generators, motors or other expensive components of the substation, by interrupting high short circuit currents very fast.
- Through fast reclosing, they ensure power restoration within a short time.
- Circuit Breakers do not open or close by themselves. The opening and closing has to be initiated either manually or automatically by protection systems.
- Circuit Breakers are like fuses except that they need not be replaced after every operation.
Fundamentals of CB action:
SIPROTEC 4
## SIPROTEC 4 Applications

<table>
<thead>
<tr>
<th>SIPROTEC 4</th>
<th>DIGSI 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>O/C-protection</td>
<td>7SJ61 7SJ62 7SJ63 7SJ64</td>
</tr>
<tr>
<td>Distance protection</td>
<td>7SA52 7SA6x 7VK61</td>
</tr>
<tr>
<td>Transformer protection</td>
<td>7UT612 7UT613 7UT633 7UT635</td>
</tr>
<tr>
<td>Bay Controller</td>
<td>6MD61 6MD63 6MD66</td>
</tr>
<tr>
<td>Line Diff. Protection</td>
<td>7SD610 7SD52 7SD53</td>
</tr>
<tr>
<td>Generator/Motor</td>
<td>7UM61 7UM62 7VE6</td>
</tr>
<tr>
<td>Busbar protection</td>
<td>7SS52 7SS60</td>
</tr>
</tbody>
</table>
Example of SIPROTEC 4 application:
Time-overcurrent protection

- Directional time-overcurrent Protection (67/67N)
- Time overcurrent Protection (50/50N, 51/51N)
- Thermal overload Protection (49)
- Inrush blocking
- Sensitive Ground Fault Protection (64, 50Ns, 67Ns)
- Motor Protection (14, 37, 48, 66/68)
- Under / Over voltage (27, 59)
- Under / Over frequency (81)
- Negative Sequence Protection (46)
- Trip Circuit Monitoring (74TC)
- Lock-out (86)
- Circuit Breaker Failure Protection (50BF)
- Synchronisation (25), only 7SJ64
- Auto reclosing (79M)
- Fault Recording
- Synchronised Real Time
- User programmable Logic Functions
- Measured Value processing
- Max demand, metered Values
- 3 serial Communications Interfaces
  (Remote temperature device interface)
- CB Control Function (Interlocking)
Time-overcurrent protection  Application

Main protection as line protection

Advantage: simple device, only current transformers are necessary
Disadvantage: near infeed higher tripping time
Time-scale for CB operation

- Fault inception
- Trip command of the relay
- Fault is cleared
- Relay drops-out

- Load current
- Short-circuit current

- 0ms to 15ms: Pick-up time of the relay
- 15ms to 30ms: Circuit breaker interrupting time
- 30ms to 60ms: Time to clear the fault
- 60ms to 120ms: Time for the relay to drop out

Time [ms]
Types of Circuit Breakers

The following types of breakers were used in Power Systems:

- Bulk oil or Oil filled (Dead Tank and Live Tank);
- Oil filled with minimum volume of oil (MOCB);
- Air Blast; AIS;
- GIS, Sulphur Hexa Flouride SF$_6$ (Dead Tank and Live Tank);
- Vacuum (generally Medium Voltage)
- Single phase (suited for single phase breaker opening and is used generally for HV / EHV lines)

In all these cases, except for vacuum, **the medium** (oil, air or SF$_6$) were used for insulation and arc quenching.
6. Types of MV Switchgears: (i) Air-insulated MV Switchgears (AIS)

a). NX Air

- Type-tested, Metal-clad and partly clad respectively
- Wheel-away Vacuum Power Switch
- Highest Availability because of modular Design
- Highest Operation Safety Level because of self-explanatory Operation Logic
- Maintenance interval > 10 Years
NX Air

A = Switching device compartment
B = Busbar compartment
C = Connection compartment
D = Vacuum circuit-breaker
E = Low-voltage compartment
b) NX AIR M

Maximum values
24kV /25 kA /2500 A

A = Switching device compartment
B = Busbar compartment
C = Connection compartment
D = Vacuum circuit-breaker
E = Low-voltage compartment
### c) NX AIR P

