Operating Instructions

KIT High Voltage Construction

MANUAL

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HAEFELY

HIGH VOLTAGE TEST

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Safety

Warnings

- High voltage can be lethal! Only trained persons are allowed to work with this equipment! The customer is responsible that the employees, which works with this equipment, are trained. The training has to be repeated in regular intervals; the training has to be documented.
- The test area has to be equipped with an adequate security circuit (see chapter “Safety equipment”, page 7.
- When working on high-voltage test equipment, at least two persons must always be present, one of whom bears responsibility for the test.
- Never open a cover or a case in which the line voltage is present before having disconnected the power supply!
- Before entering the test area, after high-voltage tests has been performed, it has to be make sure that the power supply is definitely switched of at the control unit (see operating instruction control unit) and the emergency button is pressed.
- After high-voltage tests has been performed the first thing which has to be done after entering the test area is that all high-voltage parts in the test area has to be grounded!

  This concerns especially if test with DC-voltage are performend (DC or Impulse configuration), see chapter “Special information concerning DC-voltage”, page 7. After the grounding procedure the grounding rod has to be placed at the high-voltage side of the transformer.
- When personnel exit the test area before the high voltage is connected, the manual grounding rods must be placed near the entry.
- Before the high voltage is connected, the person responsible for the test must verify that:

  The test circuit is assembled correctly

  The test object is connected correctly

  All safety systems are operable

The manual grounding rod has been removed.

If the system operates in DC or Impulse configuration the short circuit cables from the capacitors have to be removed.

All persons has quitted the test area.

It has to be take into consideration that **the earth switch type ES (see page 26) in multi-stage configurations** (two or three stages) **doesn't provide a sufficient grounding for all high-voltage parts** of the system. Even when the earth switch is activated all high-voltage parts of the system has to be grounded with the grounding rods. If DC-voltage are performend (DC or Impulse configuration) special earthing instruction has to be kept in mind (see chapter "Special information concerning DC-voltage", page 7).

The essential safety provisions governing setup and operation in combination with the regulating transformer, high-voltage transformer and other components of the high-voltage test installation are set forth in the following standards:

- VDE 0100 (DIN 57100): Setup of power-current systems up to 1000V (in German language)
- VDE 0101 (DIN 57101): Setup of power-current systems over 1000V (in German language)
- VDE 0104 (DIN 57104): Building and operation of electrical examining facilities (in German language)

Safety equipment

The test area should be enclosed by a metal grid fence of at least 1.8 meters height with a maximum grid spacing of 40 mm.

All doors leading to the test room must be equipped with door contacts, which close when the door is closed. All contacts should be connected in series to the interlock system provided by the control unit OT 276. This safety system will automatically turn off the high voltage if a door is opened while the test system is switched on. Red and green warning lights should be installed at all doors leading to the test room.

Special information concerning DC-voltage

Extra care is essential in direct current expermiments, since the high-voltage capacitors in many circuits retain their full voltage, for a long time even after disconnection. Even unused capacitors can aquire dangerous charges!

The following earthing regulations have to be strictly observed. Even unused capacitors can acquire dangerous charges. DC-voltage appears in DC- and Impulse configurations.

Grounding of capacitors for DC-Application

- No high-voltage capacitors are allowed to be touched which weren't immediately unloaded before and aren't short-circuited!

  Capacitors, which are not short-circuit after unloading, could be recharged under no-load condition even when the capacitors are directly unloaded before (Recharging effect).

- The unloading has to be carried out with two suitable grounding rods between the two Poles of the capacitor! For a correct unloading both poles of the capacitor must be connected to earth at the same time sufficiently by means of the two grounding rods for a long time.

  The capacitor has to be short-circuited after the unloading procedure in that way, that first both Poles of the capacitor have to be connected to earth with the two grounding rods. It has to be guaranteed that the two grounding rods couldn't detach from the Poles of the capacitor. As soon as this is ensured, the two connections of this capacitor must be short-circuited by means of an electrically conductive connection.

- If several capacitors are connected in series the unloading has to be started with the capacitor, which has got the highest tension (according to the method described above). After the unloading procedure these capacitor has to be short-circuited (also according to the method described above). As soon as the capacitor is unloaded and short-circuited, the process must be continued at the capacitor following most nearly. This procedure has to be repeated until all capacitors are unloaded and short-circuited!

- Capacitors have to be stored in short-circuit condition together with the instruction "Grounding of capacitors for DC-Application"! The short circuiting has to be done after the unloading of the capacitor.

Earthing instructions

A good test field has a separate grounding. This ensures that no disturbances from surrounding machines enter the test field and - in case of a failure - the earth potential of the surrounding does not rise, causing damage to electrical equipment. It is necessary for the test field to have a lower grounding resistance than the surrounding building.

Grounding connections have to be made without forming loops.

The ground connection of the measuring and control system, regulating transformer, high-voltage transformer, Floor pedestal and test object should be arranged like a star, where the central point is grounded. The grounding rods has to be connected to the central earth point, too.

For earthing of components Cu-foil (150x0.3mm) is recommended.

Emergency switch-off

See Operating instruction „control unit“!

Insulating Oil Shell DIALA D

Shell DIALA oil D is the insulating oil of the test transformer PZT100-0.1

Hazards identification

Human health hazards:

No specific hazards under normal use conditions. Contains mineral oil for which an exposure limit for oil mist applies. Prolonged or repeated exposure may give rise to dermatitis. Used oil may contain harmful impurities.

Safety hazards:

Not classified as flammable, but will burn.

Environmental hazards:

Not readily biodegradable. Expected to have a high potential to bioaccumulate.

Other information:

Not classified as dangerous for supply or conveyance.

First aid measures

Symptoms and effects:

Not expected to give rise to an acute hazard under normal conditions of use.

First aid - Inhalation:

In the unlikely event of dizziness or nausea, remove casualty to fresh air. If symptoms persist, obtain medical attention.

First aid - Skin:

Remove contaminated clothing and wash affected skin with soap and water. If persistent irritation occurs, obtain medical attention.

If high-pressure injection injuries, obtain medical attention immediately.

First aid - Eye:

Flush eye with copious quantity of water. If persistent irritation occurs, obtain medical attention.

First aid - Ingestion:

Wash out mouth with water and obtain medical attention. DO NOT INDUCE VOMITING.

Advice to physicians:

Treat symptomatically. Aspiration into the lungs may result in chemical pneumonitis. Dermatitis may result from prolonged or repeated exposure.

Fire fighting measures

Specific hazards:

Combustion is likely to get rise to a complex mixture of airborne solid and liquid particulates and gases, including carbon monoxide, oxides of sulphur, and unidentified organic and inorganic compounds.

Extinguishing media:

Foam and dry chemical powder. Carbon dioxide, sand or earth may be used for small fires only.

Unsuitable extinguishing media:

Water in a jet. Use of Halon extinguishers should be avoided for environmental reasons.

Protective equipment:

Proper protective equipment including breathing apparatus must be worn when approaching a fire in a confined space.

Accidental release measures

Personal precautions:

Avoid contact with: skin and eyes.

Personal protection:

Wear impermeable gloves and boots.

Environmental precautions:

Prevent from spreading or entering into drains, ditches or rivers by using sand, earth or other appropriate barriers. Inform local authorities if this cannot be prevented.

Clean-up methods - small spillage:

Absorb liquid with sand or earth. Sweep up and remove to a suitable, clearly marked container for disposal in accordance with local regulations.

Clean-up methods - large spillage:

Prevent from spreading by marking a barrier with sand earth or other containment material. Reclaim liquid directly or in an absorbent. Dispose of as for spills.

Handling and storage

Handling:

When handling product in drums, safety footwear should be worn and proper handling equipment should be used. Prevent spillages.

Storage:

Keep in a cool dry, well-ventilated place. Use properly labelled and closable containers. Avoid direct sunlight, heat sources, and strong oxidizing agents.

Storage temperature:

0 °C minimum to 50 °C maximum.

Recommended materials:

For containers or container linings, use: mild steel or high-density polyethylene.

Unsuitable materials:

For containers or container linings, avoid: PVC.

Other information:

Polyethylene containers should not be exposed to high temperatures because of possible of risk of distortion.

Exposure controls / Personal protection

⚠

Engineering control measures:

Use local exhaust ventilation if there is a risk of inhalation of vapours, mists or aerosols.

Occupational exposure standards:

Threshold limit values are given below. Lower exposure limits may apply locally:

Component name	Limit type	Value	Unit	Other information
Oil, mist, mineral	8-hour TWA	5	mg/m^3	ACGIH
	15-min. STEL	10	mg/m^3	ACGIH

Hygiene measures:

Wash hands before eating, drinking, smoking and using the toilet.

Respiratory protection:

Not normally required. If oil mist cannot be controlled, a respirator fitted with an organic vapour cartridge combined with a particulate pre-filter should be used.

Hand protection:

PVC or nitrile rubber gloves.

Eye protection:

Wear safety glasses or full face shield if splashes are likely to occur.

Body protection:

Minimise all forms of skin contact. Wear overall to minimise contamination of personal clothing. Launder overalls and undergarments regularly.

Physical and chemical properties

Physical state:	Liquid at ambient temperature
Colour:	Pale yellow
Odour:	Characteristic mineral oil
Initial boiling point:	>280°C
Vapour pressure:	<0,5Pa at 20°C
Density:	864 kg/m³ at 15°C
Kinematic viscosity:	9,5 mm^2/s at 40°C
Vapour density:	>1 at 20°C
Pour point:	-45°C
Flash point:	149°C
Flammability limit - lower:	1% V/V (typical)
Flammability limit - upper:	10% V/V (typical)
Auto-ignition temperature:	> 320°C (typical)
Solubility in water:	Negligible
n-octanol/water partition coefficient:	Log P_{OW}> 6 (typical)

Stability / Reactivity

Stability:

Stable

Conditions to avoid:

Extremes of temperature and direct sunlight

Materials to avoid:

Strong oxidizing agents

Hazardous decomposition products:

Hazardous decomposition products are not expected to form during normal storage

Toxicological information

Basis for assessment:

Toxicological data have not been determined specifically for this product. Information given is based on knowledge of the components and the toxicology of similar products.

Acute toxicity - oral:

LD_{50} expected to be above 2000 mg/kg

Acute toxicity - dermal:

LD_{50} expected to be above 2000 mg/kg

Acute toxicity - inhalation:

Data not available

Eye irritation:

Expected to be slightly irritant.

Skin irritation:

Expected to be slightly irritant.

Respiratory irritation:

If mists are inhaled, slight irritation of the respiratory tract may occur.

Skin sensitization:

Not expected to be a skin sensitizer.

Carcinogenicity:

May contain less then 0,1% (m/m) of distillate aromatic extract. Classified as a Category 2 carcinogen. Other components are not known to be associated with carcinogenic effects.

Mutagenicity:

Not considered to be a mutagenic hazard.

Other information:

Prolonged and/or repeated contact with this product can result in defatting of the skin, particularly at elevated temperatures. This can lead to irritation and possibly dermatitis, especially under conditions of poor personal hygiene. Skin contact should be minimised.

Used oils may contain harmful impurities that have accumulated during use. The concentration of such impurities will depend on use and they may present risks to health and the environment on disposal. All used oil should be handled with caution and skin contact avoided as far as possible.

Ecological information

Basis for assessment:

Ecotoxicological data have not been determined specifically for this product. Information given is based on knowledge of the components and the ecotoxicology of similar products.

Mobility:

Liquid under most environmental conditions. Floats on water. If it enters soil, it will adsorb to soil particles and will not be mobile.

Persistence/degradability:

Not readily biodegradable. Major constituents are expected to be inherently biodegradable, but the product contains components that may persist in the environment.

Bioaccumulation:

Has the potential to bioaccumulate.

Ecotoxicity:

Poorly soluble mixture. Product expected to be practically non-toxic to aquatic organisms, LC/EC_{50} > 100mg/L. may cause physical fouling of aquatic organisms.

(LC/EC_{50} expressed as the nominal amount of product required to prepare aqueous test extract)

Disposal considerations

Waste disposal:

Recycle or dispose of in accordance with prevailing regulations preferably to a recognised collector or contractor. The competence of the contractor to deal satisfactorily with this type of product should be established beforehand.

Container disposal:

200 litre drums should be emptied and returned to the supplier or sent to a drum reconditioner without removing or defacing markings or labels.

Non-reusable small metal and plastic containers should be recycled where possible, or disposed of as domestic refuse.

Transport information

Not dangerous for conveyance under UN, IMO, ADR/RID and IATA/ICAO codes.

Regulatory information

EC classification:	Not classified as Dangerous under EC criteria
EINECS (EC):	All components listed or polymer exempt.
TSCA (USA):	All components in compliance.
Other information:	For listing on other inventories, e.g. MITI (Japan), AICS (Australia) and DSL (Canada), please consult supplier.

General Information

Product description

Introduction

The High Voltage Construction KIT is a system of components for applications in high voltage technology. All components have the same length and mechanical interconnections. They can be combined to form a test configuration and are extremely versatile. Test configurations are available which allow the generation of **AC voltages** up to 300kV, **DC voltages** up to 400kV (under no load condition i.e. without measuring divider) and **impulse voltages** up to approx. 370kV with different output power ratings.

Such test configurations are extremely compact and their flexibility allows the test system to be matched to the prevailing conditions in the test room (dimensions, height etc.).

The application range for the high voltage KIT covers not only the use in high voltage laboratories of technical universities, but also as an industrial test system for routine and type tests on electrical equipment up to 30kV.

A complete test system requires a volume of approx. 30m^3 and a floor surface of approx 3m x 4m.

The configuration is built up, as it name suggests, by simply inserting the various elements to form a self-supporting structure. No tools are required.

In spite of its striking simplicity, the KIT is equipped with all the components of comparable large industrial test systems.

Numerous accessories are available for the basic KIT elements. The high voltage KIT has got compact dimensions and a wide range of application. It is portable and truly represents a complete high voltage test system.

Structure

Figure 1 shows the general block diagram of the KIT.

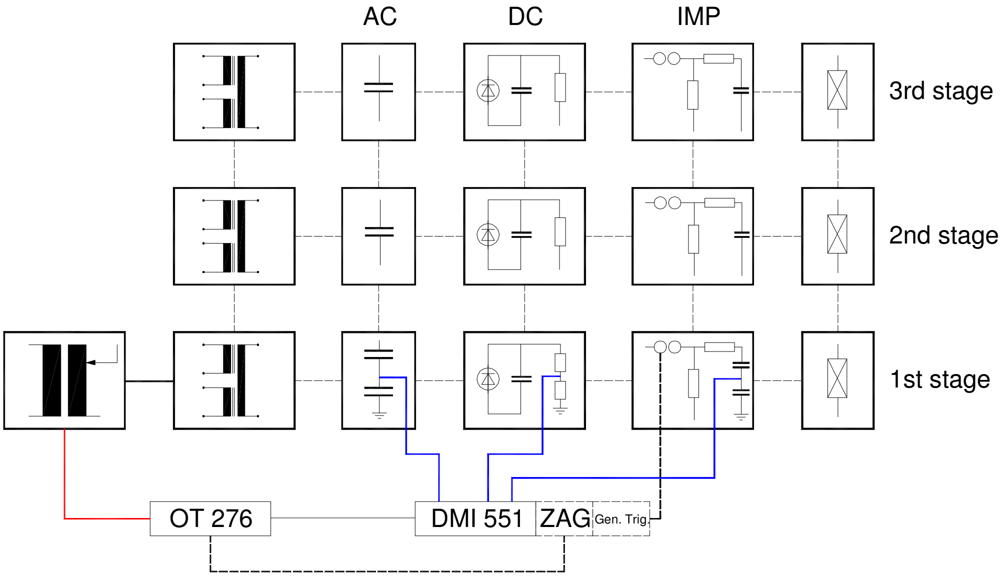

Fig. 1: Block diagram of high voltage construction KIT

There are existing for each configuration (AC, DC and Impulse) a single stage or multistage (up to maximum three stages) configuration. For DC and Impulse setup only one test transformer is necessary (even in multistage configuration). But for a two stages AC configuration two test transformers are required and for a three stages AC configuration three test transformers.

A configuration is built up by inserting different KIT components (e.g. resistors, capacitors, etc.) into connection cups resp. floor pedestal to form a self-supporting arrangement. No additional tools are required.

Due to this design the user can make changes in the circuit quickly and efficiently. Every connection cup has six possible combinations. Two vertical and four horizontal (see figure 2).

Fig. 2: Connection cup for connecting the KIT components

The floor pedestal has got one support for inserting a KIT component. The four other supports are for the conductive spacer bars (see figure 3).

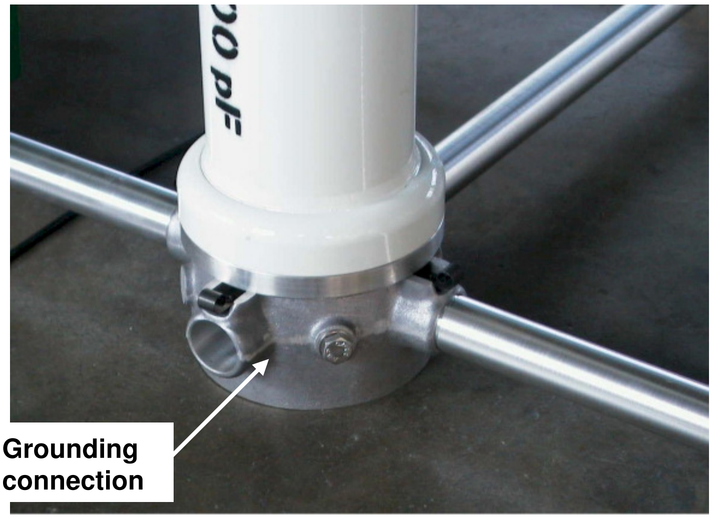

Fig. 3: Floor pedestal with one KIT component and spacer bars

Every floor pedestal has two threads on opposite sides for ground connection. This way the grounding can be made at the end of the assembly simply by screwing the copper foil to the floor pedestals without need to rearrange them.

The assembly of high voltage circuits using the high voltage construction KIT is quick and easy.

Figure 4 shows the structure of an AC circuit 100kV (without matching transformer or control unit).

Fig. 4: Build up of an AC single stage configuration

The configuration is built up by inserting elements to form a self-supporting arrangement. No additional tools are required.

Configurations with more than just one stage can be build as in the following examples (figure 5 a and b).

Fig. 5a: Build up of two transformers

Fig. 5b: Build up of different KIT elements

Components

The KIT system comprises the following elements. Depending on the configuration not all parts are necessary (see chapter “Required components for the different configurations”, page 66).

PZT 100-0.1: single phase AC voltage test transformer

Fig. 6: PZT 100-0.1

Test transformer which can be used for AC-voltage generation and as high-voltage supply for DC- and impulse voltage configuration. The output power can be extended by cascading the transformers.

Rated voltage:	2 x 220V / 100kV / 220V
Rated power:	5kVA, continuous
	10kVA, 1hour

KDL: Compensating reactor

Fig. 7: Compensating reactor

Compensating reactor type KDL are used between transformers (PZT 100-0.1) in cascade circuits to reduce input power and provide uniform voltage distribution across cascade winding. Compensating reactors are recommended for AC configurations of more than 1 stage.

Top EL: Top electrode

Fig. 8: Top electrode

For AC two and three stages a top electrode on the test transformer is recommended to avoid corona effects.

STL 5 (STL 7.5, STL 10): Regulating transformer

Fig. 9: Regulating transformer

Power supply:	230V / 22A (33A, 43A)
Secondary voltage:	0 ... 230V
Rated power:	5kVA (7.5, 10kVA) cont.
Frequency:	50/60Hz
Weight:	approx. 80kg (255kg, 260kg)

HSEV 200/300: High voltage connection 200kV/300kV

Fig. 10: HSEV 200/300

HSEV 200: Flexible connection with suitable contacts to connect a two stage AC voltage configuration to the test transformer.

HSEV 300: Connection with suitable contacts to connect a three stage AC voltage configuration to the test transformer.

GS: HV diode

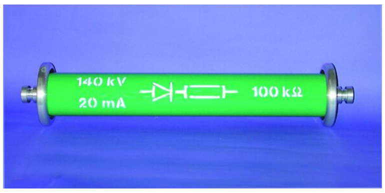

Fig. 11: Diode

Diode, which can be used for impulse and DC voltage configurations. The diode consists of a protecting resistor and a high voltage diode.

Protective resistor: 100kΩ

Inverse peak voltage: 140kV

Rated current: 20mA

RE: Parallel (Wave tail) resistor

Fig. 12: RE

Resistor, which can be used as discharge resistor for DC and impulse voltage configurations and as parallel resistor in impulse voltage configurations, determining the duration.

Resistance: different values (2.4, 120, 282kΩ)

Max. DC and IMP voltage: 140kV

CS: Smoothing and energy storage capacitor

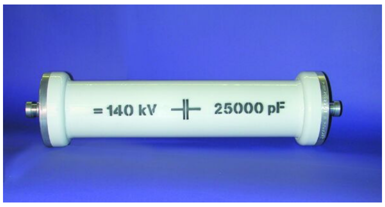

Fig. 13: CS

Capacitor, which can be used as energy storage capacitor for generation of impulse voltages or as smoothing capacitor for DC generation.

Capacitance: 25nF

Max. DC and IMP voltage: 140kV

CB: Load capacitor

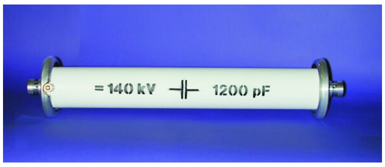

Fig. 14: CB

Capacitor, which can be used as HV unit for the impulse divider and as load capacitance.

Capacitance: 1200pF

Max. DC and IMP voltage: 140kV

RL: Charging resistor

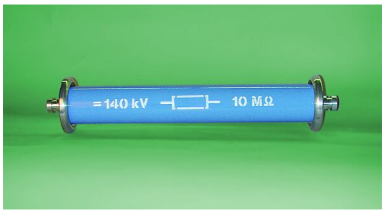

Fig. 15: RL

Resistor, which can be used as charging resistor for multistage impulse configurations, as current limiting resistor in DC configurations and as damping resistor in connection with the grounding switch.

