Gas-insulated Switchgear ELK-3
GIS for maximum performance, 550 kV
ABB has been pioneering the development and manufacturing of SF₆ Gas Insulated Switchgear (GIS) since the sixties. The first 170 kV GIS was installed in 1969 at Sempersteig (Zurich/Switzerland). The next important milestone was the delivery of the first 500 kV GIS at Claireville (Ontario/Canada).

Over 10'000 bays rated from 72,5 to 800 kV have been supplied world-wide to the full satisfaction of their users.

A large number of key substations in all parts of the world depend on the outstanding performance of ABB’s safe and reliable GIS products, based on extensive know-how, high manufacturing standards and long field experience.
GIS-Type ELK-3

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Flexibility by modular design

The background

Based on the unique experience on development of GIS products and realisation of GIS substation projects, ABB developed the most flexible modular design for GIS equipment.

Application

The proven modular design provides a high versatility to meet the most challenging present and future user requirements. The following examples exhibit the variety of applications that have been put into practice by ABB.

- Switching stations with rigorous safety requirements.
- Indoor substations to occupy a minimum of space in densely populated urban areas.
- Protected installations exposed to unusually dirty, polluted or corrosive environments.
- Underground substations for pumped storage and other hydro-electric power stations.
- Generating plants where the switchgear can be very close to the power transformers to give an ideal overall layout.
- The extension of conventional outdoor installations where space is constraint.
- Replacing existing substations and upgrading the voltage level without taking up extra space.

Main design features

- Lightweight enclosures of aluminium with good conductivity, no eddy-current losses and a high resistance to corrosion.
- Single-phase encapsulated design, assuring minimal dielectric and dynamic stresses.

Front view of a double busbar GIS substation with four line bays, a bus coupler bay and a transfer busbar.

Sectional view of type ELK-3 feeder bay with double busbars and outdoor bushing

Legend

1. Circuit-breaker
2. Operating mechanism (circuit-breaker)
3. Current transformer
4. Disconnector
5. Maintenance earthing switch
6. Fast-acting earthing switch
7. Voltage transformer
8. Bushing
Proven metal-to-metal flange connections, ensuring high gas tightness and return-current conductivity, avoiding crossbonding.

Increased personnel safety and electromagnetic compatibility.

Horizontal circuit-breaker design, saving building elevation and cost, ensuring convenient personnel access.

Minimal outage concept with segregated, individually monitored gas compartments.

Digital control, on-line condition monitoring and synchronised switching options.

Short erection times and high reliability, by providing large transport units assembled and tested in the factory.

All switchgear components, such as the circuit-breakers, disconnectors, earthing switches, instrument transformers and connecting elements are functionally separate modules of a standardised modular system. The view on page 4 shows the sectional elevation of a typical switchgear bay of the ELK-3 size. All live parts are protected aluminium enclosure. Pressurised SF₆-gas provides the insulation against the earthed enclosure. High-grade insulators of moulded resin support the active parts inside the enclosure and are used as the barriers between adjoining gas-filled compartments. The individual compartments assure maximum possible availability of the equipment during maintenance work and extensions.

The individual components are connected by silver-plated plug contacts for the current conductors and bolted flange connections for the enclosures.

The switchgear is mounted on a simple hot dip galvanized steel structure attached to the floor.
Circuit-breaker

- Reliable making and breaking capacity for heavy load and short-circuit currents
- Easy access to active parts for inspection and overhaul
- Low noise level
- Maintenance-free design
- Separate contact system for continuous current and current interruption
- High dielectric withstand in open and closed position
- Single-phase auto-reclosing
- Compact hydraulic spring operating mechanism
- Continuous self-supervision of hydraulic system
- No external hydraulic piping
- Type tested according latest IEC & ANSI standards

The simple, robust design and a horizontal layout with low center of gravity are the most famous features of the circuit-breakers. Extensive operating experiences up to voltage range 800 kV and 80 kA as well as continuous research and development activities have lead to a breaker design which fulfills newest standards in IEC and ANSI.

Breaker design

Each circuit-breaker comprises three single-phase metal enclosed breaker poles. Each pole consists of the operating mechanism, the interrupter column with 2 interrupting chambers in series and the enclosure with the basic support structure. To guarantee simultaneous interruption, the chambers are mechanically connected in series. One grading capacitor for each chamber guarantees an equalised voltage distribution across the interrupting chambers.