#### Rated values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 7.2</th>
<th>Value 12</th>
<th>Value 17.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>7.2 kV</td>
<td>12 kV</td>
<td>17.5 kV</td>
</tr>
<tr>
<td>Frequency</td>
<td>50/60 Hz</td>
<td>50/60 Hz</td>
<td>50/60 Hz</td>
</tr>
<tr>
<td>Short-duration power-frequency withstand voltage</td>
<td>20 kV</td>
<td>28 kV</td>
<td>38 kV</td>
</tr>
<tr>
<td>Lightning impulse withstand voltage</td>
<td>60 kV</td>
<td>75 kV</td>
<td>95 kV</td>
</tr>
<tr>
<td>Short-circuit breaking current</td>
<td>50 kA</td>
<td>50 kA</td>
<td>50 kA</td>
</tr>
<tr>
<td>Short-time withstand current, 3 s</td>
<td>50 kA</td>
<td>50 kA</td>
<td>50 kA</td>
</tr>
<tr>
<td>Short-circuit making current</td>
<td>125/130 kA</td>
<td>125/130 kA</td>
<td>125/130 kA</td>
</tr>
<tr>
<td>Peak withstand current</td>
<td>125/130 kA</td>
<td>125/130 kA</td>
<td>125/130 kA</td>
</tr>
<tr>
<td>Normal current of busbar</td>
<td>4000 A</td>
<td>4000 A</td>
<td>4000 A</td>
</tr>
<tr>
<td>Normal current of feeders: With circuit-breaker</td>
<td>4000 A</td>
<td>4000 A</td>
<td>4000 A</td>
</tr>
<tr>
<td>With contactor</td>
<td>4000 A</td>
<td>4000 A</td>
<td>4000 A</td>
</tr>
<tr>
<td>With disconnector link</td>
<td>4000 A</td>
<td>4000 A</td>
<td>4000 A</td>
</tr>
<tr>
<td>Bus sectionalizer</td>
<td>4000 A</td>
<td>4000 A</td>
<td>4000 A</td>
</tr>
</tbody>
</table>

#### Maximum values

- 17.5 kV /50 kA /4000 A
A - Switching device compartment
B – Busbar compartment
C – Connection compartment
D – Withdrawable circuit breaker
E – Low voltage compartment
Other brands of AIS

- NX AIR S – up to 12kV /40 kA / 3150 A
- SIMOPRIME – up to 17.5 kV / 40 kA / 3600 A
- SIMOPRIME A4 – 24 kV / 25 kA / 2500 A
- 8BT1 – up to 12 kV /25 kA / 2000 A, and 24 kV / 25 kA / 2000 A (LSC 2A)
- 8BT2 – 36 kV / 31.5 kA / 2500 A (LSC 2B)
- 8BT3 – up to 36 kV / 16 kA / 1250 A (LSC1)
- 8BK80 – up to 15 kV / 44 kA / 3150 A and 8BK80 – 36 kV / 31.5 kA /2000 A
- 8BK88 PLUS up to 12 kV / 25 kA / 1600 A
- GM SG – up to 15 kV / 63 kA / 4000 A
- GM 38 – 38 kV / 31.5 kA / 2500 A

- SIMOSEC – up to 24 kV and up to 1250 A. Have vacuum CB and the three-position earthing switch inside a sealed pressure switchgear vessel with SF$_6$ for entire service life.
### Air-insulated Medium-Voltage Switchgear for the Primary Distribution Level (IEC)

<table>
<thead>
<tr>
<th>Switchgear type</th>
<th>NXAIR</th>
<th>NXAIR M</th>
<th>NXAIR P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Busbar system</strong></td>
<td>single</td>
<td>single</td>
<td>single</td>
</tr>
<tr>
<td><strong>Voltage (kV)</strong></td>
<td>17,5</td>
<td>24</td>
<td>17,5</td>
</tr>
<tr>
<td><strong>Short-circuit current (kA)</strong></td>
<td>1s</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>3s</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td><strong>Rated current, busbar (A)</strong></td>
<td>4000</td>
<td>2500</td>
<td>4000</td>
</tr>
<tr>
<td><strong>Rated current, feeder (A)</strong></td>
<td>4000</td>
<td>2500</td>
<td>4000</td>
</tr>
</tbody>
</table>
## Air-insulated Medium-Voltage Switchgear for the Primary Distribution Level (IEC)

<table>
<thead>
<tr>
<th>Switchgear type</th>
<th>SIMOPRIME</th>
<th>8BT1</th>
<th>8BT2</th>
<th>8BT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busbar system</td>
<td>single</td>
<td>single</td>
<td>single</td>
<td>single</td>
</tr>
<tr>
<td>Voltage (kV)</td>
<td>17,5</td>
<td>24</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Short-circuit current (kA)</td>
<td>40 (1s), 40 (3s)</td>
<td>25 (1s), 25 (3s)</td>
<td>31,5 (1s), 31,5 (3s)</td>
<td>16 (1s), 16 (3s)</td>
</tr>
<tr>
<td>Rated current, busbar (A)</td>
<td>3600</td>
<td>2000</td>
<td>2500</td>
<td>1250</td>
</tr>
<tr>
<td>Rated current, feeder (A)</td>
<td>3600</td>
<td>2000</td>
<td>2500</td>
<td>1250</td>
</tr>
</tbody>
</table>
Air-insulated Medium-Voltage Switchgear for the Primary Distribution Level (ANSI)