Resistance: 2.5MΩ or 10MΩ

Max. DC and IMP voltage: 140kV

RD: Series (wave front) resistor

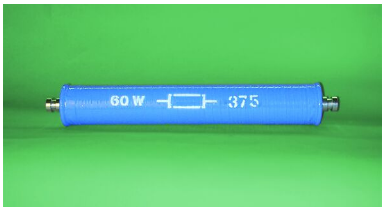

Fig. 16: RD

Resistor, which can be used as series resistor for impulse voltage configurations, determining the risetime.

Resistance: different values (95Ω, 140Ω, 220Ω, 355Ω, 15kΩ, 22kΩ, 35kΩ, 55kΩ)

Max. DC and IMP voltage: 140kV

CM: Measuring capacitor

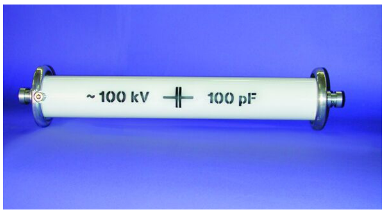

Fig. 17: CM

Capacitor, which can be used as HV unit for the AC voltage divider.

Capacitance:	100pF
Max. AC voltage:	100kV

RM: Measuring resistor

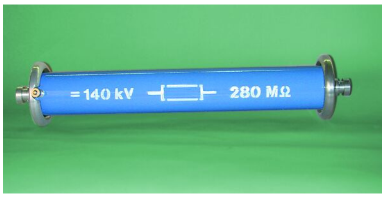

Fig. 18: RM

Resistor, which can be used as HV unit for the DC voltage divider.

Resistance:	280MΩ
Rated current (continuous):	0.5mA
Max. DC voltage:	140kV

ES: grounding switch

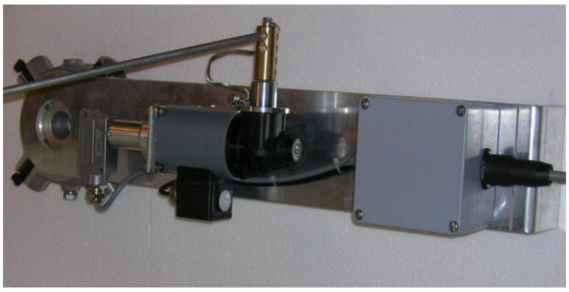

Fig. 19: ES

Remote controlled switch, which can be used to ground the high voltage construction KIT.

Max. DC and IMP voltage:	140kV
Service voltage:	24V, 50/60Hz

EST: Discharge and Grounding rod

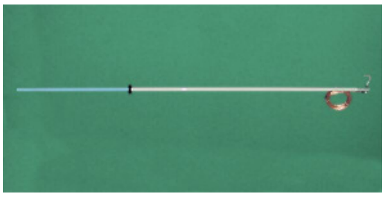

Fig. 20: EST

Rod, for manual discharge of HV KIT components.

Length: approx. 2.5m

Discharge resistance: 100Ω

EB: Grounding foil

Fig. 21: EB

Copper ground foil, which can be used to make ground connections between the individual high-voltage apparatus.

EL: Electrode

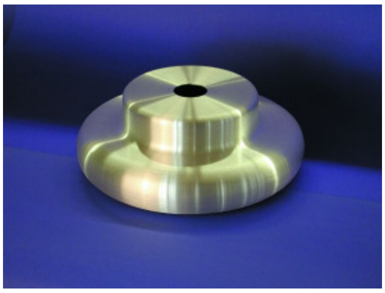

Fig. 22: EL

Electrode, used together with grounding switch ES and to reduce corona discharges on high-voltage parts of the different configurations.

Diameter: 300mm

IS: Insulating support

Fig. 23: IS

Support insulator, which can be used as insulating component.

Max. AC voltage: 100kV

Max. DC and IMP voltage: 140kV

KF: Sphere gap

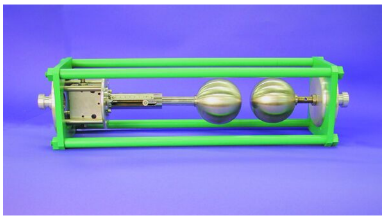

Fig. 24: KF

Sphere gap, for impulse voltage configuration.

Max. IMP voltage: 140kV

Sphere diameter: 100mm

Max. gap setting: 80mm

AKF: Drive for sphere gap

Fig. 25: AKF

Fig. 26: Cable for AKF

Remote controlled drive for sphere gap KF. Drive shaft ASA (short) for 1st Stage and ASB (long) for 2nd and 3rd Stage needed. The AKF is clamped onto a spacer bar D.

With capacitor motor:	230V
Frequency:	50/60Hz

V: Connecting rod

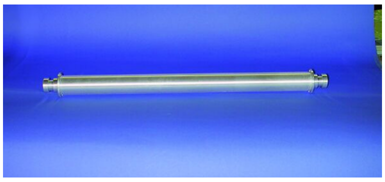

Fig. 27: Connector V

Conductive connection element (aluminium tube).

K: Connecting cup

Fig. 28: Connecting cup K

Conductive connection element, four components can be connected horizontally and two components vertically.

F(s): Floor pedestal

Fig. 29: Floor pedestal F(s)

Conductive element, for mounting up to four spacer bars horizontally and supporting one component vertically.

D: Spacer bar

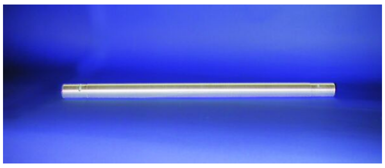

Fig. 30: Spacer bar D

Spacer bar, which can be used for mechanical and electrical connection at ground level inserted into a floor pedestal F(s).

NTZ: Secondary part for CB (Impulse)

Fig. 31: NTZ

Secondary unit for the impulse divider, which incorporates the LV capacitors and a 75Ω matching resistor. Connected between the HF-socket of the load capacitor CB and the DMI 551 by means of a coaxial cable (MK BNC).

SEK AC: Secondary part for CM (AC)

Fig. 32: SEK AC

Secondary unit for the AC divider, which incorporates the LV capacitors and a 75Ω matching resistor. Connected between the HF-socket of the measuring capacitor CM and the DMI551 by means of a coaxial cable (MK BNC).

SEK DC: Secondary part for RM (DC)

Fig. 33: SEK DC

Secondary unit for the DC divider, which incorporates the LV resistors and a 75Ω matching resistor. Connected between the HF-socket of the measuring resistor RM and the DMI551 by means of a coaxial cable (MK BNC).

MK BNC

Fig. 34: MK BNC

Coaxial cable with BNC plugs can be used to connect the secondary part of the high-voltage dividers to measuring instrument (DMI551).

Impedance: 75Ω

Standard Length: 10m (other lengths on request)

EZK: Electronic trigger sphere

Fig. 35: EZK

Fig. 36: Cable for EZK

Trigger sphere, which is used to generate triggered impulses in impulse voltage configurations together with sphere gap KF and triggering device DMI ZAG. Chopped impulses can be generated with an additional EZK together with the measuring spark gap MF 100. Supplied with fibre-optics cable LWL.

Diameter:	100mm
Standard length of cable:	10m

DKU: Vessel for vacuum and pressure

Fig. 37: DKU

Vessel, which can be used to determine flashover voltage of electrode arrangements as a function of vacuum and over pressure.

Max. AC voltage:	100kV
Max. DC and IMP voltage:	140kV
Max. operating pressure (abs.):	0 - 6bar

DKU ZUB: Additional set of electrodes

Fig. 38: DKU ZUB

Additional electrodes for use with the DKU.

Sphere electrodes: Ø50mm

Sphere electrodes: Ø20mm

Needle electrodes

KR: Corona cage

Fig. 39: Corona cage KR

Corona cage, which can be used to determine glow intensity as a function of wire diameter. The corona cage is inserted into the vacuum and overpressure vessel (DKU). Measurements can be made at vacuum and over pressure.

Max. AC voltage: 100kV

Max. DC voltage: 140kV

OP: Oil testing cup

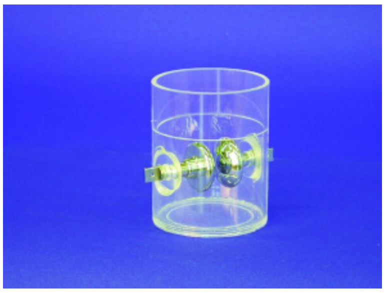

Fig. 40: OP

Oil testing cup, which can be used to measure flashover voltage of insulating oil. Fitted into the vacuum and pressure vessel (DKU). Electrodes have spherical caps acc. to VDE 370, par. 13.

Gap setting : 2.5mm

MF 100: Measuring sphere gap

Fig. 41: MF100

Sphere gap to measure flashover voltage and to generate chopped impulses together with the trigger sphere EZK. Motor-driven but also with hand-wheel for manual gap setting.

Max. AC voltage:	100kV
Max. DC and IMP voltage:	140kV
Sphere electrodes:	Ø100mm
With motor-drive	230V, 50/60Hz

MF 100 ZUB

Additional electrodes available for the MF 100.

Sphere electrodes:	Ø 50mm
Rod-type electrodes:	Ø 20mm

Needles electrodes

Flat electrodes (Rogowski profile)

Control and Measuring

The high voltage KIT is supplied with two separate instruments:

The control unit OT276 and the AC, DC and impulse measurement unit DMI551.

Operating terminal OT276

OT276 controls the regulating transformer. It is based on conventional relay technology and is built into a 19" standard housing of 3 units height. Operation is by means of push buttons. The state of contactors as well as the current and voltage on the secondary side of the regulating transformer are clearly indicated on the front plate by means of LED displays.

Figure 42 shows a picture of the OT276

Fig. 42: OT276

Measuring instrument DMI551

With the KIT it is often required to measure AC, DC and impulse voltages at the same time. Therefore the DMI551 is equipped with three independent measuring channels (AC, DC, IMP), see figure 43a, and can display all three values simultaneously.

Fig. 43a: Rear side of DMI551 with measuring channels

The DMI551 is a microprocessor controlled instrument. Input is via the numeric keypad. A LCD-Display indicates measured values and the function options.

With its optional triggering function, firing of the impulse configuration or a chopping gap is possible.

An interface (RS-232 or IEEE-488) is also available for connection to a host computer. The DMI551 is designed in accordance with the international standard IEC 60060.

Figure 43b shows a picture of the DMI551

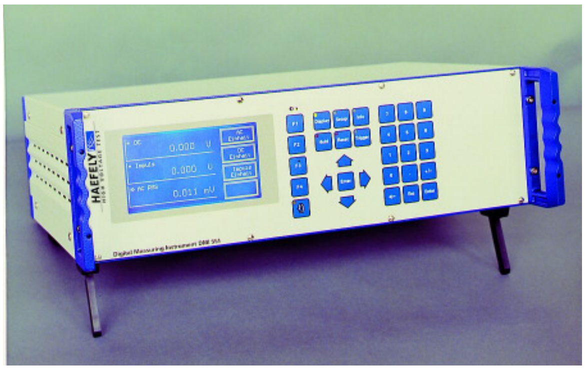

Fig. 43b: DMI551

For more information about the OT276 and DMI551 please study the coresponding operation instructions.

Technical description

There are existing for each setup (AC, DC or Impulse) three configurations (one, two and three stages), which allows different maximum output voltages.

AC-configuration

High alternating voltage AC are required for experiments and AC tests as well as a supply for most of the circuits to generate high direct (DC) or impulse voltage. Test transformers generally used for this purpose have considerably lower power rating and frequently much larger transformation ratios than power transformers. The primary winding is usually supplied by regulating transformers fed from the main supply.

Most tests and experiments with high AC voltage require precise knowledge of the value of the voltage. This demand can normally only be fulfilled by measurement of the voltage on the high-voltage side.

The circuit for the AC-configuration 1stage consist's of a high-voltage transformer with a maximum output voltage of 100kV and a capacitive voltage divider (maximum AC voltage: 100kV) for the measurement of the voltage on the high-voltage side.

For the 2 stages configuration two transformer are put together in a cascade configuration to reach an maximum output voltage of 2x 100kV. For this reason each transformer is equipped with a tertiary winding. The tertiary winding is used for coupling two transformer modules. For this the tertiary winding of one module is connected to the primary winding of the succeeding module. Also two measuring capacitors are connected in series for the measuring of an AC voltage of 200kV.

For the 3 stages configuration three transformer are put together in a cascade configuration to reach an maximum output voltage of 3x 100kV and three measuring capacitors are connected in series for the measuring of an AC voltage of 300kV.

For configurations with more than one stage, compensating reactors type KDL are recommended to extend the load range of the cascade configuration.

DC-configuration

The DC test voltage is defined as the arithmetic mean value

$$U_{DC} = \frac{1}{T} \cdot \int_0^T u(t)\,dt \qquad (1)$$

Ripple is the periodic deviation from the arithmetic mean value of the voltage. The amplitude δU of the ripple is defined as half the difference between the maximum and minimum value:

$$\delta U = \frac{1}{2} \cdot (U_{Max} - U_{Min}) \qquad (2)$$

The **ripple factor** is the ratio of the ripple amplitude δU to the arithmetic mean value U_{DC}. *)

*) REMARK: The DMI 551 measuring device is able to display the exactly ripple factor only with an (optional) separate capacitive compensated voltage divider. The KIT DC measuring divider is consisting of resistive components for DC measurements only. It is not suitable for accurate ripple factor measurements.

DC 1 stage

This configuration is realised with a half-wave rectifier circuit (see figure 43).

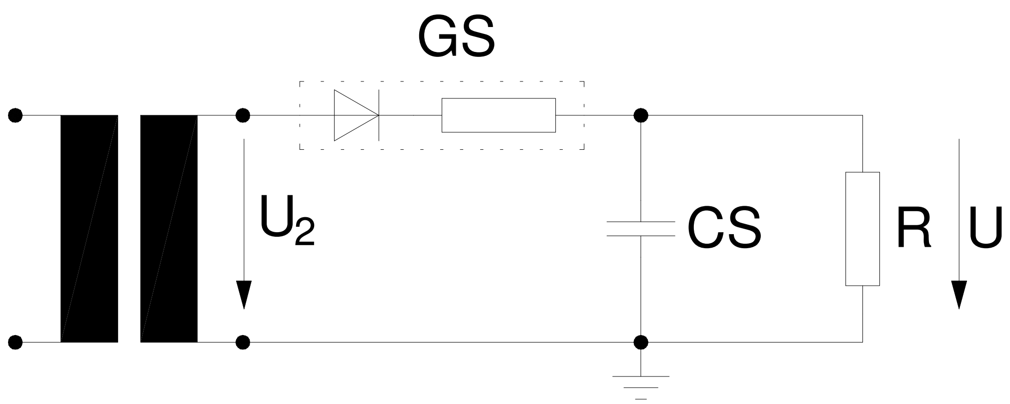

Fig. 44: Half-wave rectifier

The smoothing capacitor CS is charged via the diode GS to the direct voltage U

$$U = \sqrt{2} \cdot U_{2\,rms} \qquad (3)$$

The inverse voltage of the diode must be

$$U_{inv} = 2 \cdot \sqrt{2} \cdot U_{2\,rms} \qquad (4)$$

Under no load conditions (i.e. no test object **and** no ohmic divider for the voltage measurement) an ideal DC-voltage without ripple will be generated.

Under load conditions (divider is part of the load) the ripple of the DC-voltage will increase. During the blocking period t of the diode GS the smoothing capacitor is discharged via the load R. Only during the short period α the capacitor CS will be recharged from the transformer. During the period α the diode is conductive and a short forward current pulse I_D flows (see figure 45).

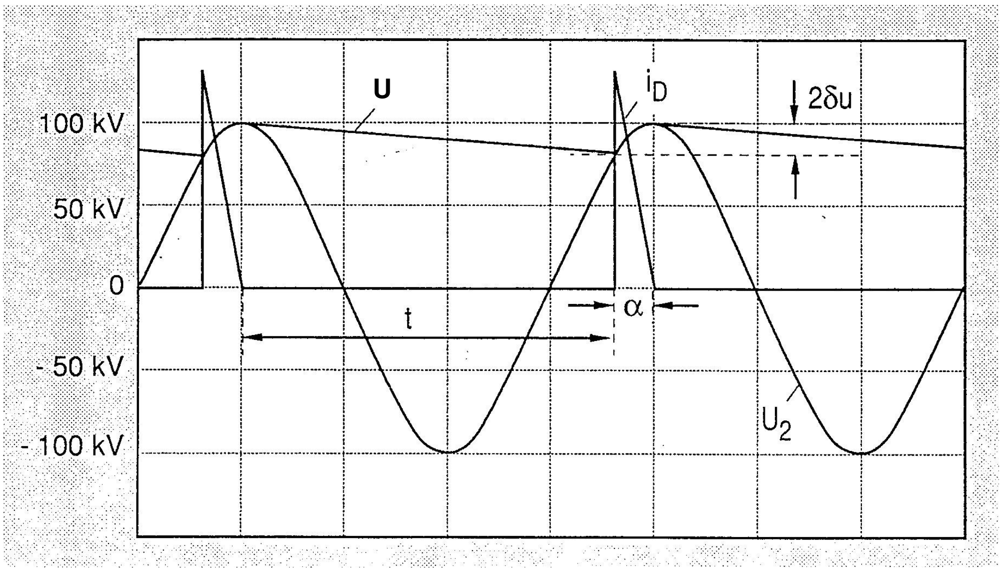

Fig. 45: Voltage characteristics

The lower the value R (i.e. the higher the required DC-current) the higher will be the ripple of the DC-voltage, because the capacitor will be more discharged by the load. Also the achievable DC-voltage will be decreasing with higher load current.

DC 2 stages

This configuration is realised with a multiplier circuit (called “Greinacher Doubler-Circuit”) so that the same transformer as for the single stage configuration could be used. The electrical diagram shows figure 46 the voltage characteristic is shown in figure 47.

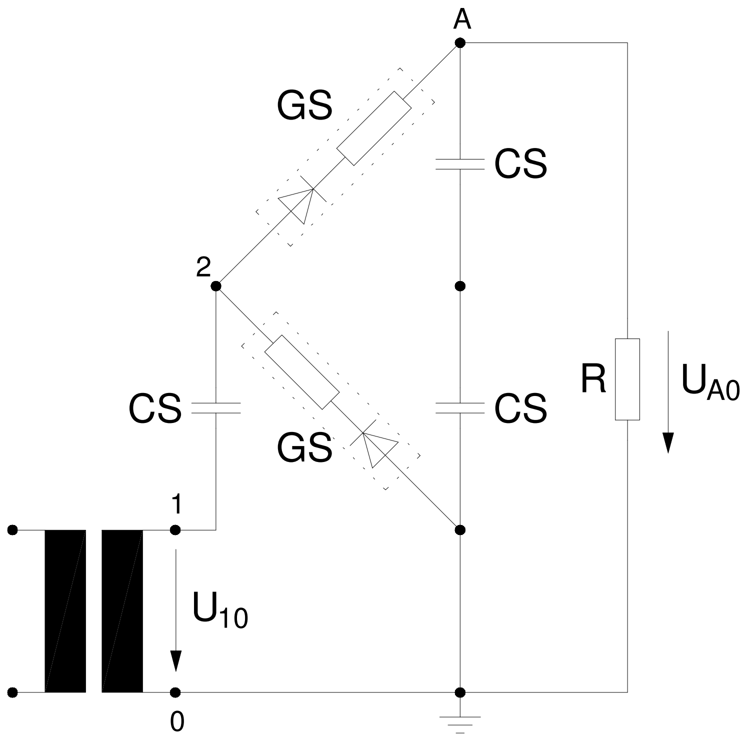

Fig 46: Greinacher Doubler-Circuit

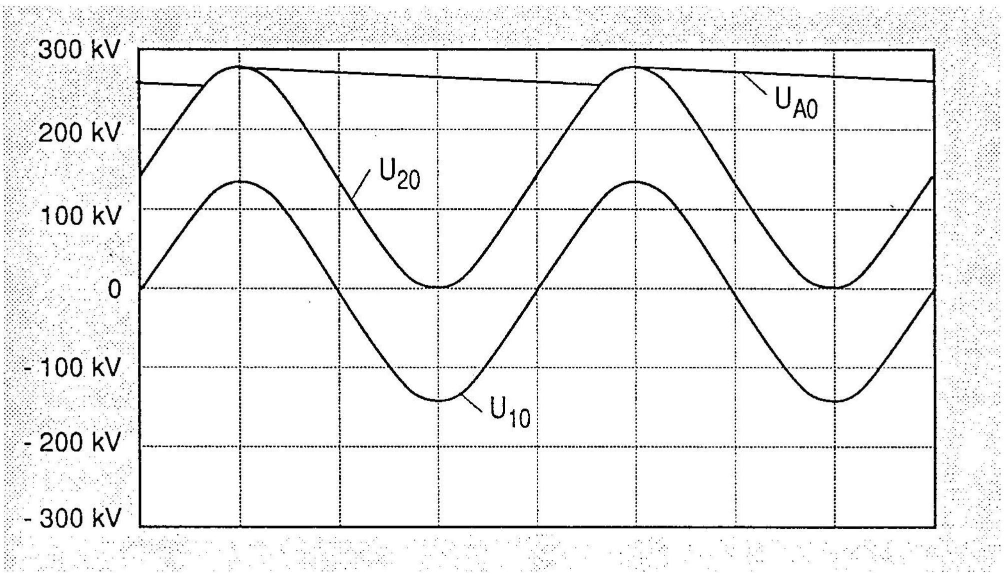

Fig. 47: Voltage characteristics

The left blocking capacitor CS is charged to the peak value of the transformer voltage U_{10} and thus increases the potential of the terminal 2 with respect to the transformer voltage by this amount (voltage U_{20} in figure 47). Via another diode CS the smoothing capacitors will be charged. Under no load condition ((i.e. no test object **and** no ohmic divider for the voltage measurement) a DC-voltage with

$$U_{DC} = 2 \cdot \sqrt{2} \cdot U_{10,rms} \quad (5)$$

will be generated.

The inverse voltage of the diode must be

$$U_{inv} = 2 \cdot \sqrt{2} \cdot U_{10,rms} \quad (6)$$

The ripple will be increased and the achievable output voltage will be decrease with increasing load.

DC 3 stages

This configuration is realised with the “Greinacher Cascade Circuit” with three stages (see figure 48). This is an extension of the “Greinacher Doubler-Circuit”.