In case of an overhaul, the interrupter column can easily be removed from the enclosure.

The circuit-breaker is of the single-pressure type and works on the well proven puffer principle. During an interruption, a compression piston in each chamber generates the SF₆-gas pressure required to extinguish the arc between the contacts.

Breaking sequence of the circuit-breaker

ELK-3 Substation
Operating mechanism

Each pole of the circuit-breaker is equipped with the hydraulic spring operating mechanism. It combines the advantages of the hydraulic operating mechanism with those of the spring energy storage type. It’s compact, modular design, consisting of

- the housing with position indicator
- power-pack for energy storage without any kind of external hydraulic pipe
- monitoring module for control

It guarantees easy access to all components inside the drive for overhaul and repair. Sealing of the pressure operated hydraulic circuit against the atmosphere is achieved entirely by highly reliable static seals.

Working principle

A hydraulic pump moves oil from the low pressure reservoir to the high pressure side of the energy storage piston, connected to the disc springs. The output piston, which is connected to the operating rod of the circuit-breaker column, is controlled by a change-over valve. For opening, it switches hydraulically to the open position after the trip coil is activated for opening the breaker and connects the bottom side of the output piston with the low pressure reservoir. The circuit-breaker moves than to open position where it will be retained due to the hydraulic pressure. For closing the circuit-breaker, the change-over valve connects the bottom side of the output piston to the high-pressure reservoir after actuation of the closing coil.

Now, both sides of the output piston are connected to the high pressure and the circuit-breaker is moving to its closed position due to the differential pressure principle.

Schematic diagramme of the operating principle

Hydraulic spring operating mechanism
Disconnected and earthing switch

**Disconnected**
- Safe SF₆-gas insulation across the open gap
- Slow moving tubular contact
- Motor-operated mechanism, common for all 3-phases, padlockable
- Designed for full load and short-circuit current in closed position
- Reliable switching of small capacitive and bus transfer currents
- Manual operation is possible

The no-load type disconnector according to IEC 60129 is available either as an in-line or an angular disconnector. The angular disconnector integrated in the busbars, greatly simplifies the layout of the installation.

Supporting insulators carry the active parts of the disconnector inside the modular enclosure.

It is also possible to accommodate a maintenance earthing switch in the same enclosure. The active part consists of the fixed part with contact fingers and follow-up contact and the contact support carrying the tubular moving contact. Inspection of the main contact status is possible by means of an endoscope through the viewport in the enclosure. The moving contact is operated from a motor gear drive through a rotary seal by an insulated shaft. The position indicator and the auxiliary contacts are mechanically coupled with the mechanism.

The operating mechanism is mounted outside the gas compartment on one phase. The two other phases are operated by intermediate gear. The same mechanism is also employed for the maintenance earthing switch.
Earthing switches are mounted directly on the enclosure (see figure below). Slow-motion maintenance earthing switches are used for earthing isolated sections of switchgear to protect personnel during maintenance and overhauls or erection. The operating mechanism is the same as used for the disconnector switches. It is mounted on one phase. The two other phases are operated by intermediate gear.

The fast-acting earthing switch is mainly used to discharge static charges on overhead lines, HV cables or long buses. It is designed to close on and carry full short-circuit currents and to safely break capacitive and inductive induced currents from long energised parallel lines. Each phase is provided with its own operating mechanism. For the closing operation a spring in the drive is loaded by the motor. At the end of the charging operation the spring is automatically released and the switch closed. The opening process is slow, similar to that of the maintenance earthing switch.

In certain cases, an interposed insulation is fitted between the earthing switch and the enclosure. This provides access to the active parts for measuring purposes through the closed contacts, without opening the enclosure. During normal operation the insulation is by-passed. All the earthing switches have a mechanically coupled position indicator. The gap between contacts can also be verified through a viewport by means of an endoscope. To check whether a point to be earthed really is dead, the earthing switch can be equipped with a capacitive tap for connecting a voltage test unit. This additional safety device reduces the risk of closing onto a live conductor.