<table>
<thead>
<tr>
<th>Switchgear type</th>
<th>GM SG</th>
<th>GM 38</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busbar system</td>
<td>single</td>
<td>single</td>
</tr>
<tr>
<td>Voltage (kV)</td>
<td>15</td>
<td>38</td>
</tr>
<tr>
<td>Short-circuit current (kA)</td>
<td>63  63</td>
<td>31,5  31,5</td>
</tr>
<tr>
<td>Rated current, busbar (A)</td>
<td>4000</td>
<td>2500</td>
</tr>
<tr>
<td>Rated current, feeder (A)</td>
<td>4000</td>
<td>2500</td>
</tr>
</tbody>
</table>
Gas- / Air-insulated Medium-Voltage Switchgear for the Secondary Distribution Level (IEC)

<table>
<thead>
<tr>
<th>Switchgear type</th>
<th>8DJH</th>
<th>SIMOSEC</th>
<th>SIMOSEC 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busbar system</td>
<td>single</td>
<td>single</td>
<td>single</td>
</tr>
<tr>
<td>Voltage (kV)</td>
<td>7,2 12 15 17,5 24</td>
<td>12 17,5 24</td>
<td>12</td>
</tr>
<tr>
<td>Short-circuit current (kA)</td>
<td>1s</td>
<td>25 25 25 25 20</td>
<td>25 20 20 25</td>
</tr>
<tr>
<td></td>
<td>3s</td>
<td>20 20 20 20 20</td>
<td>20 20 20 20</td>
</tr>
<tr>
<td>Rated current, busbar (A)</td>
<td></td>
<td>630 630 630 630 630</td>
<td>630 1250 1250 1250</td>
</tr>
<tr>
<td>Rated current, feeder (A)</td>
<td></td>
<td>630 630 630 630 630</td>
<td>1250 1250 1250 1250</td>
</tr>
</tbody>
</table>
(ii) Medium-Voltage Vacuum switchgears

SION vacuum circuit-breaker from 7.2 to 24 kV

(a) Standard circuit-breaker (fixed mounting)
SION vacuum circuit-breaker from 7.2 to 24 kV

(b) Slide in module
The Heart of the Circuit-Breaker - The Vacuum Interrupter

Terminal disc
Insulator (ceramics)
Arcing chamber made of copper
Fixed contact
Movable contact
Metal bellows
Operating and connecting bolt
Endurance - Arc Energy

\[ W = \int_0^T u \cdot i \cdot dt \]

Vacuum Circuit-Breaker
- low arc voltage
- short arc length
- short arcing time
\[ \Rightarrow \text{low arc energy} \]
(iii). MV Gas-Insulated Switchgears (GIS)

(a). NXPLUS C

- Up to 24 kV, 31.5 kA, 2500 A busbar, 2500 A feeder
- Up to 24 kV, 25 kA, 2500 A busbar; 2500 A feeder (for up to 15 kV), 2000 A feeder (for 17.5 kV and 24 kV)
- Metal-enclosed
- Three-position earthing switch
- Single- and double-busbar
- Gas-insulated
- Hermetically enclosed
- Factory-assembled, type-tested switchgear according IEC 62 271-200
(b). SF6-insulated MV Switchgear type NX Plus

- Type-tested, Metal-clad
- Compact and powerful, Single Busbar
- Maintenance-free for life
- Hermetically-welded Switchgear Container
- Without Gas Works mountable and extendable
Gas-insulated Medium-Voltage Switchgears for the Primary Distribution Level (IEC)

<table>
<thead>
<tr>
<th>Switchgear type</th>
<th>NXPLUS C</th>
<th>NX PLUS C Wind</th>
<th>NXPLUS</th>
<th>8DA/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busbar system</td>
<td>single</td>
<td>double</td>
<td>single</td>
<td>double</td>
</tr>
<tr>
<td>Voltage (kV)</td>
<td>15</td>
<td>24</td>
<td>24</td>
<td>36</td>
</tr>
<tr>
<td>Voltage (kV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-circuit current (kA)</td>
<td>1s</td>
<td>31,5</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Short-circuit current (kA)</td>
<td>3s</td>
<td>31,5</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Rated current, busbar (A)</td>
<td></td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td>Rated current, feeder (A)</td>
<td></td>
<td>2500</td>
<td>2000</td>
<td>1250</td>
</tr>
</tbody>
</table>
Gas-Insulated Medium-Voltage Switchgears (GIS)
GIS type 8DB10

- Up to 40.5 kV, 40 kA (3s), 5000 A busbar, 2500 A feeder
- Metal-enclosed
- Double-busbar System (8DB10)
- Gas-insulated
- Hermetically enclosed
- Factory-assembled, type-tested switchgear according IEC 62 271-200
Siemens Medium Voltage SF6 Switchgear 8DA and 8DB for a Single and Double Busbar System