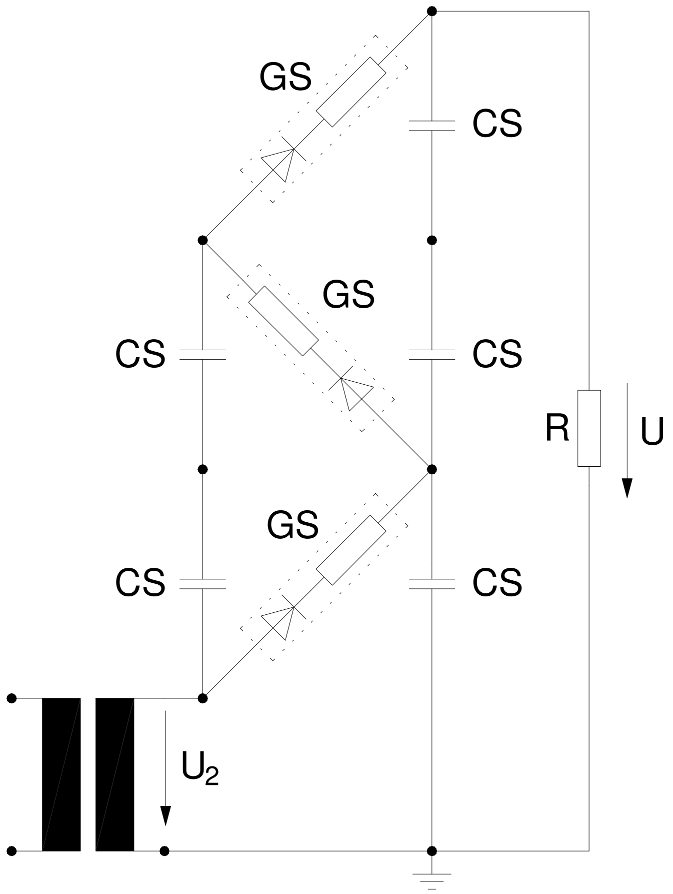

Fig. 48: Greinacher Cascade Circuit with three stages

Under no load condition ((i.e. no test object **and** no ohmic divider for the voltage measurement) a DC-voltage with

$$U = n \cdot 2 \cdot \sqrt{2} \cdot U_{2\,rms} \tag{7}$$

will be generated, where n ist the quantity of stages.

The inverse voltage of the diode must be

$$U_{inv} = 2 \cdot \sqrt{2} \cdot U_{2\,rms} \tag{8}$$

Impulse configuration

General

Impulse voltages are required in high-voltage tests to simulate the stresses due to external and internal overvoltages, and also forfundamental investigations of the brakdown mechanism. They are usually generated by discharging high-voltage capacitors through switching onto a network of resistors and capacitors, whereby multiplier circuits are often used.

In high-voltage technology a single, unipolar voltage pulse is termed an impulse voltage. For testing purposes, double exponential impulse voltages have been standardized; without appreciable oscillation these rapidly reach a maximum, the peak value U_{Peak}, and finally drop less abruptly to zero. If an intentional or unintentional breakdown occurs in the high-voltage circuit during the impulse, leading to a sudden collapse of the voltage, this is then called a chopped impulse voltage. The chopping can occur on the front, at the peak or in the tail section of the impulse.

For overvoltages following lightning strokes, the time required to reach the peak yalue is in the order of 1µs; they are named atmospheric or external overvoltages. Voltages generated in a laboratory to simulate these are called **lightning impulse voltages (LI)**.

For internal overvoltages, occurring as a consequence of switching operations in high-voltage networks, the time taken to reach the peak value is at least about 100µs. Their reproduction in the laboratory is effected by **switching impulse voltages (SI)**; these are of approximately the same shape as lightning impulse voltages, but last considerably longer.

In case of impulse voltages for testing purposes, the shape of the voltage is determined by certain time parameters for the front and tail, as shown in figure 49 and 50.

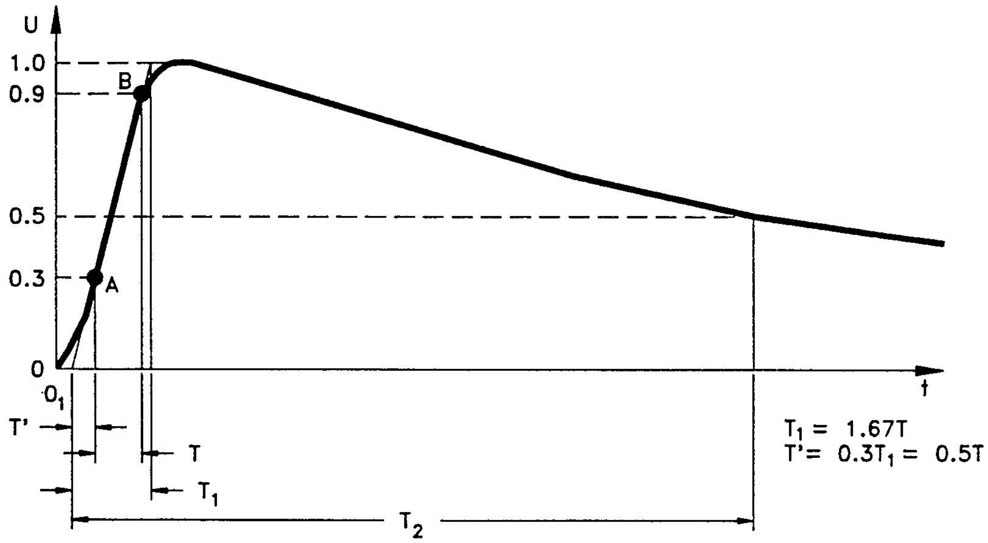

Fig. 49. Lightning impulse curve

In the international standard IEC 60060-1 the **front time T_1** ot a lightning impulse is a virtual parameter defined as the 1.67 times the interval T between the instants when the impulse is 30% and 90% of the peak value (point A and B in figure 49).

The virtual origin O_1 of a lightning impulse is the instant preceding that corresponding to point A by a time $0.3T_1$. For records with linear time scales, this is the intersection with the time axis of a straight line drawn through the reference points A and B on the front.

The **time to half-value T_2** (or tail time) of a lightning impulse is a virtual parameter defined as the time interval between the virtual origin O_1 and the instant when the voltage has decreased to half the peak value.

The curves of lightning impulses often have high-frequency oscillations superimposed, due to the pararistic inductances of the impulse circuit, the amplitude should not exceed 5% of the test voltage.

Standard lightning impulse:

- Front time T_1: 1.2µs (tolerance: ±30%)
- Time to half-value T_2: 50µs (tolerance: ±20%)

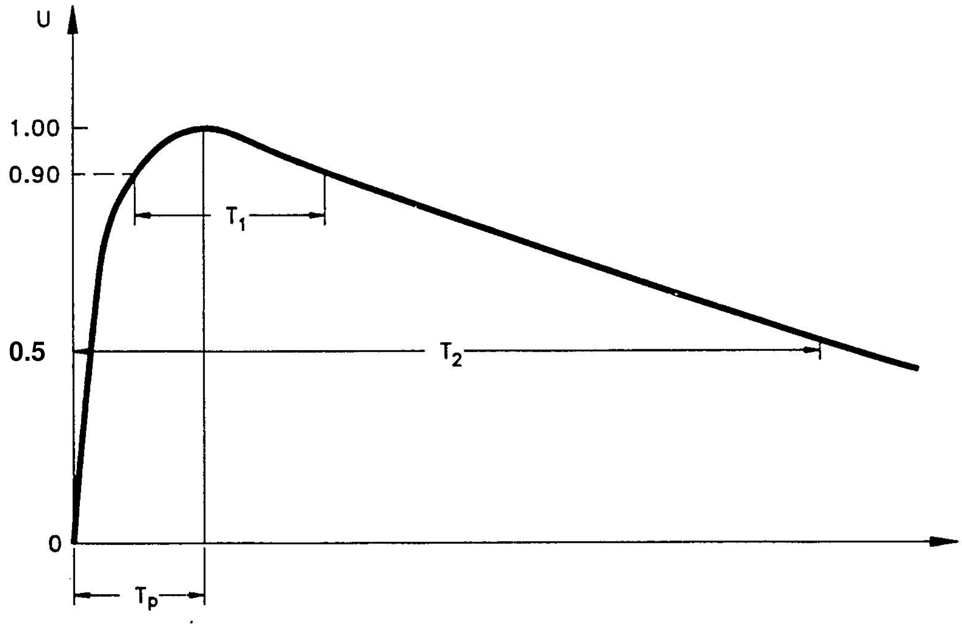

Fig. 50. Switching impulse curve

In the international standard IEC 60060-1 the **time to peak T_p** of a switching impulse is the time interval between the actual origin and the instant when the voltage has reached its peak value.

The **time to half-value T_2** for a switching impulse is the time interval between the actual and the instant when the voltage has first decreased to half the peak value.

The **time above 90% T_1** is the time interval during which the impulse voltage exceeds 90% of its peak value.

Standard switching impulse:

- Time to peak T_p: 250µs (tolerance: ±20%)
- Time to half-value T_2: 2500µs (tolerance: ±60%)

Impulse 1 stage

Figure 51 shows the basic circuit for generating impulse voltages.

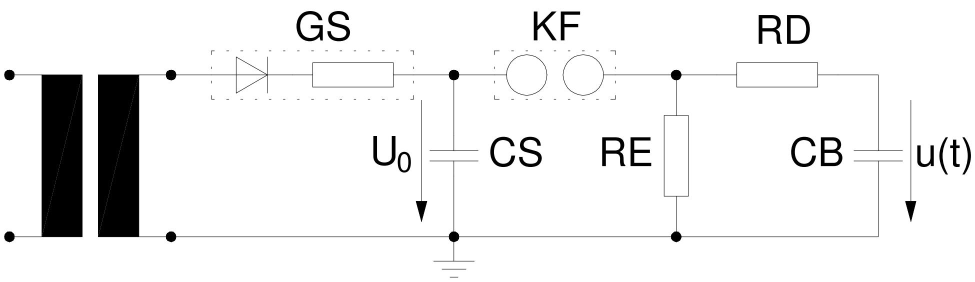

Fig. 51: Circuit for generating impulse voltages

The impulse capacitor CS is charged via a diode GS to the direct voltage U_0 and then discharged by ignition of the switching gap KF. The desired impulse voltage u(t) appears across the load capacitor CB.

The value of the circuit elements determines the curve shape of the impulse voltage. The impulse voltage is given by the difference of two exponentially decaying functions with time constants $\tau 1$ and $\tau 2$.

With the usually satisfied approximation

$$RE \cdot CS >> RD \cdot CB \qquad (9)$$

the following simple expressions are obtained :

$$\tau_1 \approx R_D \cdot \frac{C_S \cdot C_B}{C_S + C_B} \qquad (10)$$

$$\tau_2 \approx R_E \cdot (C_S + C_B) \qquad (11)$$

There are existing a correlation between $\tau 1$ and $\tau 2$ and the front and tail time of lightning and switching impulses defined in the internatioal standards:

$$T_1 = T_p = K_1 \cdot \tau_1 \qquad (12)$$

$$T_2 = K_2 \cdot \tau_2 \qquad (13)$$

The values of K_1 and K_2 are:

	1.2/50µs	250/2500µs
K_1	2.96	2.41
K_2	0.73	0.87

The **efficiency factor η** is the ratio between the peak value U_{Peak} of the impulse voltage and the charging voltage U_0 of the impulse capacitor ($\eta = U_{Peak}/U_0$). η could be approximately calculated with the following formula:

$$\eta \approx \frac{C_S}{C_S + C_B} \tag{14}$$

Impulse 2 and 3 stages

For given DC charging voltage, to obtain impulse voltage with as high a peak value as possible, the multiplier circuit proposed by *E. Marx* is commonly used. Several identical impulse capactitors are charged in parallel and then discharged in series, obtaining in this way a multiplied total charging voltage, corresponding to the number of stages.

The following two figures shows the multiplier circuit for the 2 and 3stages impulse configuration.

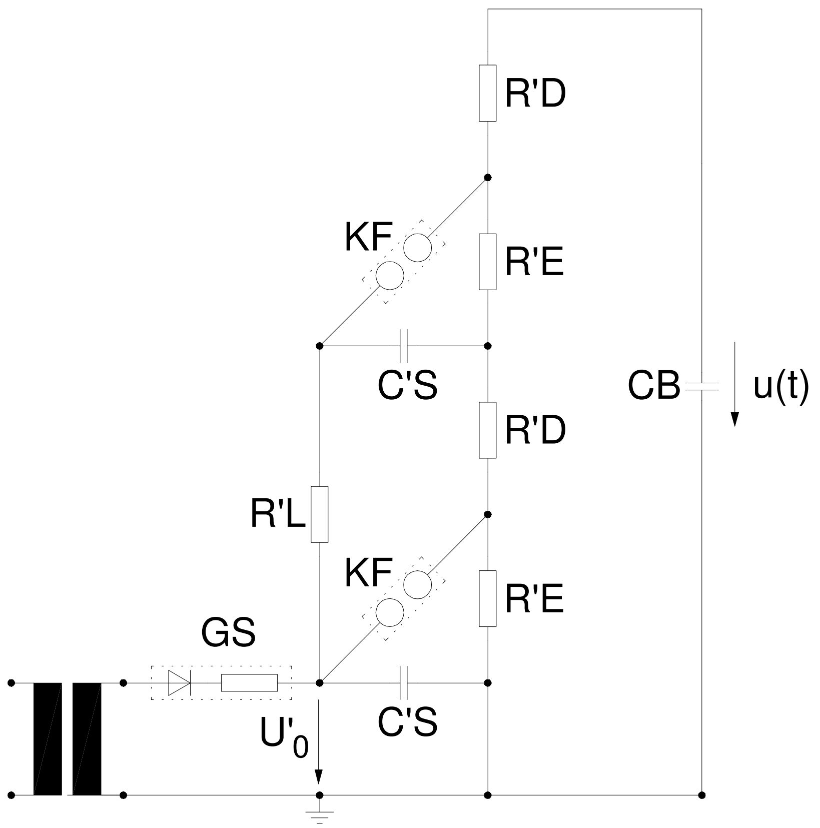

Fig. 52: Multiplier circuit for Impulse 2 stages

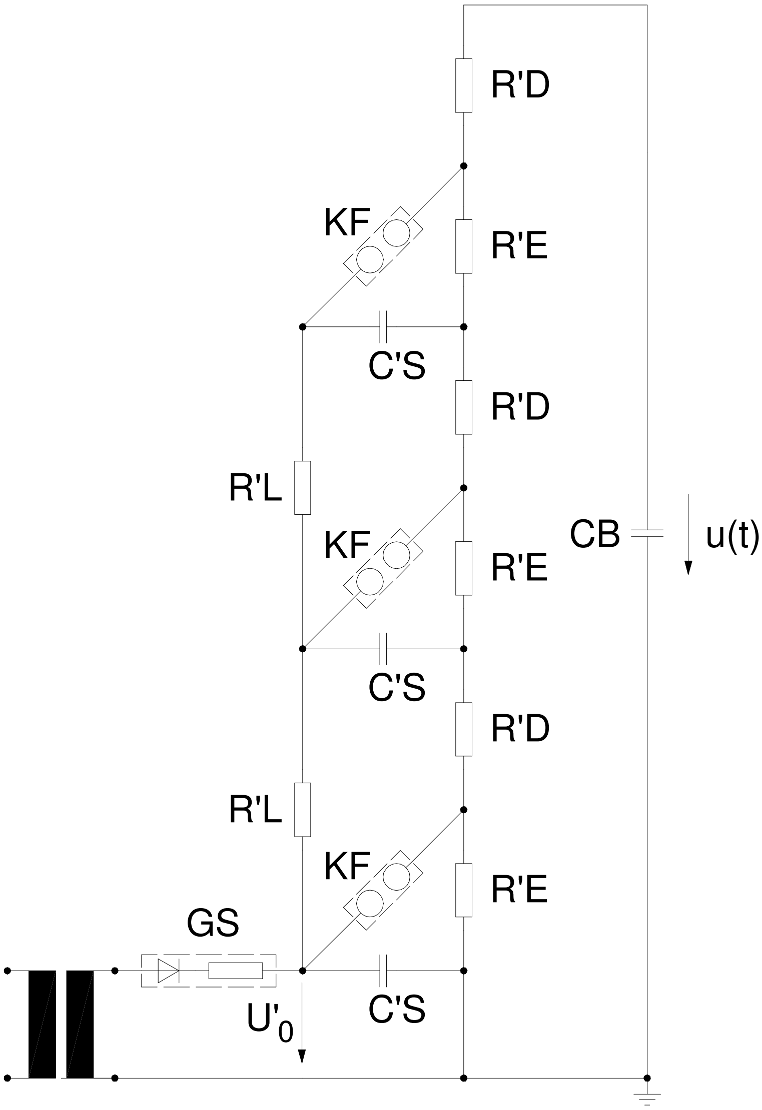

Fig. 53: Multiplier circuit for Impulse 3 stages

The impulse capacitors of the stages C'S are charged to the stage voltage U'_0 via the high charging resistor R'L in parallel.

When all switching gaps SF break down, C'S will be connected in series, so that CB is charged via the series connection of all damping resistors R'D; finally C'S and CB will discharge again via the resistors R'E and R'D. It is expedient to choose R'L >> R'E.

The n-stage circuit can be reduced to a single stage equivalent circuit, such as in chapter "Impulse 1 stage", where the following relationships are valid:

$$U_0=n\cdot U'_0 \tag{15}$$

$$RD=n\cdot R'D \tag{16}$$

$$CS=1/n \cdot C'S \tag{17}$$

$$RE=n \cdot R'E \tag{18}$$

Packing material, Transportation, Storage, Unpacking

The rules, instructions and tips concerning this are component specific. Please read the corresponding chapters in the manuals of the respective used components.

Interfaces to operating environment

- The interface to the power supply at the customer side are the primary terminals of the regulating transformer.
- The interface to the test object is the connecting cup K.
- System earth at test area/field.
- Supply voltage for control unit OT276 and digital measuring instrument DMI551.

Assembling, Installation, First putting into operation

Installation area

The floor of the test location must be prepared in a way that there is no sag under the load of the heaviest component.

There must be sufficient clearances from high voltage parts of the system to components connected to earth. The following diagram gives guide value for clearances:

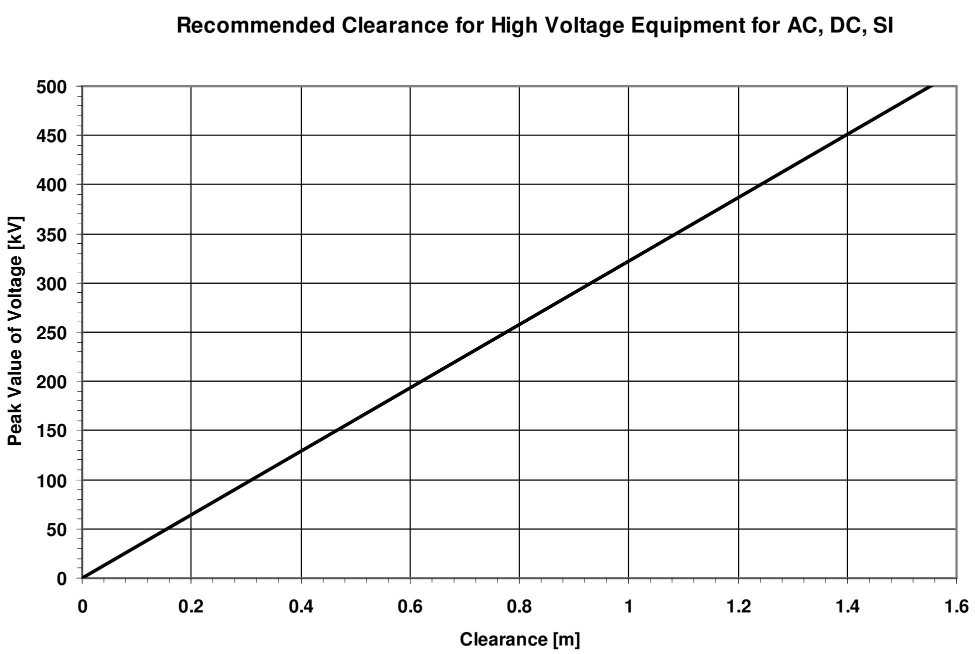

Diagram 1: Clearances for AC, DC and SI

For lightning impulse the empirical formula 5kV/mm could be used for determining the recommended clearance.

Test room

A suitable room is required to accommodate the high voltage construction KIT. Depending on the KIT configuration a floor surface of 3m x 4m is recommended, and a favourable height is 2.5m to 3m.

Since voltages in excess of 1000V are to be generated, it is necessary that the respective safety regulations are carefully followed.The most important criteria of a good test room are the screening and grounding.

Safety equipment

The test area should be enclosed by a metal grid fence of at least 1.8m height with a maximum grid spacing of 40mm.

All doors leading to the test room must be equipped with door contacts, which close when the door is closed. All contacts should be connected in series to the interlock system, by means of a shielded cable, provided by the control unit OT276. This safety system will automatically turn off the high voltage if a door is opened while the test system is switched on. Red and green warning lights should be installed at all doors leading to the test room.

Screening

The test transformer of the high voltage construction KIT can be used for partial discharge measurements. In order to ensure that the partial discharge measurement is not disturbed by external interference, it is necessary that the test room is screened like a Faraday cage. Walls, ceiling and the floor of the test area have to be covered with a metallic surface. This surface can either be a copper mesh having a spacing of less than 10 mm or a 0.1 to 0.2 mm copper foil. The edges of each individual strip must be carefully joined to the next one so that the conductivity between the sheets is as high as possible. Using a wire mesh, the wires should be bound and soldered. Copper foils can be joined by folding the edges or by soldering. Welding or soldering points are preferable to screw or clamp connections. A steel sheet floor with non-slip surface (waffle sheeting) is recommended. All cables leading into the shielded room should enter the Faraday cage at a central position. Ask your Haefely Test Sales Person for assistance on how to erect shielded enclosures and for power line filters.

Grounding

A good test field has a separate grounding. This ensures that no disturbances from surrounding machines enter the test field and - in case of a failure - the earth potential of the surrounding does not rise, causing damage to electrical equipment. It is necessary for the test field to have a lower grounding resistance than the surrounding building.

The following measures are required: Use a deep ground rod, radial ground wires below the ground surface, a lightning conductor or water mains outside the building for grounding.