Manual operation is possible. In this case electrical control connections are automatically disconnected. The mechanism is padlockable in both, open or close position.

**Earthing switch**

- Safe earthing of sections of the main circuit
- Designed for full short-circuit current in closed position
- Insulated version available (optional)
- Motor-operated mechanism, slow closing or high-speed spring-loaded
- Full short-circuit making and induced currents switching capability
Instrument transformer and surge arrester

Voltage transformer
- Inductive type, with SF₆-gas insulated high-voltage winding
- Rectangular type core of low loss magnetic sheets
- High cable or line discharging capability
- Efficient damping of ferro-resonance and fast transients

The single-pole inductive voltage transformers are connected to the switchgear with the standardised connecting flange with a barrier insulator. The primary winding is insulated with SF₆-gas and connected to the high-voltage terminal. The primary winding is wound on top of the core and the secondary windings. The secondary windings are connected to the terminals in the external terminal box through a gas-tight multiple bushing.

The transformers may be equipped with two metering windings and one tertiary winding for earth-fault protection.

Current transformer
- Ring cores surrounding the enclosure, impregnated with moulded resin
- Cores outside of the gas, protected by metallic cover

The necessary number of cores is accommodated around tubular enclosures of suitable length. The main conductor within the enclosure forms the primary winding. Ring cores, are protected against external influences by a metal cover which is designed to carry the return current. An insulation gap prevents the return current from flowing inside the cores through the enclosure. A terminal box mounted on the cover contains the secondary terminals.
Surge arrester

- Metal-oxide resistors housed by SF₆-gas insulated enclosure
- Without spark gaps
- Low protection level
- High energy input capacity
- Stable characteristics, ageing-proof

Gas-insulated substations and connected HV cables, power transformers, etc. often require over-voltage protection by surge arresters. Gas-insulated arresters are a reliable and space-saving alternative to the conventional type, avoiding the need of aerial links.

The active parts, mainly non-linear metal-oxide resistors, series connected and assembled to stacks, are housed in a pressurised SF₆-gas enclosure, which is connected to the GIS by a standard ELK-3 flange connection with barrier insulator.

The resistors are manufactured as disks with a conductive, metallic coating on the flat contact surfaces and a gas-tight coating on the cylindrical surfaces. Arresters with metal-oxide resistors have a high energy absorption capability. A grading electrode surrounds the resistors on top and ensures an even voltage distribution along the resistors. An advantage of this design is that the SF₆-gas flows around the resistors, ensuring efficient cooling when required, i.e. after repeated heavy discharges.
Connecting elements, terminations

Versatile connecting elements

A modular range of straight busbars, tees, elbows is available, enabling the different major components to be arranged in a space-saving way, coping with any customer requirements.

The busbar enclosure is dimensioned for the full return current. The metallic connection of the flanges is also assured at points where supporting or barrier insulators are interposed. Tubular conductors are supported at each end by an insulator. The conductors are plugged to silver-plated spiral spring contacts on the supporting insulator. These sliding contacts permit the tubular conductors to expand axially on a temperature rise, without imposing any mechanical stresses on the supporting insulators where required. Longitudinal expansion is taken up by metal bellows or parallel compensators.

Lateral dismantling unit

Where required, lateral dismantling units are inserted. They enable sections of the switchgear to be removed and re-inserted, without interfering with the adjacent parts. This is achieved by sliding sections in the enclosure and in the tubular conductor.
**SF₆/air termination**

SF₆-air bushings used for connection to open terminal equipment and overhead lines are available with composite or porcelain insulators. The internal insulation consists of pressurised SF₆-gas or resin impregnated paper winding (RIP).

Nowadays composite insulators are used more and more for high-voltage applications because of their outstanding mechanical and dielectric properties; the latter due to the hydrophobic capability of the silicon rubber sheds. Bushings with composite insulators are absolutely explosion proof.

**Cable termination**

High-voltage cables of various types are connected to the SF₆ switchgear via cable connection assembly. It consists of the cable sealing with connecting flange, the main circuit end terminal and the surrounding enclosure.

An isolating link between the switchgear and the cable termination enables the GIS and the cable to be tested separately.