Double-busbar panel

Legend for 8DA10, 8DA11, 8DA12, and 8DB10

1. Low-voltage compartment
2. Electronic control board, e.g. multifunction protection
3. Operating mechanism and interlock for three-position disconnector as well as mechanical switch position indication for three-position disconnector and circuit-breaker
4. Manometer for gas monitoring of feeder gas compartments
5. Circuit-breaker operating mechanism
6. Operating shaft for vacuum interrupters
7. Voltage detection system
8. Operating shaft for three-position disconnector
Siemens Medium Voltage SF6 Switchgear 8DA and 8DB for a Single and Double Busbar System

Single-pole design

1 Busbar housing
2 Busbar
3 Three-position disconnector
4 Gas-tight bushing between three-position disconnector and circuit-breaker
5 Circuit-breaker housing
6 Vacuum interrupter
7 Current transformer
8 Pole supporting plate
9 Panel connection

Single busbar

Double busbar

Items 1 to 9 as above
10 Gas-tight bushing between three-position disconnector and disconnector and busbar
11 Gas-tight bushing between three-position disconnector (busbar 1) and disconnector (busbar 2)
12 Busbar disconnector for busbar system 2
7. Global Medium-Voltage Production Locations – with a Uniform Quality Standard

Part of the global Siemens network
Examples of Industrial applications:
1. Ring-Main Unit for Saudi Electricity Company

Customer: Saudi Electricity Company
Country: Saudi Arabia
Date: 2006

Requirements
- Ring-main units for transformer substations under desert climate conditions.
- Main features: Environmental independence and maintenance-free design.

Products
- 8DJ20 switchgear
- 345 panels
- Technical data: 13.8 kV, 21 kA, 60 Hz, 630 A
- Height: 1760 mm
- Panel type: Scheme 10 (Cable connection panel type, Cable connection panel type, Transformer panel type)

Customer benefits
- GIS type 8DJ20 withstands every environmental challenges:
  - Dust, sand
  - High ambient air temperatures
  - High temperature changes within 24 h (night/day cycles)
2. Switchgear for the Lignite Open-Cast Mining of Vattenfall Europe Mining AG

<table>
<thead>
<tr>
<th>Customer</th>
<th>Vattenfall Europe Mining AG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Germany</td>
</tr>
<tr>
<td>Date</td>
<td>2005</td>
</tr>
</tbody>
</table>

### Requirements
- Environmentally independent and maintenance-free switchgear for lignite open-cast mining.

### Products
- NXPLUS C switchgear
- 281 panels
  - Technical data: 12 kV, 25 kA, 1250 A
  - Panel types: Vacuum circuit-breaker panel type, contactor panel type

### Customer benefits
- GIS type NXPLUS C features a hermetically welded and compact design:
  - Resistance against shock and vibrations
  - Resistance against harsh ambient conditions
  - Maximum availability
3. Safe Power Distribution in a Complex Refinery
Kirishi Hydrocracker Complex, Kirishinefteorgsentez (KINEF)

Customer: ABB Lummus Global B.V.
Country: Russia
Date: 2006 - 2008

Requirements
- Complete realization of power distribution for a major refinery
- Approved after IEC 62271-200 and GOST
- Highest reliability and user-friendliness
- Long-term, continuous customer support
- Proven technology, competent consulting

Products
- 296 panels NXAIR with SION/ NXAIR P with SIPROTEC panels 8DJ20;
- AC/DC UPS, LV-distribution and -control (SIVACON)
- Geafol Transformers 6.3/0.4 kV

Customer benefits
- Fast realization of the challenging timetable
- Reliable and efficient power distribution
- Complete solution from one source
4. New Switching Stations (Carl-Legien & Fritz Remy) for EVO (Energie Versorgung Offenbach)

Customer: EVO
Country: Germany
Date: 2006 - 2007

Requirements
- High quality for a favorable price
- All switchgears tested by new standard IEC 62271-200
- Maintenance free components

Products
25 panels:
8BT1 family with SION-circuit-breaker

Customer benefits
- Replacing old with new switchgears within four weeks
- Continuous customer support during the whole project life span
- 15% decrease of invest-costs
  (the right switchgear for the respective switching duty)
5. Power Distribution with 8BT2 for Dubai Electricity & Water Authority (DEWA)

Customer: DEWA  
Country: U.A.E.  
Date: 2007

Requirements
- Highest reliability and availability
- Maximum compatibility due to existing installation
- Utilization of existing space
- Implement of the DEWA-Specification

Products
- 40 panels
- 8BT2 (36 kV / 31.5 kA / 2,500 A)

Customer benefits
- Fast realization of the project
- Continuous customer support on-site
- Adaptation of given situation
THANK YOU FOR YOUR ATTENTION