If possible, the whole test room should be screened. Attention should be paid to ensure a good lasting electrical connection between all parts of the screening. The screening surfaces should be made with wide metal strips (at least 60mm in width), since strips of this width are of lower inductivity than round wires having the same cross-sectional area.

Connections have to be made without forming loops.

The ground connection of the high voltage generator, measuring system and test object should be arranged like a star, where the central point is grounded.

To avoid ground loops between different grounding points, the KIT is grounded at only one position through a grounding rod. The rod should have a ground resistance of less than 2Ω.

If the resistivity of the soil near the factory is not known, we recommend the following procedure: A rod with a diameter of about 20mm is driven into the soil to a depth of approx. 30m. The first 3m of this rod below the soil level have to be insulated in order to avoid picking up surface currents. Then the ground resistance is measured. If the resistance is higher than 2Ω, a second rod must be driven into the soil approx. 10 m from the first, following the same procedure. The two ground rods are then connected in parallel with a copper foil of 150 x 0.3mm cross section for example. This procedure is repeated until the ground resistance of < 2Ω is achieved.

The length of the grounding rod is not important but the ground resistance must be < 2Ω for personnel protection.

A local construction company can give you some more details about the depth of the rod.The grounding rod(s) shall be placed close to the test area. The enclosure's ground stud will be connected to the ground rod with a strong copper band for example 0.3 x 100 mm.

Figure 54 shows the grounding resistance as a function of length of rod and soil resistivity

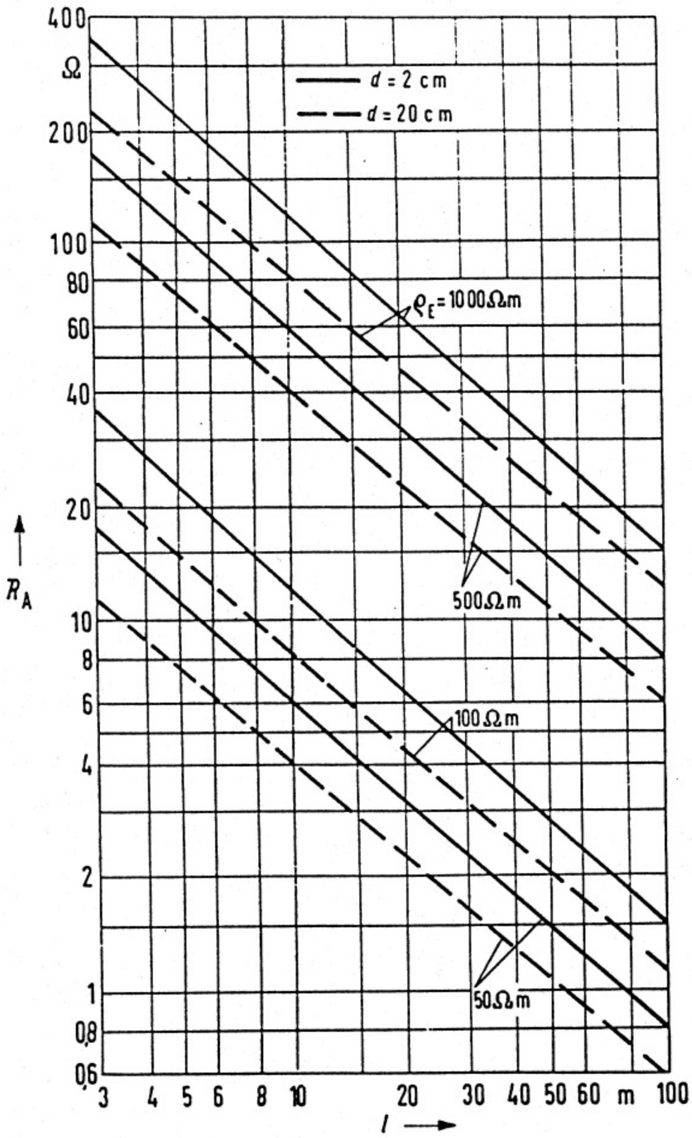

Fig. 54: Grounding resistance as a function of length of rod and soil resistivity

In figure 54 means:

RA: Ground resistance [Ω]

ρ_E: soil resitivity [Ωm]

l: depth of grounding rod [m]

d: diameter of grounding rod [m]

Assembling

Before the erection work can start it is absolutely necessary to study the chapter ‘Safety’ detailed.

Terminals

Before components will be connected it is absolutely necessary to study the chapter ‘Safety’ detailed.

Only trained people are allowed to do erection work. The terminal data are component specific. Please read the corresponding chapters in the respective component manuals. The following chapters give basic information’s about the terminals of the regulating transformer and transformer cascade.

Regulating transformer STL 5

Figure 55 shows the interior view of the regulating transformer with the terminal board for connecting the control cable from the control unit, the input power cables and the power cables to the test transformer.

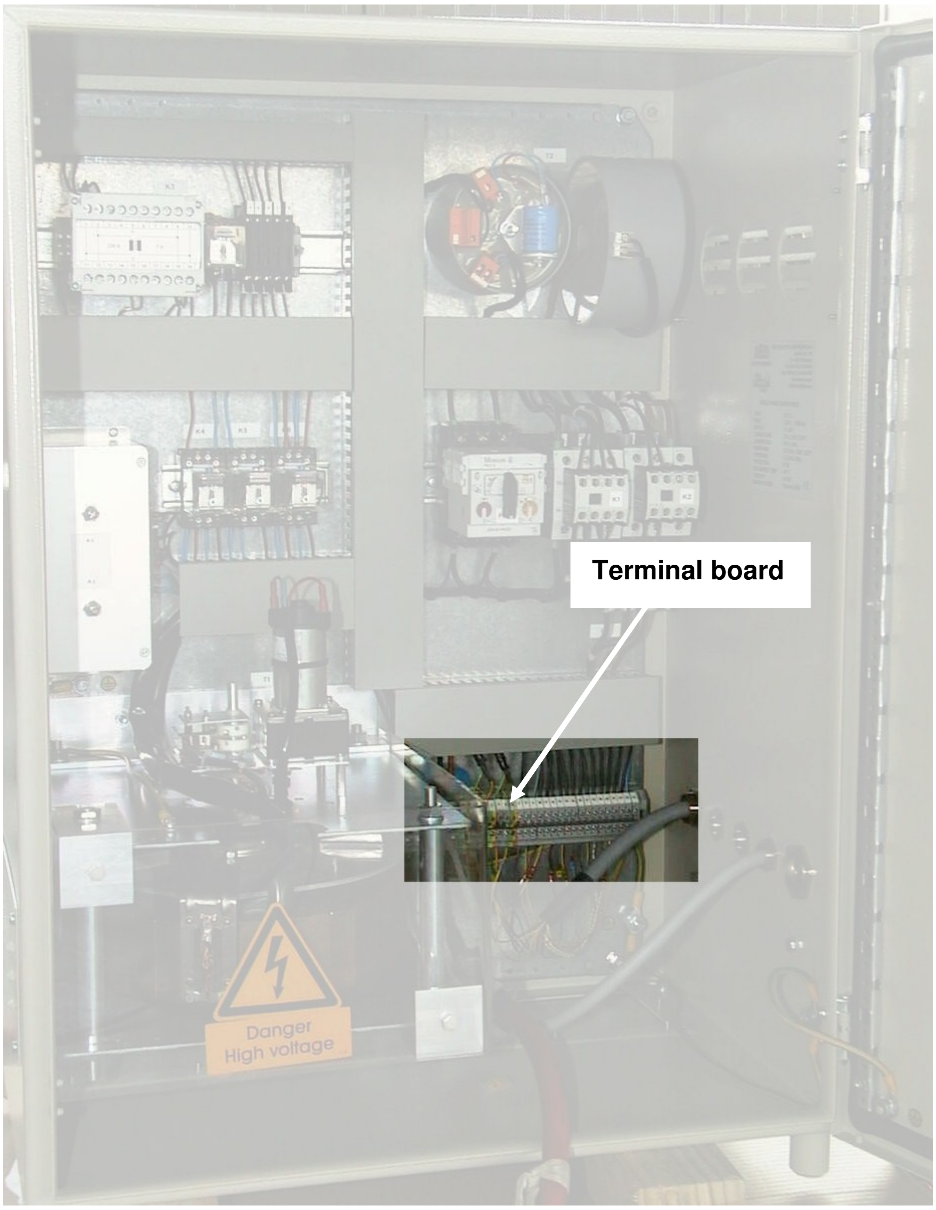

Fig. 55: Interior view of the STL 5 with terminal board

Figure 56 shows the terminal board of the regulating transformer

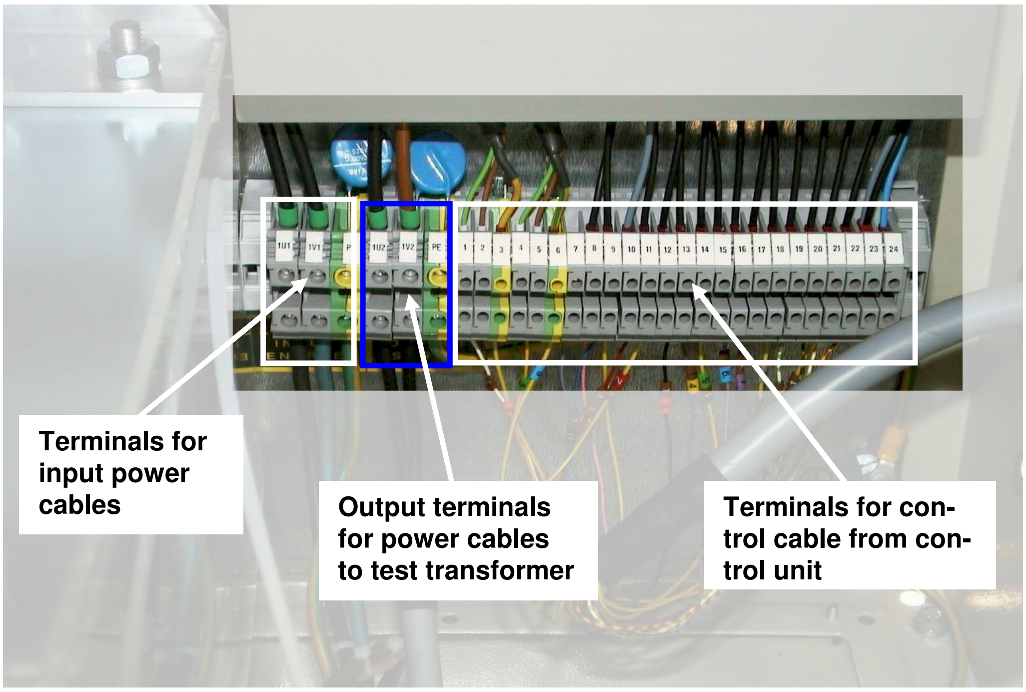

Fig. 56: Terminal board of regulating transformer

The earth point of the regulating transformer is located outside of the cubicle (see figure 57).

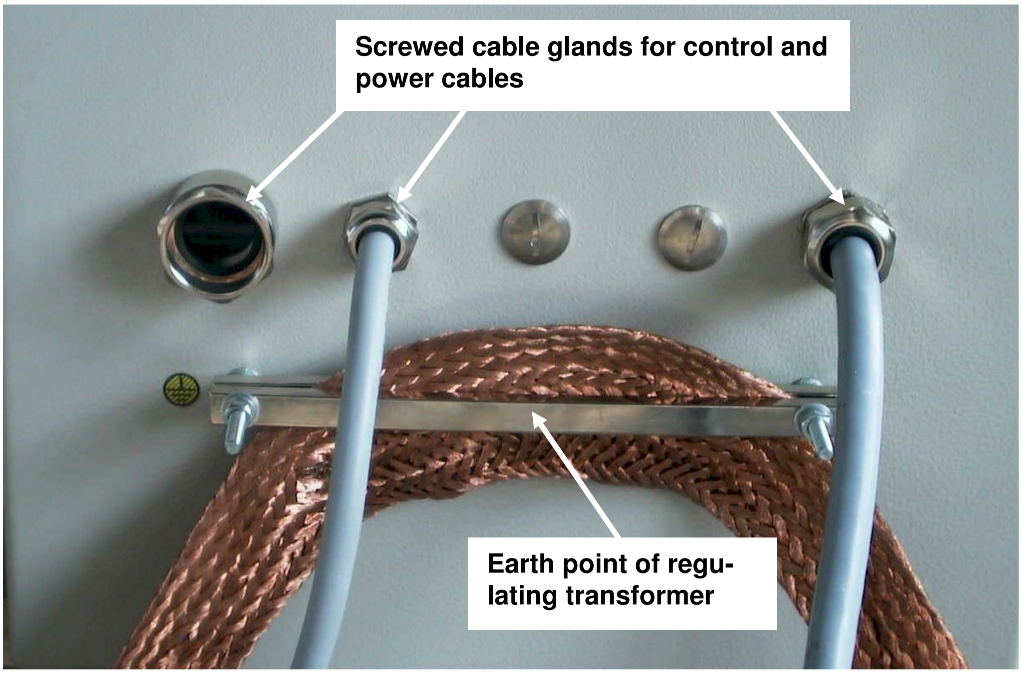

Fig. 57: Earth point of regulating transformer

Transformer cascade

2 stages transformer cascade

Figure 58a shows a schematic diagram with the connections for a 2 stages transformer cascade without compensating reactors. Figure 58b shows the schematic diagram for a 2 stages cascade with compensating reactors.

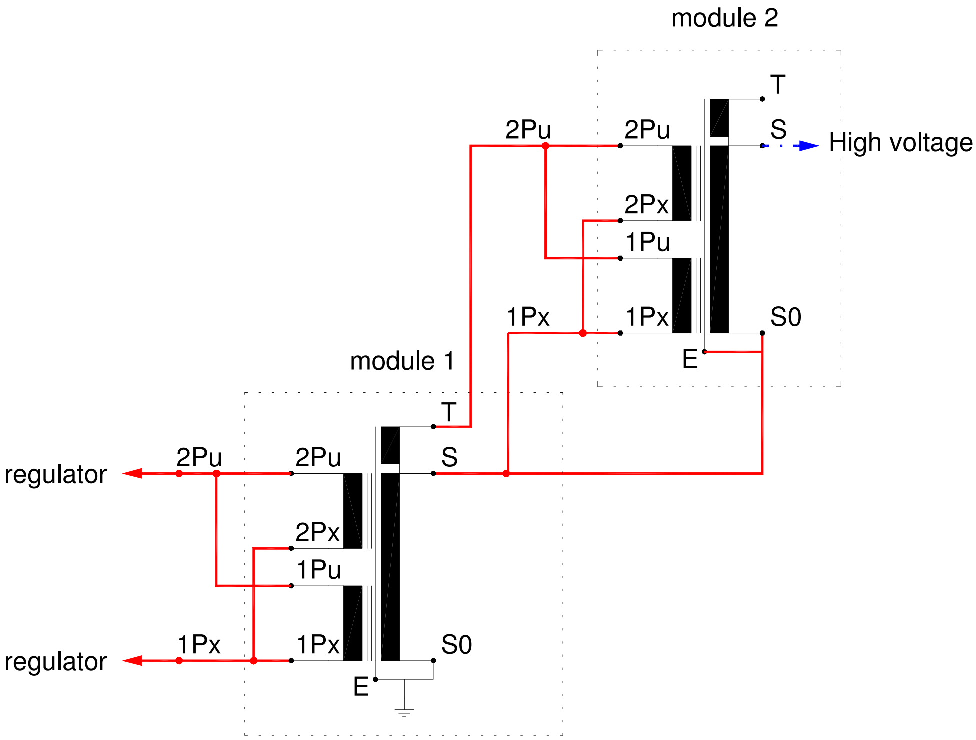

Fig. 58a: Schematic diagram for cascade connection of two test transformer

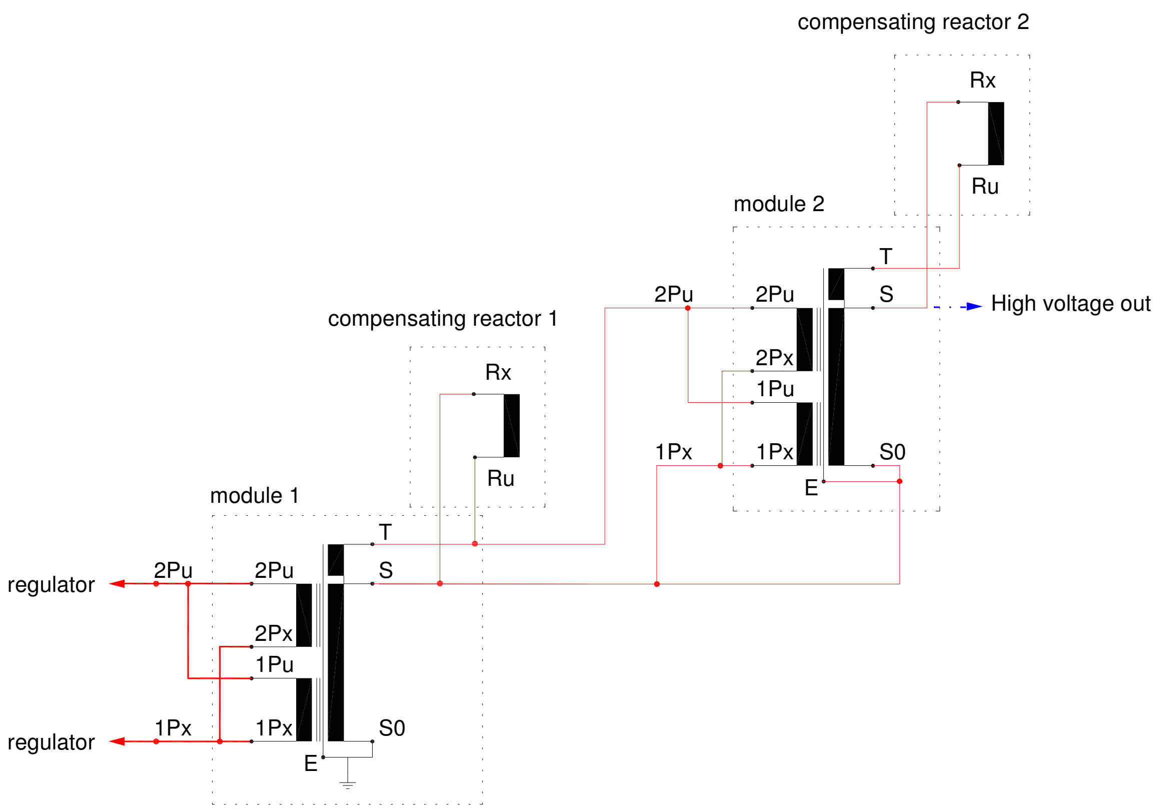

Fig. 58b: Schematic 2 stages with compensating reactors

S0 is the beginning of the secondary winding, S is the high-voltage end of the secondary winding and T is the end of the tertiary winding.

The low voltage winding of the transformer consist's of two winding groups (1Px-1Pu, resp. 2Px-2Pu) which could be connected either in series or in parallel. For cascade operation of the transformer the two winding groups must be connected in parallel!

- Module 1 has to be connected to earth.
- The primary windings of the test transformers has to be connected in parallel with the Multi-contact plugs (see figure 59), i.e. 1Px has to be connected with 2Px, and 1Pu has to be connected with 2Pu.

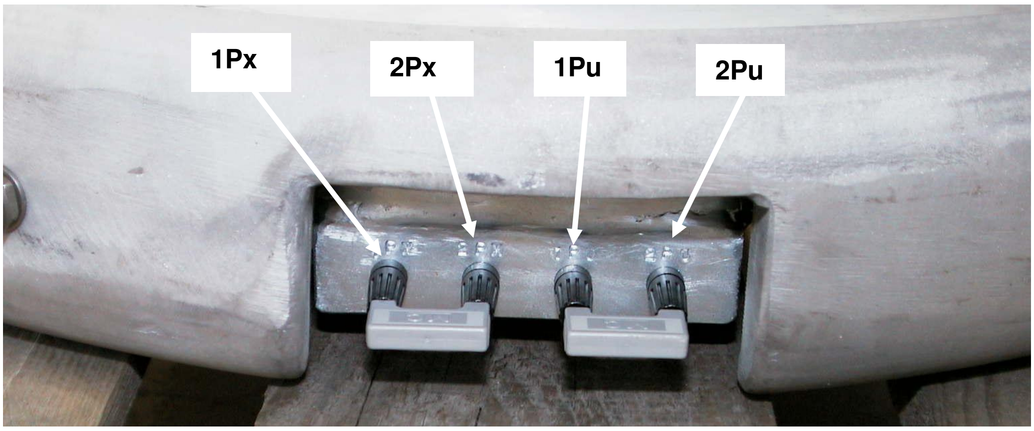

Fig. 59: Parallel connection of primary windings

- Terminal S0 of module 1 has to be connected with terminal E of module 1 (these two terminals are realized as Mutli-contact sockets) (see figure 60).
- The input power cables has to be connected to the terminals 1Px and 2Pu of module 1 (these two terminals are realized as bushings) (see figure 60).