**Transformer connection**

The transformer connection consists of the oil/SF₆-bushing, the enclosure, the main circuit end terminal and the removable connection. The pressure-tight bushing separates the gas-filled compartment from the insulating oil of the transformer. The lateral dismantling unit takes up axial assembly tolerances and enables the transformer to be easily connected, or disconnected from the switchgear. For the high-voltage tests on the GIS, the transformer is isolated from the switchgear by dismantling the removable conductor connection.
Local Control

The local control cubicle is based on the Bay Control Solution concept BCS as a comprehensive scalable solution for control cubicles. The BCS is suitable for all types of switchgear used in transmission and subtransmission systems and every possible busbar configuration. The BCS includes all required functions for control and supervision of a complete GIS as well as the marshalling of all connections to and from the GIS bays.

Safe station operation is ensured through following base functions.

Functions
- Feeder and station interlocking, depending on the position of all high-voltage apparatuses with their blocking functionality
- Blocking of commands when crank handle of disconnectors or earthing switches is introduced.
- Extensive circuit-breaker supervision through “Anti-pumping”, pump and hydraulic system supervision, operation counter for circuit-breaker and pumps.
- Gas density and position supervision of circuit-breaker.

The Bay Control Mimic BCM is the main component of the control cubicle.

Features
- Representation of the single-line diagramme/gas schematic diagramme including position indication of all primary apparatuses such as circuit-breaker, disconnectors and earthing switches with reliable LED’s
- Up to 8 high-voltage switching devices can be monitored and controlled with an easy-to-use two hand push-button system based on the “select before operate” principle
- Optional light guided operation to support the operator
- Digital display of measuring values as current, voltage, active and reactive power
- Integrated local/remote key switch
- Alarm unit for 16 feeder alarms e.g. gas alarm, DC and AC supervision
The local control cubicle is fitted with prewired interface terminal blocks for the connection to feeder and station protection. This interface includes all needed measuring values of the feeder as well as protection trip 1, trip 2 and signals from the auto-reclose system. Additional prewired terminal groups are provided for the connection to remote control systems and remote alarm systems.

On customer’s request additional functions (optional) can be provided.

Standardised plug connections instead of terminal connections are available.
The world-wide experience shows that the proven ELK-3 architecture with its modular concept and versatility opens the way for efficient arrangements for virtually any application and individual user requirements. Stringent space requirements can be met without concessions to service access. Horizontal circuit-breaker design provides a substantial reduction of the height of the building and civil work cost. It offers also convenient possibilities for simple and efficient future extension of the substation with minimal outage.

As example the two most common applications are shown, double busbar and one-and-a-half breaker arrangement. Single busbar, ring and various other arrangement are as well possible.
Four diameters of a typical ELK-3 one-and-a-half breaker arrangement

Bay section one-and-a-half breaker arrangement
Reliable gas compartments

Individual, fully equipped gas compartments

A prerequisite for safe and reliable operation is the segregation of the sections and phases of the equipment into individual and independent gas compartment. This is also required to keep parts of the system in operation while other parts are out of service. The segregation is achieved by barrier insulators. To avoid any impact from each other, all gas compartments are fitted with their individual non-return filling valve and density monitor. Any pipe connections to common sampling points are therefore strictly avoided. Each compartment is also fitted with its own moisture absorber and pressure relief.

Safe gas sealing system

Reliability of SF₆ gas-insulated switchgear depends to a large extent on the low rate of gas leakage. Thus special attention is given to the sealing system. The proven static sealing system at the flange joints is effected by single sealing rings (“O-rings”). High-quality finish limits the gas losses to much less than 0.5 % per annum.

Gas density monitor

The dielectric strength of the GIS depends on the gas density, which is therefore directly monitored. The proven density monitor is directly mounted on the enclosure. The gas pressure acts on metal bellows, with a reference volume for compensation of the temperature. In case of gas leakage a micro-switch is actuated. Thresholds for refilling (first stage) or lock-out alarm (second stage) can be mechanically set. The response characteristic is shown in the Mollier diagramme. Density monitors can be easily removed for testing with a separate calibration device.
Main technical data ELK-3

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<td>Rated power-frequency withstand voltage</td>
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**Mollier diagramme 420 kV**

**Mollier diagramme 550 kV**