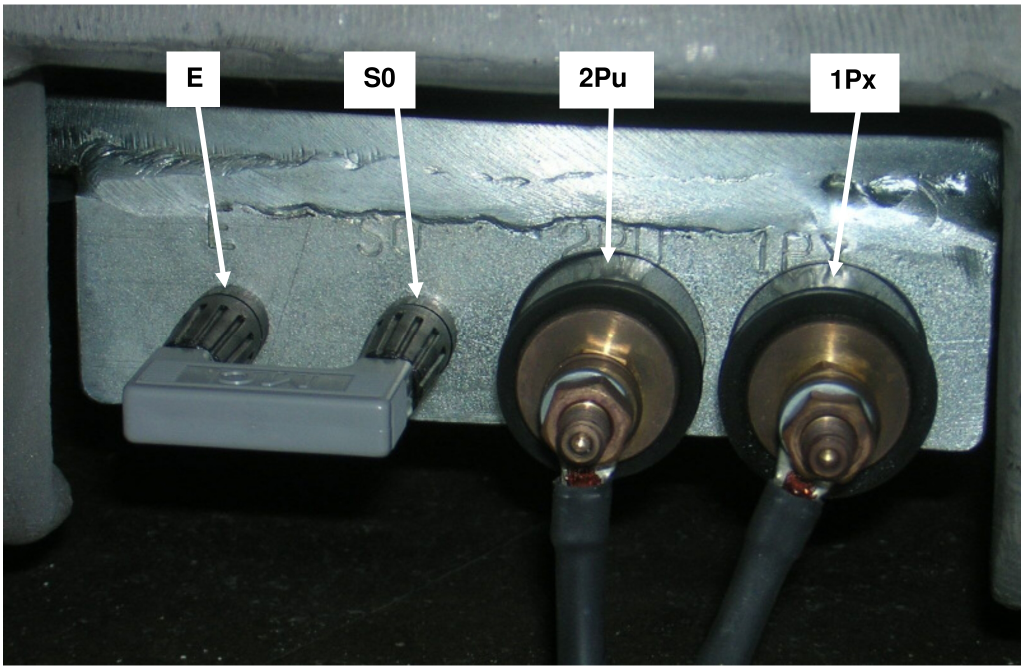

Fig. 60: Input terminals modul

Connections without compensating reactors:

- Terminal T of module 1 has to be connected with terminal 2Pu of module 2 (these two terminals are realized as bushings) (see figure 61a).
- Terminal S of module 1 has to be connected with terminal 1Px of module 2 (these two terminals are realized as bushings) (see figure 61a).
- Terminal S of module 1 has to be connected with terminal S0 of module 2 (these two terminals are realized as Mutli-contact sockets) (see figure 61a).
- Terminal S0 of module 2 has to be connected with terminal E of module 2 (these two terminals are realized as Mutli-contact sockets) (see figure 61a).

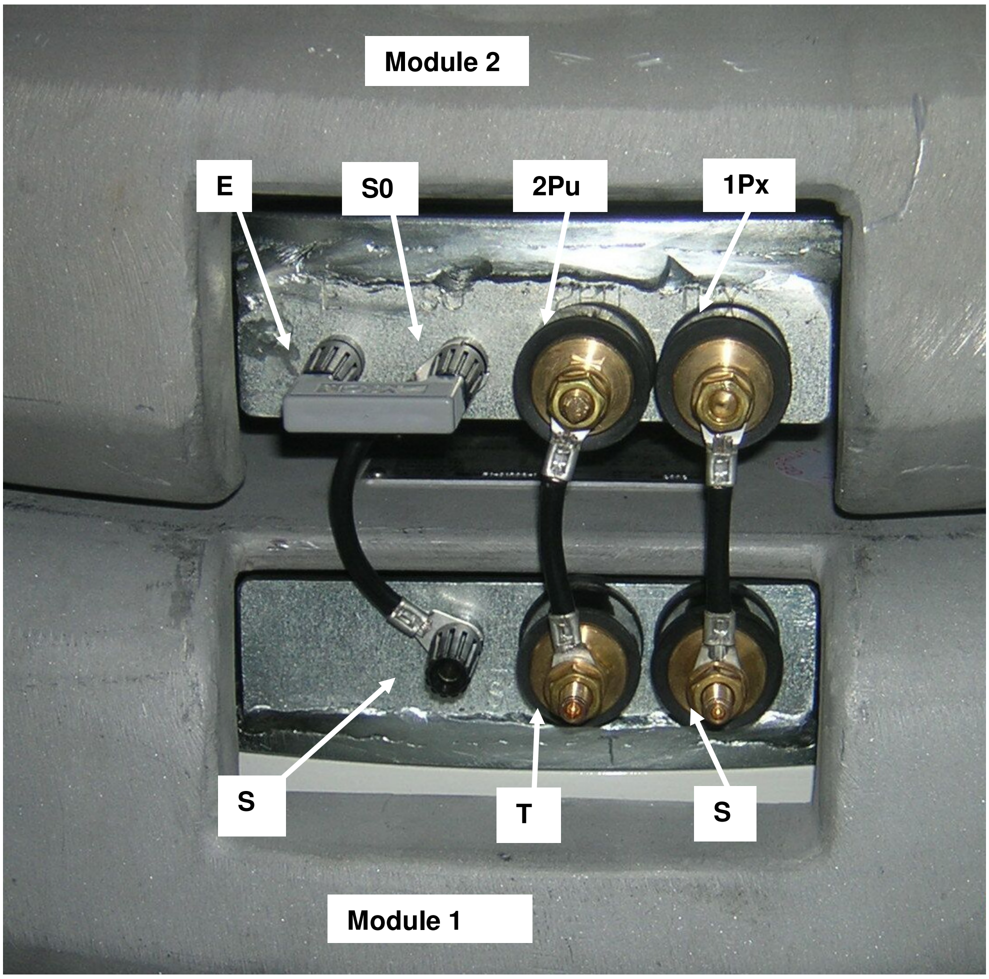

Fig. 61a: Connections between the two modules

Connections with compensating reactors:

- Terminal T of module 1 has to be connected with terminal Ru of the compensating reactor 1. Terminal 2Pu of module 2 has also to be connected to terminal Ru (see figure 61b).
- Terminal S (bushing) of module 1 has to be connected with terminal Rx of the compensating reactor 1. Terminal 1Px of module 2 has also to be connected to terminal Rx (see figure 61b).
- Terminal S (Multi-contact socket) of module 1 has to be connected with terminal S0 of module 2. The connection has to be done over a blind terminal at the compensation reactor 1 (see figure 61b).
- Terminal S0 of module 2 has to be connected with terminal E of module 2 (Mutli-contact sockets) (see figure 61b).
- Terminal T of module 2 has to be connected to terminal Ru of the compensationg reactor 2 (see figure 61c).
- Terminal S of module 2 has to be connenced to terminal Rx of the compensating reactor 2 (see figure 61c).

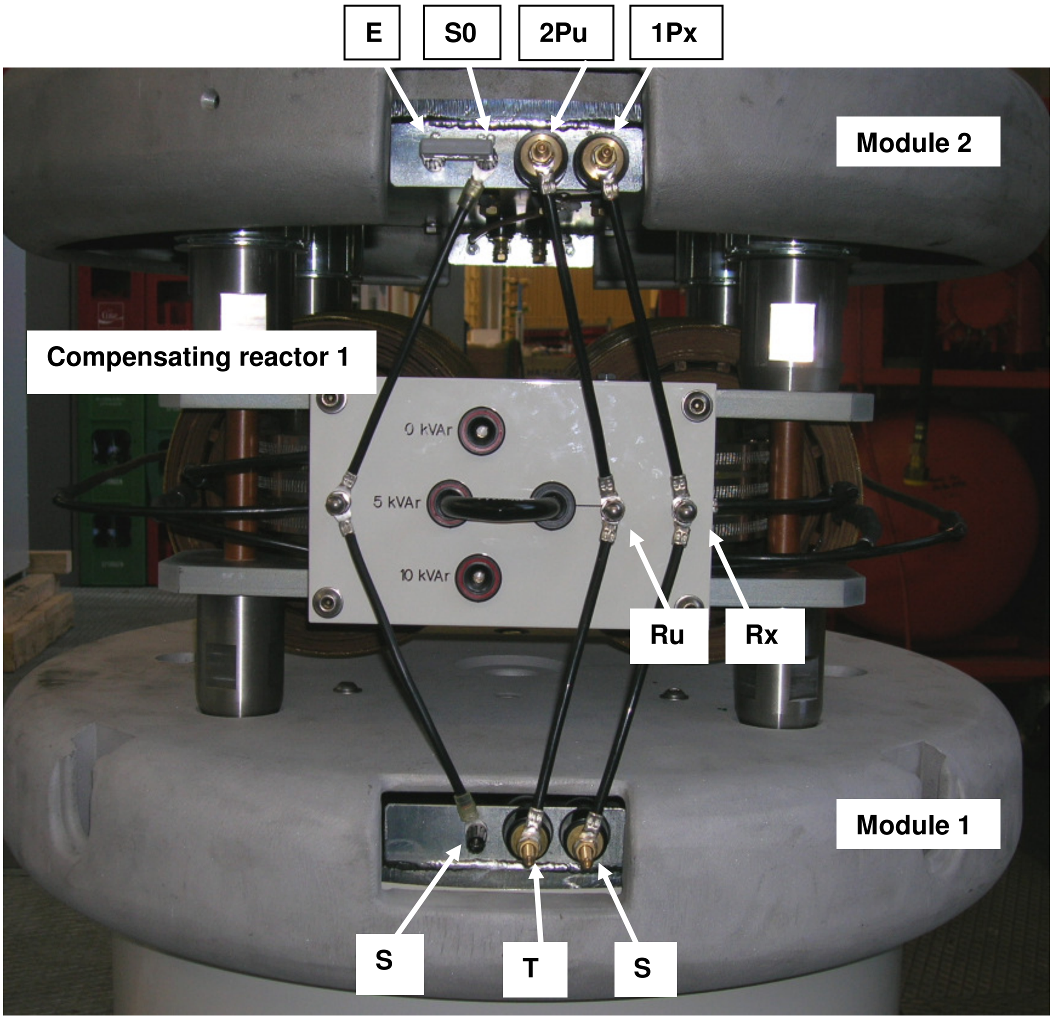

Fig. 61b: Connections between the two modules and the compensating reactor

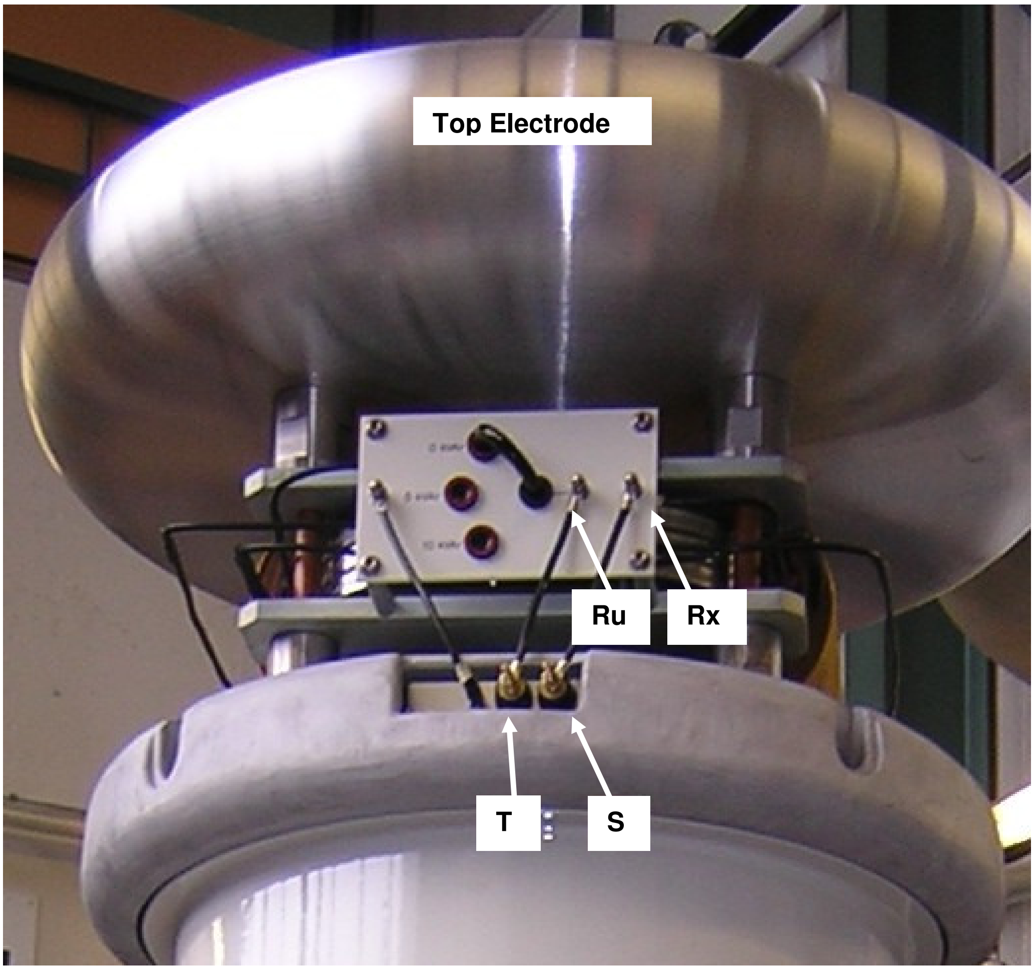

Fig. 61c: Connections between the last module and compensating reactor

The required power range for each compensation reactor has to be selected by a wire bridge. Following positions are available:

- 10 kVAr
- 5 kVAr
- 0 kVAr (disconnected)

3 stages transformer cascade

Figure 62a shows a schematic diagram with the connections for a 3 stages transformer cascade without compensating reactors. Figure 60b shows the schematic diagram for a 3 stages cascade with compensating reactors.

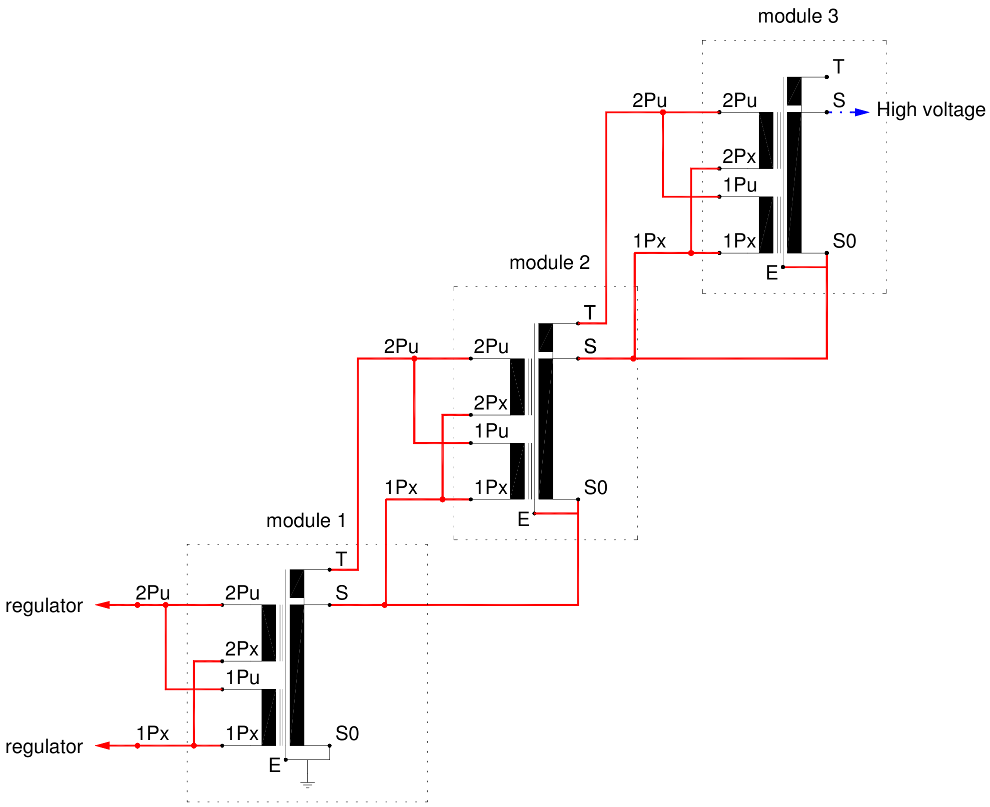

Fig. 62a: Schematic diagram for cascade connection of three test transformers

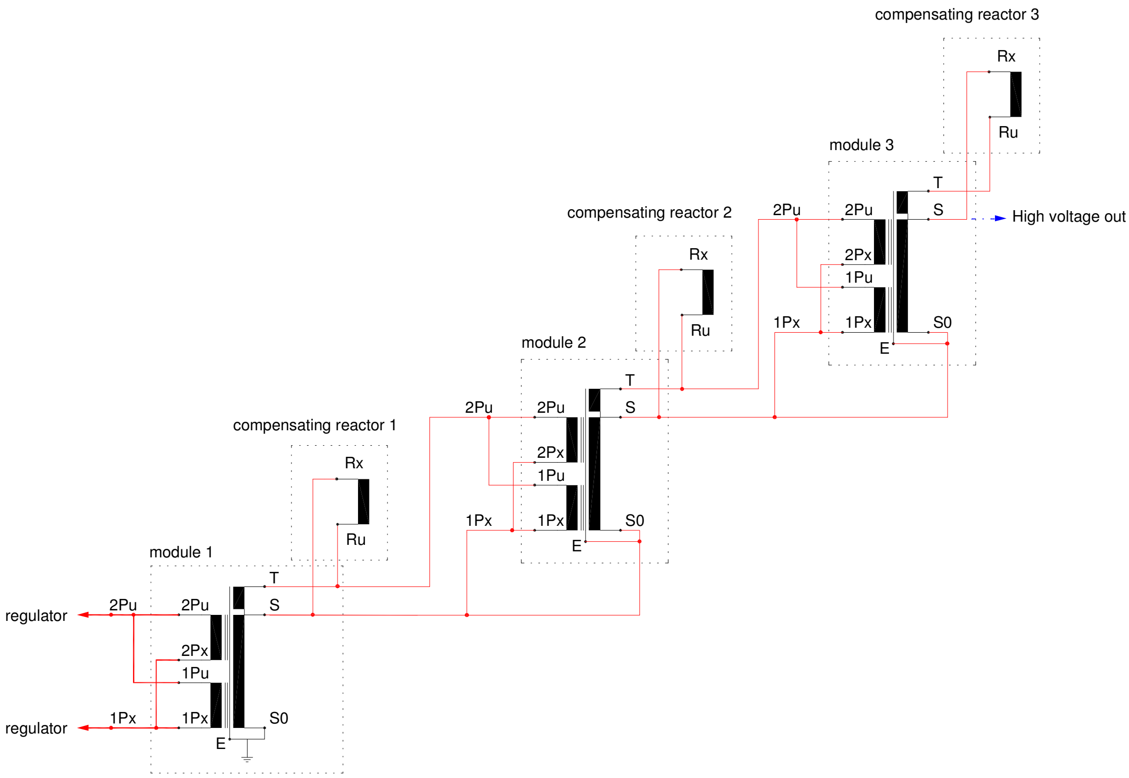

Fig. 62a: Schematic 3 stages with compensation reactor

- Module 1 has to be connected to earth.
- Terminal S0 of module 1 has to be connected with terminal E of module 1 (these two terminals are realized as Mutli-contact sockets) (see figure 61).
- The primary windings of all test transformers has to be connected in parallel with the Multi-contact plugs (see figure 59), i.e. 1Px has to be connected with 2Px, and 1Pu has to be connected with 2Pu.

Connections without compensating reactors:

- Terminal T of module 1 has to be connected with terminal 2Pu of module 2 (these two terminals are realized as bushings) (see figure 61a).
- Terminal S of module 1 has to be connected with terminal 1Px of module 2 (these two terminals are realized as bushings) (see figure 61a).
- Terminal S of module 1 has to be connected with terminal S0 of module 2 (these two terminals are realized as Mutli-contact sockets) (see figure 61a).
- Terminal S0 of module 2 has to be connected with terminal E of module 2 (these two terminal are realized as Mutli-contact sockets) (see figure 61a).
- Terminal T of module 2 has to be connected with terminal 2Pu of module 3 (these two terminals are realized as bushings) (see figure 61a).
- Terminal S of module 2 has to be connected with terminal 1Px of module 3 (these two terminals are realized as bushings) (see figure 61a).

- Terminal S of module 2 has to be connected with terminal S0 of module 3 (these two terminals are realized as Mutli-contact sockets) (see figure 61a).
- Terminal S0 of module 3 has to be connected with terminal E of module 3 (these two terminals are realized as Mutli-contact sockets) (see figure 61a).

Connections with compensating reactors:

- Terminal T of module 1 has to be connected with terminal Ru of the compensating reactor 1. Terminal 2Pu of module 2 has also to be connected to terminal Ru (see figure 61b).
- Terminal S (bushing) of module 1 has to be connected with terminal Rx of the compensating reactor 1. Terminal 1Px of module 2 has also to be connected to terminal Rx (see figure 61b).
- Terminal S (Multi-contact socket) of module 1 has to be connected with terminal S0 of module 2. The connection has to be done over a blind terminal at the compensation reactor 1 (see figure 61b).
- Terminal S0 of module 2 has to be connected with terminal E of module 2 (Mutli-contact sockets) (see figure 61b).
- Terminal T of module 2 has to be connected with terminal Ru of the compensating reactor 2. Terminal 2Pu of module 3 has also to be connected to this terminal Ru (see figure 61b).
- Terminal S (bushing) of module 2 has to be connected with terminal Rx of the compensating reactor 2. Terminal 1Px of module 3 has also to be connected to this terminal Rx (see figure 61b).
- Terminal S (Multi-contact socket) of module 2 has to be connected with terminal S0 of module 3. The connection has to be done over a blind terminal at the compensation reactor 2 (see figure 61b).
- Terminal S0 of module 3 has to be connected with terminal E of module 3 (Mutli-contact sockets) (see figure 61b).
- Terminal T of module 3 has to be connected to terminal Ru of the compensationg reactor 3 (see figure 61c).
- Terminal S of module 3 has to be connencted to terminal Rx of the compensating reactor 3 (see figure 61c).

Preparation for first putting into operation

Before the system can be put into operation it is absolutely necessary to study the chapter 'Safety' detailed.

A specialist of Haefely Test AG should generally make the first commissioning.

It is basically recommended to first operate the low voltage components of the system without connection to the high voltage components to make sure of their faultless function.

Condition

Condition for this is, that all components of the system are assembled, connected and operative according to the manual.

Procedure

- Cut the system OFF the electric mains.
- Disconnect the cable connection between the regulating transformer and the test transformer.
- Connect a voltmeter to the output of the regulating transformer instead of the cable connection.

For the selection of the voltage meter it is necessary to pay attention to the max. output voltage of the regulating transformer.

- Connect the system with the electric mains.
- Switch on control unit according to the manual.
- Unlock emergency button.
- Make sure, all interlock contacts are closed, regulator is at zero position.
- Switch the primary breaker and the secondary contactor through the control unit on (according to the control unit manual).
- Increase the output voltage at the regulating transformer by the control unit continuously and check the correspondence of the voltage meter and the voltage indication on the control unit.
- Decrease the output voltage at the regulating transformer continuously to zero by the control unit .
- Switch the primary breaker and the secondary contactor through the control unit off (according to the control unit manual)

Can the steps be done without differences out of the tolerance between voltage meter and the voltage indication on the control unit a faultless operation of the low voltage components can be assumed.

- Disconnect the system from the electric mains
- Reinstall the cable connection between regulating transformer and test transformer

Operating Instructions

Introduction

Basically, the control unit does the operation of the system. Detailed information of the following instructions is primary to be taken from the manual of the control unit.

Required components for the different configurations

type	AC voltage			DC voltage			IMP voltage		
	Number of stages			Number of stages			Number of stages		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
PZT 100-0.1	1	2	3	1	1	1	1	1	1
Top EL		1	1						
KDL		1	1						
STL 5	1	1	1	1	1	1	1	1	1
OT 276	1	1	1	1	1	1	1	1	1
DMI 551	1	1	1	1	1	1	1	1	1
DMI 551 AC-Mode	*1*	*1*	*1*						
DMI 551 DC-Mode				*1*	*1*	*1*	*1*	*1*	*1*
DMI 551 IMP-Mode							*1*	*1*	*1*
DMI ZAG							1	1	1
HSV 200		1							
HSV 300			1						
V	1			1	3	3	1	4	8
K	1	2	3	4	11	15	6	13	22

type	AC voltage			DC voltage			IMP voltage		
	Number of stages			Number of stages			Number of stages		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
F(s)	1	1	1	4	6	7	6	8	9
D				3	6	8	5	8	10
IS				2	8	12	2	5	13
EL	1	3	3	1	7	12	1	1	1
Top EL 3G						1			
GS				2	4	6	2	2	2
RL								1	2
RD							1	2	3
RE							1	2	3
RM				1	2	3	1	1	1
CS 25				1	3	5	1	2	3
CB							1	2	3
CM	1	2	3						
ES	1	1	1	1	1	1	1	1	1
RE 2.4				1	1	1	1	1	1
EST	1	1	1	2	2	2	2	2	2
KF							1	2	3
EZK							1	1	1
AKF							1	1	1
ASA							1	1	1
ASB								1	2
NTZ							1	1	1
SEK AC	1	1	1						
SEK DC				1	1	1	1	1	1
MK BNC	1	1	1	1	1	1	2	2	2

Table 1: Components for KIT configurations

The above table shows the required components and the needed quantity to realise the different configuration for AC, DC and Impulse. The build-up of the different configurations is shown in the following chapter.

For the shortcuts of the different components please see chapter “Components” at page 21ff.

Build-up of the different KIT-configurations

The following pictures shows how the KIT-components has to be assembled to realize the different configurations for AC, DC and Impulse according the chapter “Technical description” on page 37ff.

AC-configuration

1 stage

Fig. 63: Build-up AC configuration 1 stage

2 stages

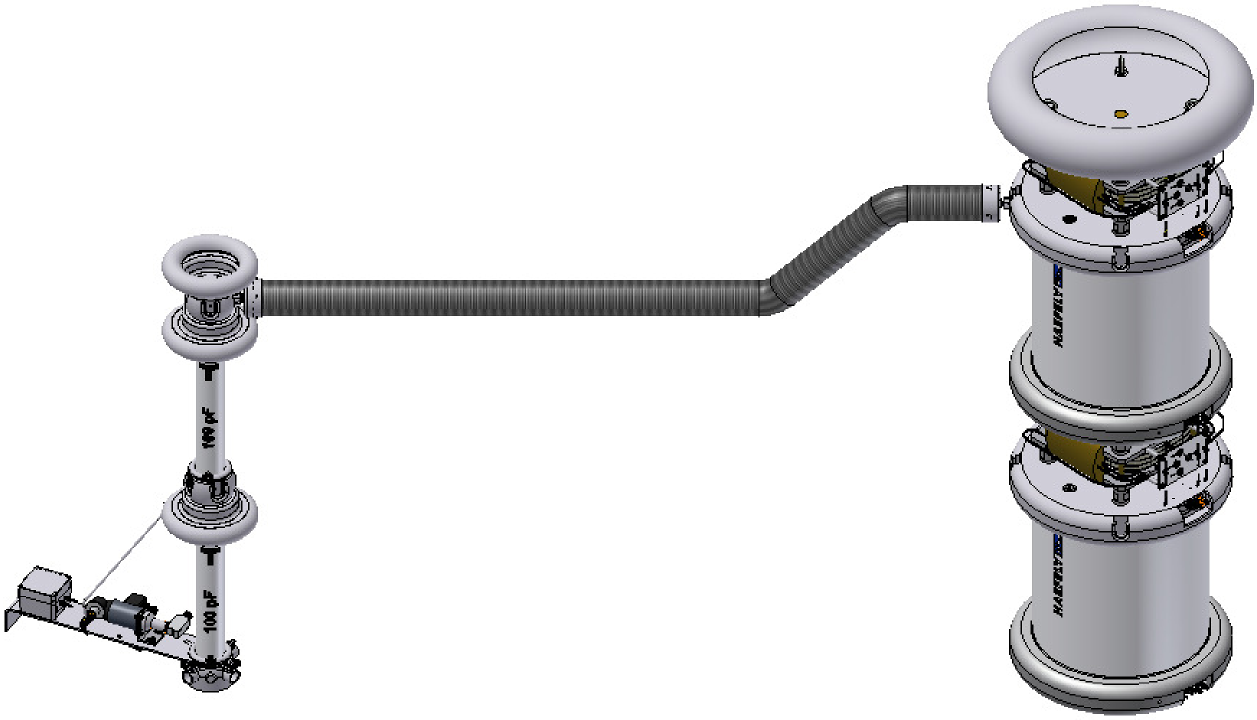

Fig. 64: Build-up AC configuration 2 stages

3 stages

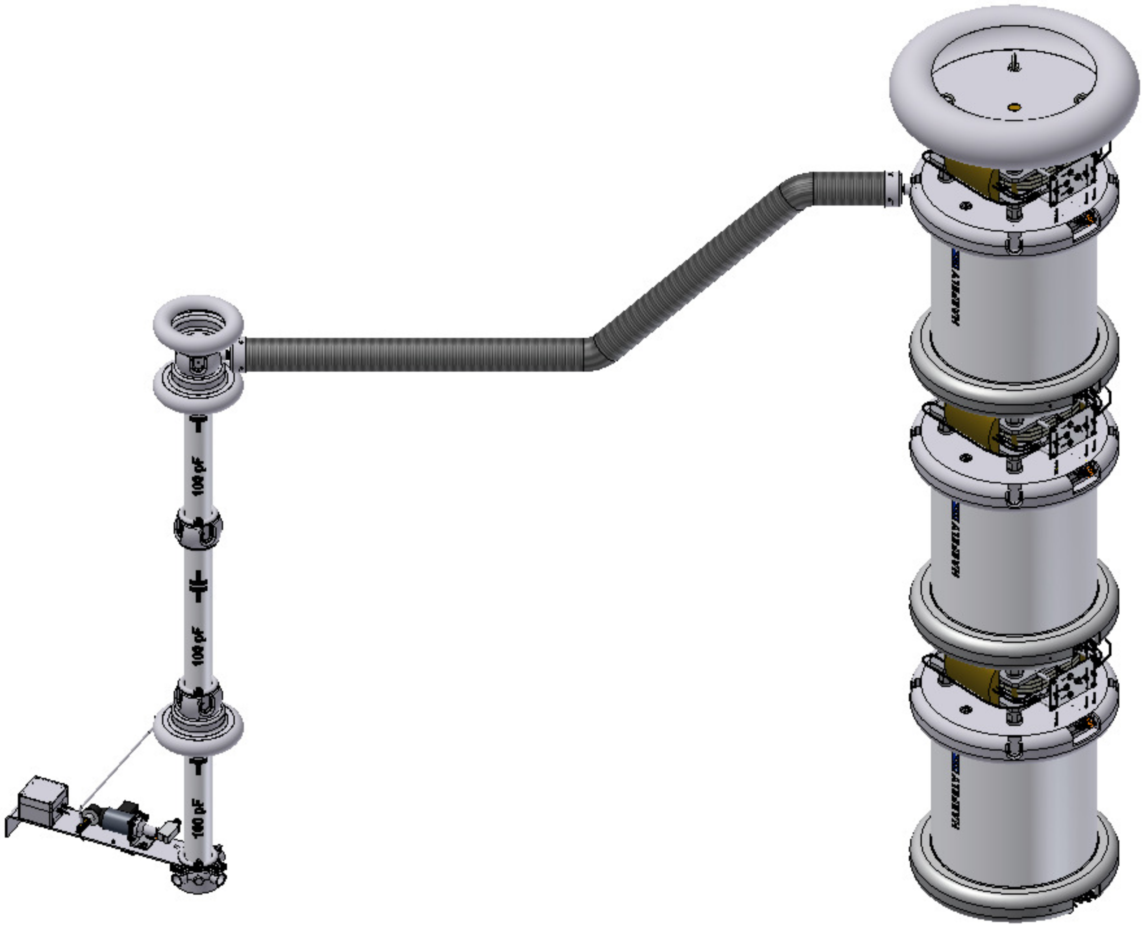

Fig. 65: Build-up AC configuration 3 stages

DC-configuration

1 stage

Fig 66: Build-up DC configuration 1 stage

2 stages

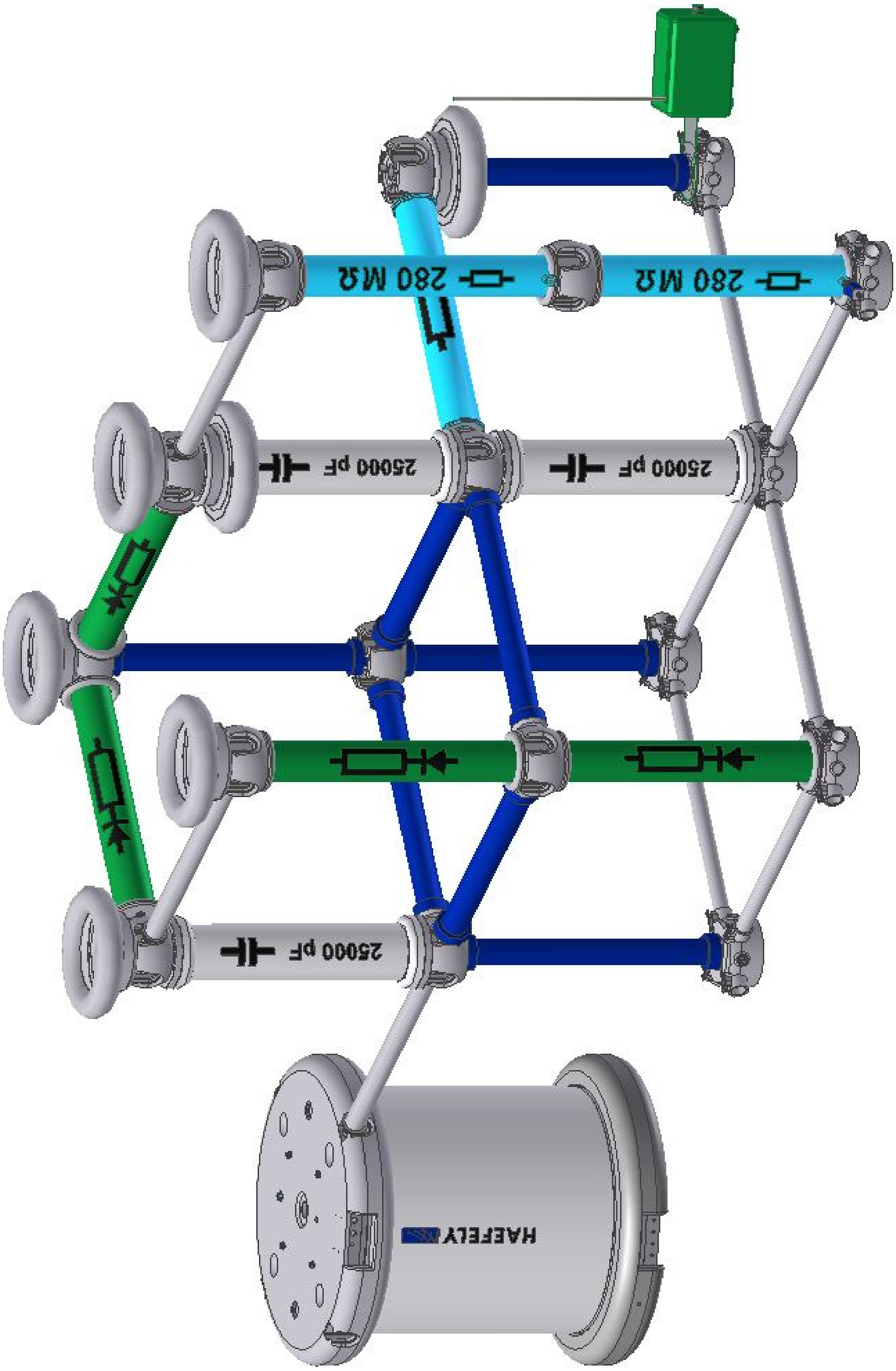

Fig. 67: Build-up DC configuration 2 stages

3 stages

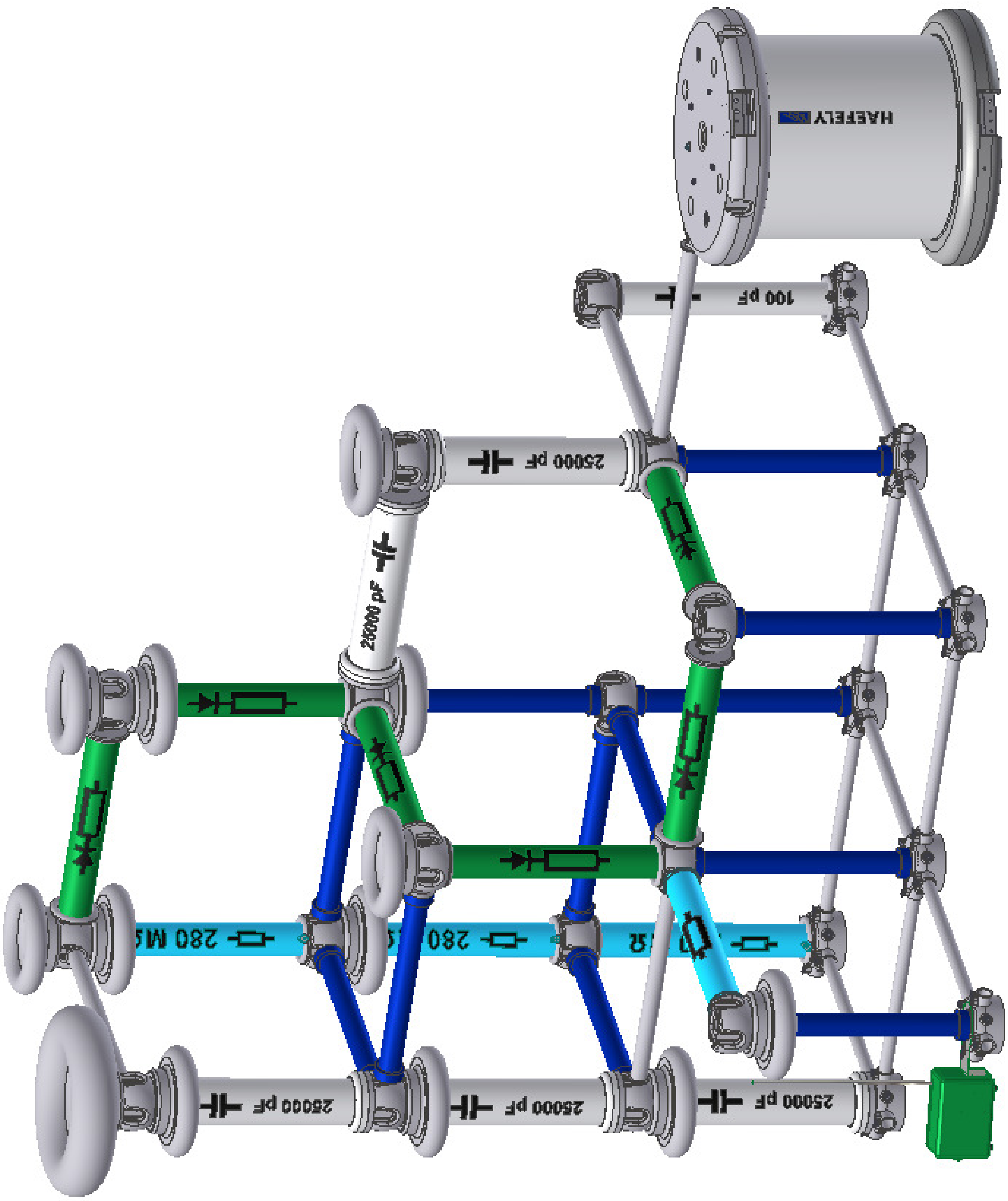

Fig. 68: Build-up DC configuration 3 stages

Impulse configuration

1 stage

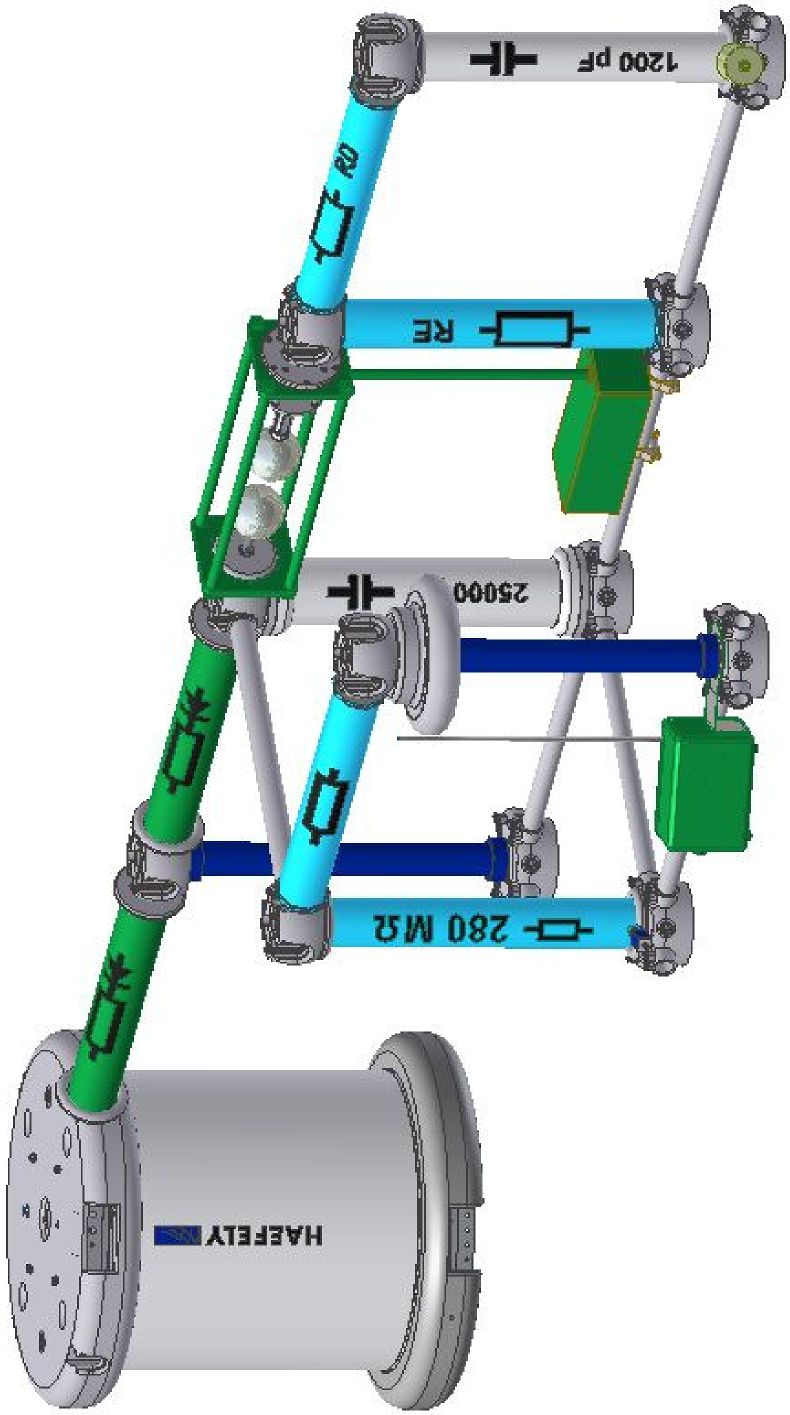

Fig. 69: Build-up Impulse configuration 1 stage

2 stages

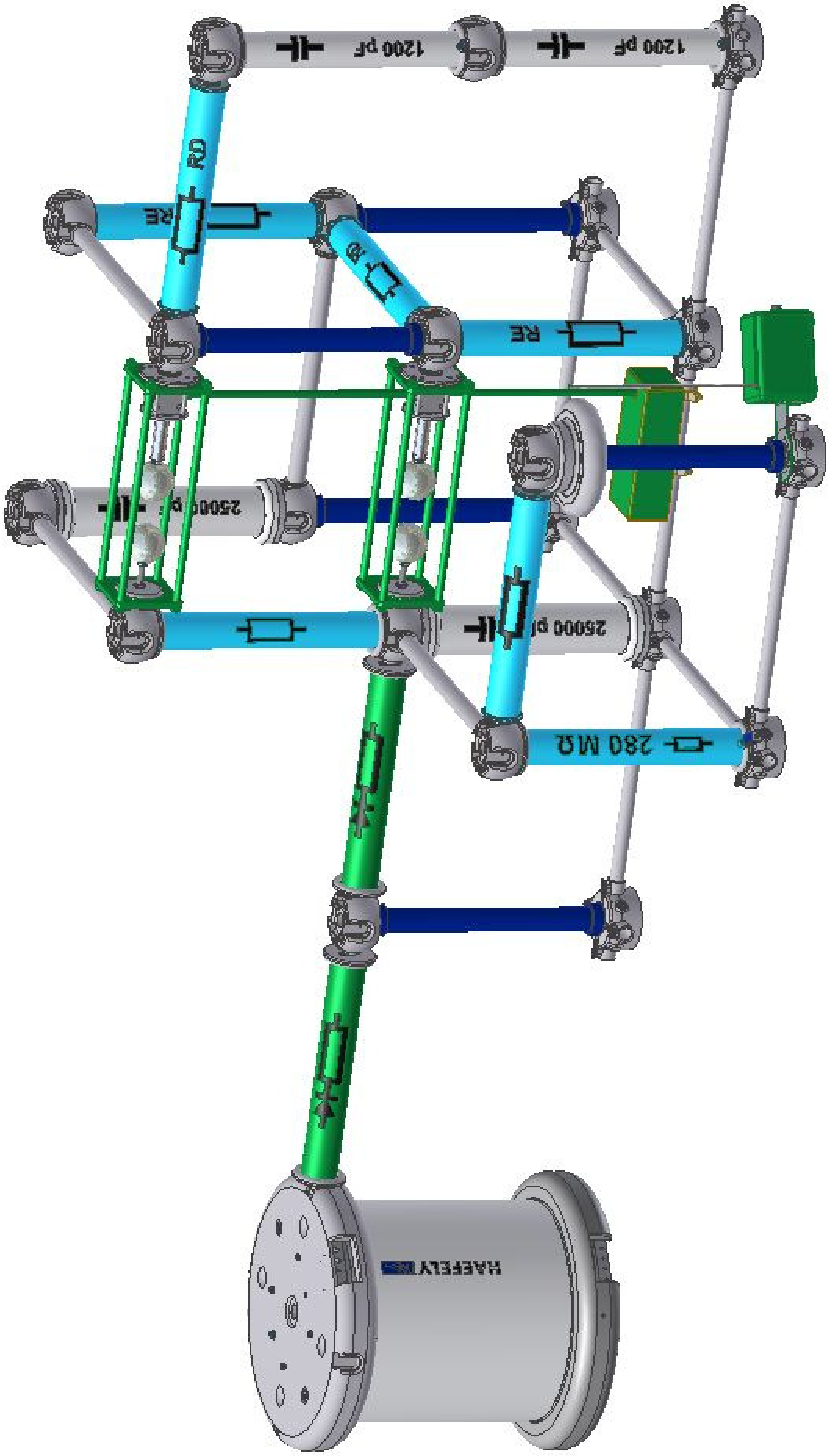

Fig. 70: Build-up Impulse configuration 2 stages

3 stages

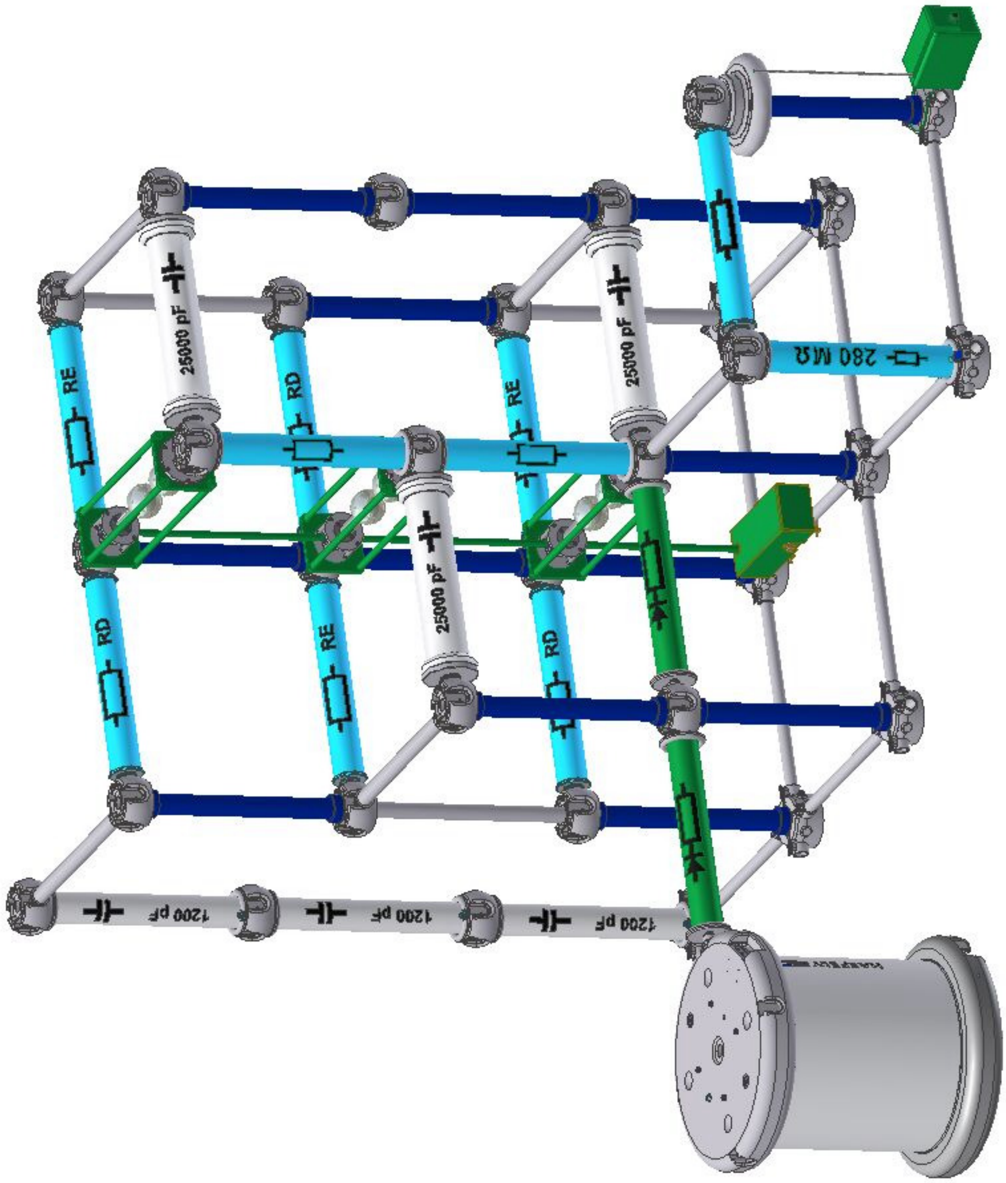

Fig. 71: Build-up Impulse configuration 3 stages

Load ranges of the different KIT-configurations

Technical data is subject to alterations!

AC-configuration

1 stage

		continuous			1h ON, 1h OFF, 4x per day
Regulating tran-former		STL 5	STL 7.5	STL 10	STL 10
Rated voltage [rms]	[kV]	100	100	100	100
Base load (CM)	[pF]	100	100	100	100
Frequency	[Hz]	50	50	50	50
Rated current	[mA]	50	75	90	100
Output	[kVA]	5	7.5	9	10
Impedance voltage (approx.)	[%]	2.6	3.9	4.6	-
Max. capacitive load, Cload	[nF]	1.4	2.3	2.7	3.1
Frequency	[Hz]	60	60	60	60
Rated current	[mA]	50	75	90	100
Output	[kVA]	5	7.5	9	10
Impedance voltage (approx.)	[%]	3.1	4.7	5.6	-
Max. capacitive load, Cload	[nF]	1.2	1.9	2.3	2.5

Table 2: Load range AC 1 stage

Impedance voltage relates to rated power continuous and rated frequency

2 stages

Without compensating reactor:

		continuous		
Regulating transformer		STL 5	STL 7.5	STL 10
Rated voltage [rms]	[kV]	200	200	200
Base load (2 x CM)	[pF]	50	50	50
Frequency	[Hz]	50	50	50
Rated current	[mA]	15	30	38
Output	[kVA]	3	6	7.6
Impedance voltage (ap-prox.)	[%]	4	7	8
Max. capacitive load, Cload	[pF]	180	420	550
Frequency	[Hz]	60	60	60
Rated current	[mA]	15	28	36
Output	[kVA]	3	5.6	7.2
Impedance voltage (approx.)	[%]	5	8	10
Max. capacitive load, Cload	[nF]	0.15	0.32	0.42

Table 3a: Load range AC 2 stages without compensating reactors

With compensating reactor:

		continuous			1h ON, 1h OFF, 4x per day
Regulating tran-former		STL 5	STL 7.5	STL 10	STL 10
Rated voltage [rms]	[kV]	200	200	200	200
Base load (CM)	[pF]	50	50	50	50
Frequency	[Hz]	50	50	50	50
Rated current	[mA]	39	75	80	100
Output	[kVA]	7.8	15	16	20
Max. capacitive load, Cload	[nF]	0.57	1.15	1.2	1.55
Frequency	[Hz]	60	60	60	60
Rated current	[mA]	36	65	80	100
Output	[kVA]	7.2	13	16	20
Max. capacitive load, Cload	[nF]	0.4	0.75	0.95	1.25

Table 3b: Load range AC 2 stages with compensating reactors

3 stages

Without compensating reactor:

		continuous	
Regulating transformer		STL 7.5	STL 10
Rated voltage [rms]	[kV]	300	300
Base load (3 x CM)	[pF]	33	33
Frequency	[Hz]	50	50
Rated current	[mA]	10	10
Output	[kVA]	3	3
Impedance voltage (approx.)	[%]	8	9
Max. capacitive load, Cload	[pF]	70	70
Frequency	[Hz]	60	60
Rated current	[mA]	5	5
Output	[kVA]	1.5	1.5
Impedance voltage (approx.)	[%]	8	9
Max. capacitive load, Cload	[pF]	10	10

Table 4a: Load range AC 3 stages without compensating reactors

With compensating reactor:

		continuous			1h ON, 1h OFF, 4x per day
Regulating tran-former		STL 5	STL 7.5	STL 10	STL 10
Rated voltage [rms]	[kV]	300	300	300	300
Base load (CM)	[pF]	33	33	33	33
Frequency	[Hz]	50	50	50	50
Rated current	[mA]	20	60	80	-
Output	[kVA]	6	18	24	-
Max. capacitive load, Cload	[pF]	175	595	815	-
Frequency	[Hz]	60	60	60	60
Rated current	[mA]	17	50	60	80
Output	[kVA]	5.1	15	18	24
Max. capacitive load, Cload	[pF]	115	405	495	675

Table 4b: Load range AC 3 stages with compensating reactors

DC-configuration

⚠

The divider is always part of the load!

1 stage

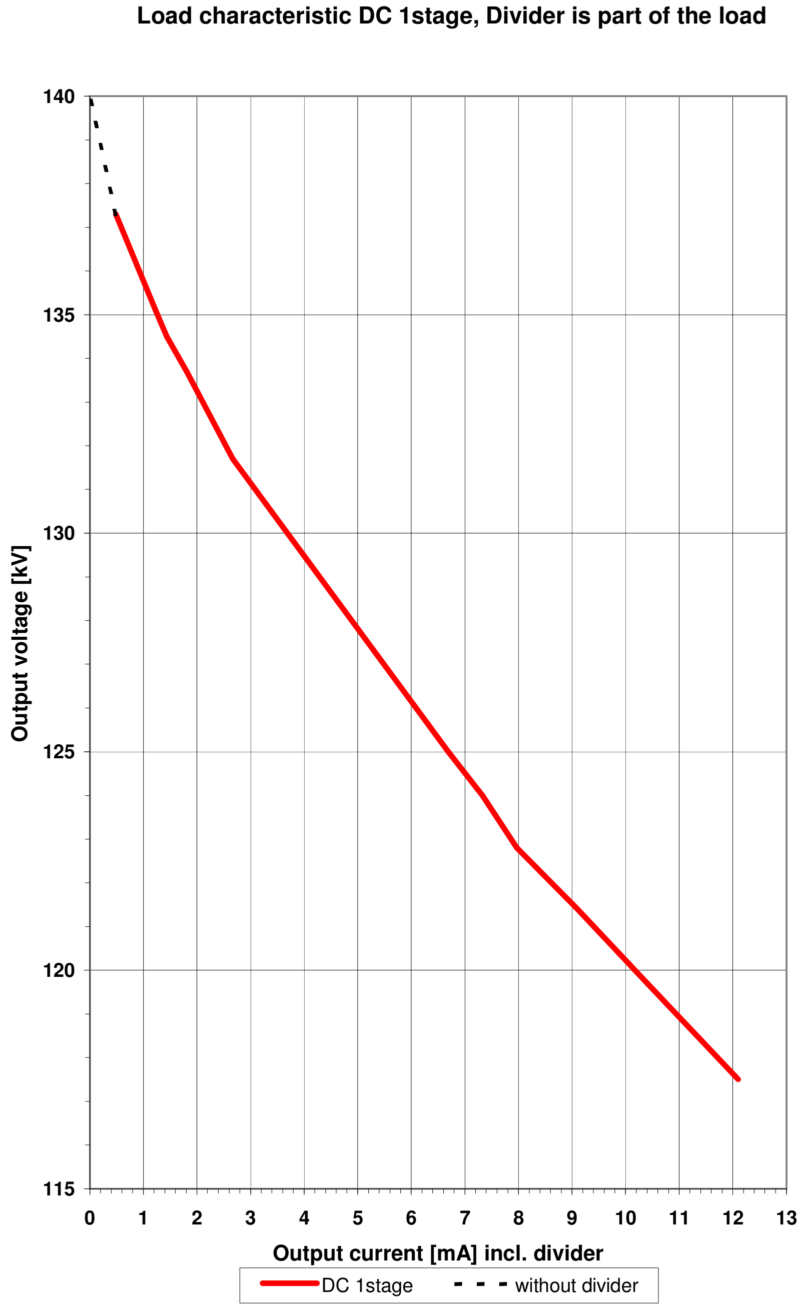

Diagram 1: Load range DC 1 stage

With divider an output voltage of approx. 137kV is possible.

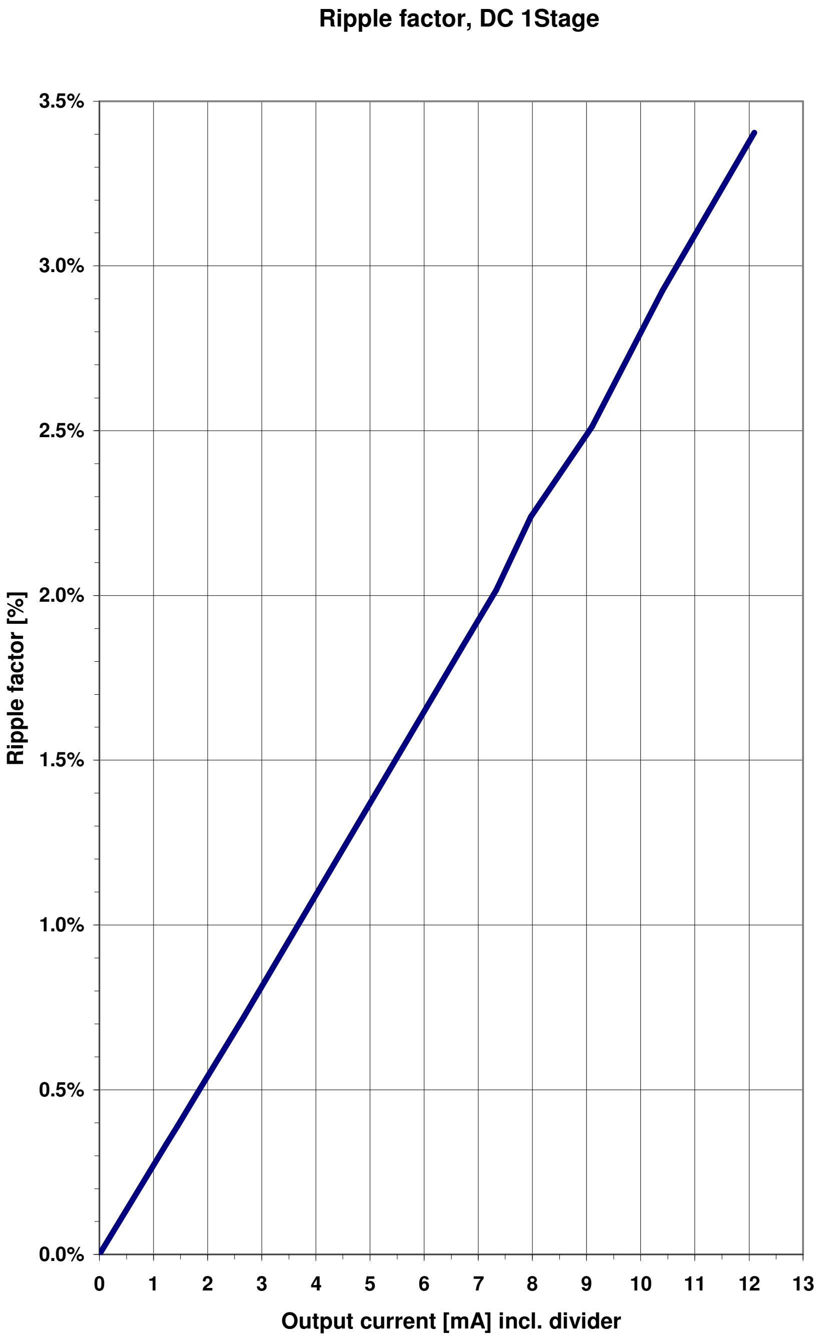

Diagram 2: Ripple factor DC 1 stage

For a ripple factor of 3% an output current including divider of approx. 10mA is possible.

2 stages

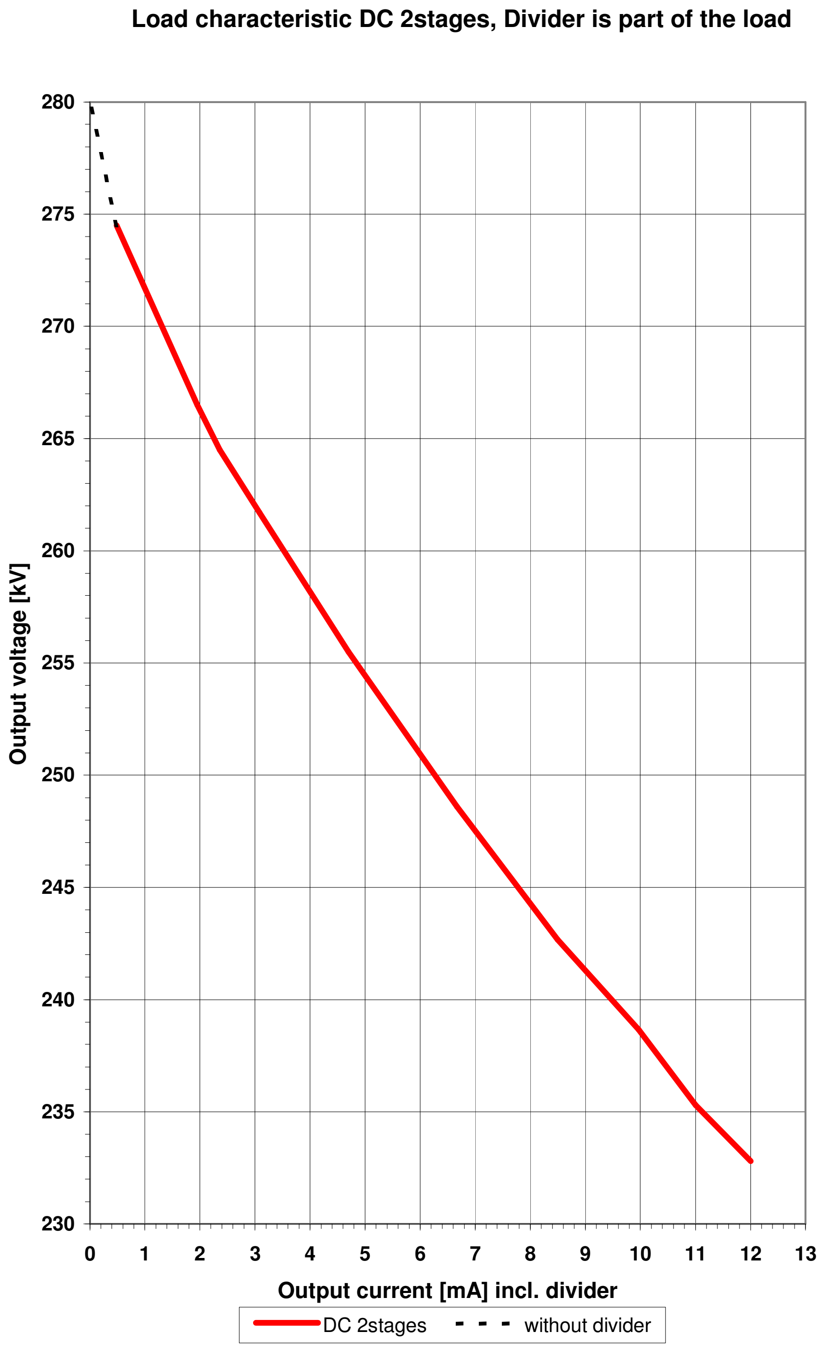

Diagram 3: Load range DC 2 stages

With divider an output voltage of approx. 274kV is possible.

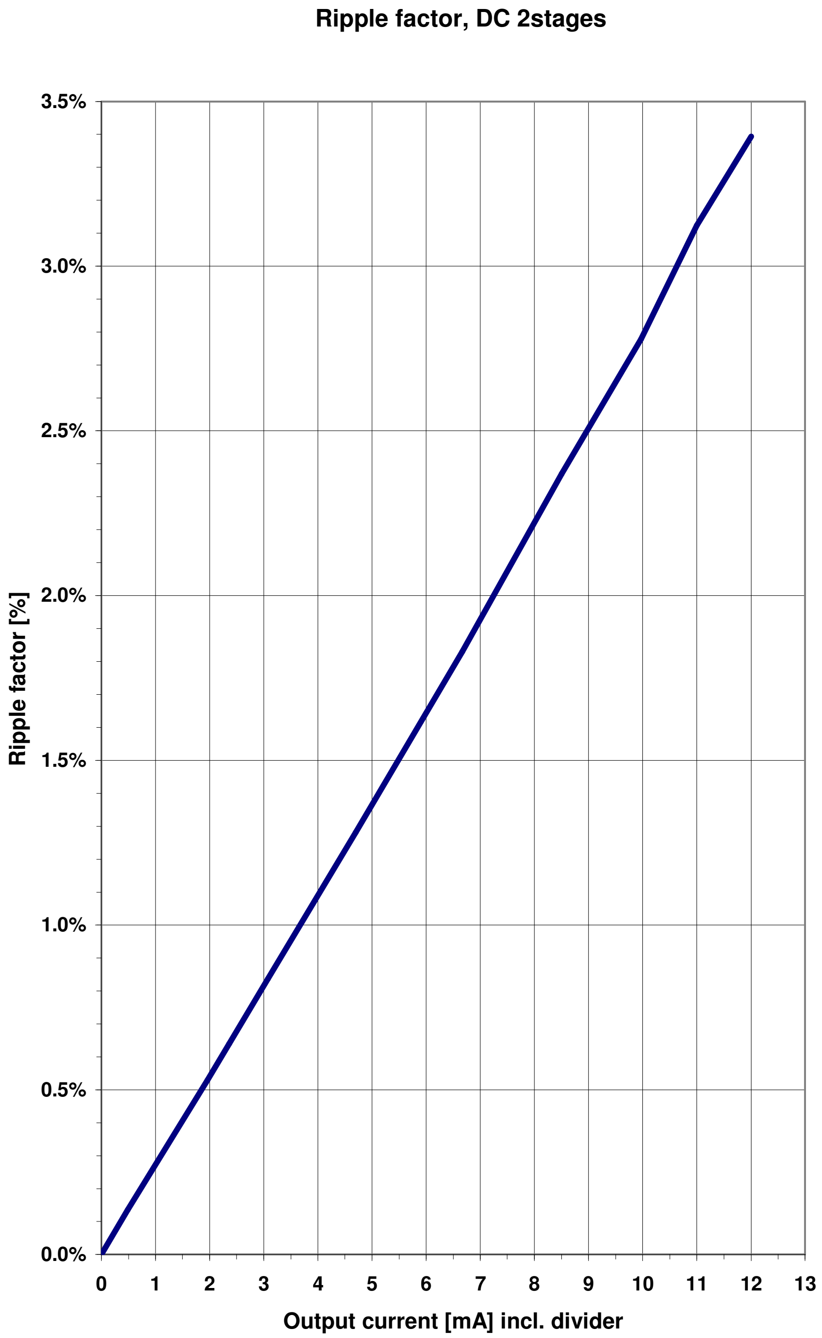

Diagram 4: Ripple factor DC 2 stages

For a ripple factor of 3% an output current including divider of approx. 10mA is possible.

3 stages

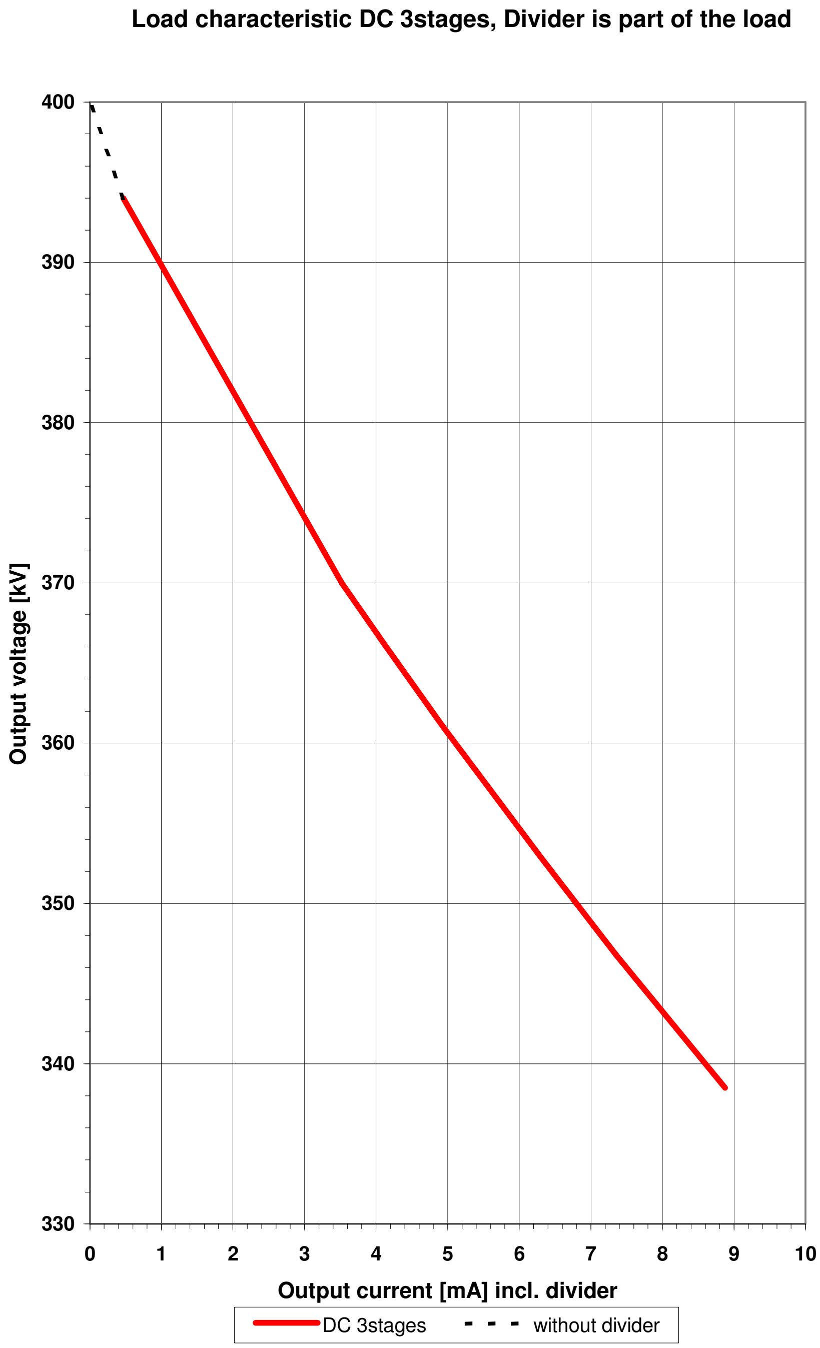

Diagram 5: Load range DC 3 stages

With divider an output voltage of approx. 394kV is possible.

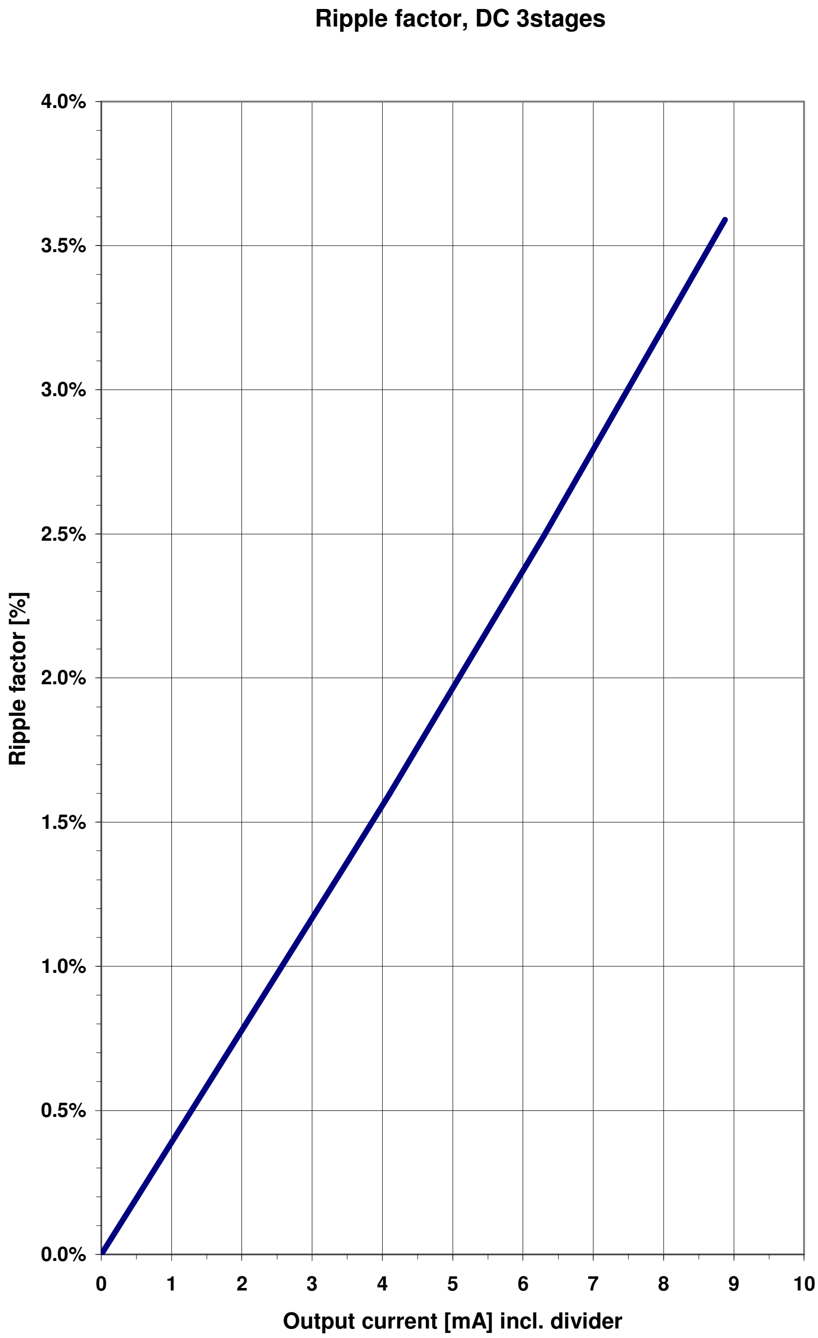

Diagram 6: Ripple factor DC 3 stages

For a ripple factor of 3% an output current including divider of approx. 7.4mA is possible.

Impulse-configuration

There are existing for lightning (LI) and switching (SI) impulse four different wave front resistors RD_A to RD_D (see table 5) to realize different load configurations.

Resistor name	LI (IEC 60060-1)	SI (IEC 60060-1)
RD_A	355Ω	55kΩ
RD_B	220Ω	35kΩ
RD_C	140Ω	22kΩ
RD_D	95Ω	15kΩ

Table 5: Wave front resistors and their values

It has to taken into consideration that the divider for impulse measurement is a pure capacitive voltage divider, i.e. due to the not existing ohmic damping oscillations in the waveform could be occur if the impulse is recorded with an oscilloscope.

1 stage

		Impulse Capacitance	
		25nF (1x CS25)	
Max. total charging voltage	[kV]	140	
Max. energy at max. charging voltage	[J]	250	
Max. output voltage LI no load	[kV]	125	
Max. output voltage LI max. load	[kV]	100	
Max. capacitive load for LI	[pF]	6100	
Max. output voltage SI no load	[kV]	118	
Max. output voltage SI max. load	[kV]	99	
Max. capacitive load for SI	[pF]	5000	

Table 6: Impulse single stage

Basic configuration per stage:		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Load capacitor, CB (divider)	[nF]	1.2		1.2	
Wave tail resistor, RE	[kΩ]	**2.4**		**120**	

Table 7: Basic configuration per stage

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_A	[Ω]	**355**		**55000**	
Load range with RD_A, Cload	[pF]	0...400		0...300	
Output voltage at min. load with RD_A	[kV]	125		118	
Output voltage at max. load with RD_A	[kV]	122		115	

Table 8: Load range for wave front resistor RD_A

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_B	[Ω]	**220**		**35000**	
Load range with RD_B, Cload	[pF]	250...1500		220...1200	
Output voltage at min. load with RD_B	[kV]	124		119	
Output voltage at max. load with RD_B	[kV]	117		112	

Table 9: Load range for wave front resistor RD_B

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_C	[Ω]	**140**		**22000**	
Load range with RD_C, Cload	[pF]	1300...3300		1100...2800	
Output voltage at min. load with RD_C	[kV]	120		115	
Output voltage at max. load with RD_C	[kV]	110		106	

Table 10: Load range for wave front resistor RD_C

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_D	[Ω]	**95**		**15000**	
Load range with RD_D, Cload	[pF]	3000...6100		2300...5000	
Output voltage at min. load with RD_D	[kV]	112		111	
Output voltage at max. load with RD_D	[kV]	100		99	

Table 11: Load range for wave front resistor RD_D

2 stages

		Impulse Capacitance	
		25nF (1x CS25)	
Max. total charging voltage	[kV]	280	
Max. energy at max. charging voltage	[J]	490	
Max. output voltage LI no load	[kV]	249	
Max. output voltage LI max. load	[kV]	196	
Max. capacitive load for LI	[pF]	3500	
Max. output voltage SI no load	[kV]	234	
Max. output voltage SI max. load	[kV]	198	
Max. capacitive load for SI	[pF]	3500	

Table 12: Impulse two stages

Basic configuration per stage:		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Load capacitor, CB (divider)	[nF]	1.2		1.2	
Charging resistor, RL	[MΩ]	**2.5**		**2.5**	
Wave tail resistor, RE	[kΩ]	**2.4**		**120**	

Table 13: Basic configuration per stage

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_A	[Ω]	**355**		**55000**	
Load range with RD_A, Cload	[pF]	0...200		0...150	
Output voltage at min. load with RD_A	[kV]	249		234	
Output voltage at max. load with RD_A	[kV]	243		229	

Table 14: Load range for wave front resistor RD_A

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_B	[Ω]	**220**		**35000**	
Load range with RD_B, Cload	[pF]	150...710		120...600	
Output voltage at min. load with RD_B	[kV]	248		237	
Output voltage at max. load with RD_B	[kV]	235		222	

Table 15: Load range for wave front resistor RD_B

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_C	[Ω]	**140**		**22000**	
Load range with RD_C, Cload	[pF]	650...1600		570...1400	
Output voltage at min. load with RD_C	[kV]	239		229	
Output voltage at max. load with RD_C	[kV]	221		212	

Table 16: Load range for wave front resistor RD_C

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_D	[Ω]	**95**		**15000**	
Load range with RD_D, Cload	[pF]	1500...3500		1200...2500	
Output voltage at min. load with RD_D	[kV]	225		220	
Output voltage at max. load with RD_D	[kV]	196		198	

Table 17: Load range for wave front resistor RD_D

3 stages

		Impulse Capacitance	
		25nF (1x CS25)	
Max. total charging voltage	[kV]	420	
Max. energy at max. charging voltage	[J]	740	
Max. output voltage LI no load	[kV]	373	
Max. output voltage LI max. load	[kV]	305	
Max. capacitive load for LI	[pF]	2000	
Max. output voltage SI no load	[kV]	350	
Max. output voltage SI max. load	[kV]	295	
Max. capacitive load for SI	[pF]	1700	

Table 18: Impulse three stages

Basic configuration per stage:		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Load capacitor, CB (divider)	[nF]	1.2		1.2	
Charging resistor, RL	[MΩ]	**2.5**		**2.5**	
Wave tail resistor, RE	[kΩ]	**2.4**		**120**	

Table 19: Basic configuration per stage

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_A	[Ω]	**355**		**55000**	
Load range with RD_A, Cload	[pF]	0...130		0...100	
Output voltage at min. load with RD_A	[kV]	373		350	
Output voltage at max. load with RD_A	[kV]	365		341	

Table 20: Load range for wave front resistor RD_A

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_B	[Ω]	**220**		**35000**	
Load range with RD_B, Cload	[pF]	80...450		80...400	
Output voltage at min. load with RD_B	[kV]	373		354	
Output voltage at max. load with RD_B	[kV]	355		332	

Table 21: Load range for wave front resistor RD_B

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_C	[Ω]	**140**		**22000**	
Load range with RD_C, Cload	[pF]	430...1100		380...950	
Output voltage at min. load with RD_C	[kV]	359		340	
Output voltage at max. load with RD_C	[kV]	329		316	

Table 22: Load range for wave front resistor RD_C

		LI (IEC 60060-1)		SI (IEC 60060-1)	
Smoothing capacitor, CS	[nF]	25		25	
Wave front resistor RD_D	[Ω]	**95**		**15000**	
Load range with RD_D, Cload	[pF]	1000...2000		790...1700	
Output voltage at min. load with RD_D	[kV]	338		329	
Output voltage at max. load with RD_D	[kV]	305		295	

Table 23: Load range for wave front resistor RD_D

Switch on procedure

Condition

Generally only trained people are allowed to operate the system.

Before the system can be put into operation it is absolutely necessary to study the chapter ‘Safety’ detailed.

All components of the chosen configuration have to be assembled, connected and operative.

System has to be connected to the chosen electric mains.

Procedure

- Switch on control unit according to its manual
- Unlock emergency-button
- Switch on low voltage: close the primary breaker at the regulating transformer by the control unit (according to the control unit manual)
- Make sure, no humans are in the danger zone
- Remove earth bar from the system
- Switch on the high voltage: close the secondary switch at the regulating transformer by the control unit (according to the control unit manual)

Operation

Normal operation

After switching on the high voltage, the output voltage of the system can be varied by the control unit and the chosen tests and measurements can be done.

Abnormal occurrence

In case of irregularities during tests and measurements the system will be selectively shut off depending on the control unit.

Switch off procedure

Procedure

- Decrease the output voltage at the regulating transformer continuously to zero by the control unit
- Switch off the high voltage: open the secondary switch at the regulating transformer by the control unit (according to the control unit manual)
- Press emergency button
- Open the interlock (safety circuits) contacts
- All high-voltage parts have to be grounded with the grounding rod.

If test with DC-voltage are performend (DC or Impulse configuration) extra care is essential when grounding capacitors, see chapter “Special information concerning DC-voltage”, page 7.

- Put earth bar into the system.
- Switch off low voltage: open the primary breaker at the regulating transformer by the control unit (according to the control unit manual)
- Switch off control unit according to its manual
- (Disconnect system from the electric mains)

Emergency switch off

Switch off

By pressing the emergency button the system will be switched off until the input of the regulating transformer in any operating state.

The switch off procedure of the system with an output voltage unequal zero should only be done in case of an emergency, because this procedure means a higher stress for the test object and also for the system.

Restart

After system switch off by the emergency button with an output voltage unequal zero the following procedure has to be done:

- Unlock the emergency button
- Switch on low voltage: close the primary breaker at the regulating transformer by the control unit (according to the control unit manual)
  ⇒ Wait until the regulating transformer is back in the zero position
- Switch on the high voltage: close the secondary switch at the regulating transformer by the control unit (according to the control unit manual)

Options

All system options and their use are mentioned in the chapter general Information under „Components“.

Additional equipment

Additional equipment and their use are mentioned in the chapter general Information under „Components“.

Additional KIT components:

- KF with EZK: electronic trigger sphere (see page 32)
- DKU: vessel for vacuum and pressure (see page 32)
- DKU ZUB: additional set of electrodes (see page 33)
- KR: Corona cage (see page 33)
- OP:oil testing cup (see page 33)
- MF 100: measuring sphere gap (see page 34)
- MF 100 ZUB (see page 34)

Trouble shooting

Errors and Disturbances

How an error or a disturbance is indicated, is strongly depending on the used control unit. The corresponding Information is therefore primary to be looked up in the manual of the control unit.

Basically occurring errors and disturbances are separated into three different classes, depending on their effects:

Alarms: after automatically decreasing the output voltage to zero, the system switches off itself

Interlock: the system will switch off the high voltage immediately

Trips: the system will be switched off until the input of the regulating transformer in any operating state

Basic trouble shooting

In case of an error or a disturbance, the error indication on the control unit should be regarded first. The interpretation of it and the resultant actions have to be taken from the manual of the control unit.

Common failures

- Electric mains are not switched ON
- Emergency button resp. key switch is switched OFF
- Interlock contacts (security circuit) not closed
- Alarms, Trips not set back (optional)
- Wrong current and voltage limiter set (optional)
- Earth bar not removed
- Regulating transformer is not in zero position

Minimum data for reporting a fault

If an error or a disturbance can't be located or solved despite of all in the manuals listed actions, contact the customer support of Haefely Test AG.

For an efficient work, the customer support needs the following system specific information:

- Project number of system KA______.
- Customers name.
- Description of the last actions, before the error or the disturbance occurred, if possible with layout.
- Detailed description of how the error showed itself, if possible with print out or pictures.
- Type of installation.

Maintenance

Utility services

The concerning information has to be taken from the manuals of the individual components.

Support, Maintenance

KIT test systems are normally maintenance-free. Component specific maintenances have to be taken from their manuals.

All connections must be checked regularly to good fitting of the crews.

Cleaning

Because the individual components are made by different materials, there can't be given any general information about detergents and interval.

Before any cleaning, the concerning instructions in the component manual have to be studied.

Repairs

A specialist should generally only do reparations. This means, by a specialist of Haefely Test AG or by a Haefely Test AG authorised person.

The action has to be taken from the respective component manual and/or to be discussed with the customer support of Haefely Test AG.

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To warrant adequate servicing, no general instructions for repair can be given!

Spare parts

Basically, only original replacement parts can be used. Original or equivalent replacement parts can be obtained by Haefely Test AG.

For an efficient work, the customer support needs the following system specific information:

- Project number of system KA______.
- Client’s name.
- System name plate information of the main components, which contains the replaceable part.
- Detailed description of the component that has to be replaced, if possible with picture.
- Type of installation.

Components from sub-suppliers

To possible existing components from third deliverers, it is referred to in the individual manuals.

Onward Transfers

Resale

Haefely Test AG has to be informed if the test equipment will be sold to a third company. In case of a resale the equipment has to be sold complete including all operating instructions, test reports etc.

If the equipment is resold without information to Haefely Test AG, Haefely Test AG rejects any warranty, liability and claims.

Shut down procedure

If the KIT system has to be stored the following items have to be checked:

- Disconnect power, measuring and control cables.
- The floor of the storage place must be suitable concerning the load capacity
- The storage temperature has to be in range of -5 ... +40℃
- The maximum humidity should be <90% (non condensing)

The component specific recommendations have to be taken from the concerning manuals.

Disposal

The information about disposal is very component specific. It is therefore to be taken from the concerning component manual.

Taking back

The question of taking back has to be discussed individually. Please contact the customer support of Haefely Test AG.

Training, Education

Training

Before a person works with or on a system or it’s components, it is absolutely necessary to instruct him/her by a trained person.

Education

If the system is operated irregularly, periodic training helps to prevent user faults and increases user security visibly.

Diagrams, Drawings

Summary

Because the system can be arranged optional with different components (depending on the customers order) the concerning plans and drawings are individually, all put together in a client specific file and can be looked into.

Technical Data

Ambient conditions for storage and operation, system data etc...

Because the system can be arranged optional with different components (depending on the customers order) and the technical data strongly depends on the used components in the system they are to be taken from the following documents:

System

- System test report

Components

- Component test report (if the component is tested separately!)
- Component name plate (if existing)

Test Reports

Summary

Because the system can be arranged optional with different components (depending on the client’s order) the concerning test reports are put individually in a client specific file and can be looked into.