Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3704 (2022-11)

Emergency Power Facilities with Static and Rotary Converters in Nuclear Power Plants

(Notstromanlagen mit statischen und rotierenden Umformern in Kernkraftwerken)

Previous versions of this safety standard
were issued in 1984-06, 1999-06 and 2013-11.

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KTA SAFETY STANDARD

November 2022	**Emergency Power Facilities with Static and Rotary ~~AC/DC~~ Converters in Nuclear Power Plants**	KTA 3704

Previous versions of this safety standard: 1984-06 (BAnz No. 191a of October 9, 1984, Addendum 51/84)
1999-06 (BAnz No. 243b of December 23, 1999)
2013-11 (BAnz AT 17.01.2014 B3)

Contents

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Comments by the Editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of **shall normally** - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, exceptions used shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of the present safety standard.

Basic Principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against damage arising from the construction and operation of the plant (Sec. 7, para. (2), subpara. (3) Atomic Energy Act - AtG) in order to attain the protective goals specified in the AtG, the Radiation Protection Act (StrlSchG) and the Radiation Protection Ordinance (StrlSchV) as well as further detailed in the Safety Requirements for Nuclear Power Plants (SiAnf) and the Interpretations of the SiAnf.

(2) Based on the Safety Requirements and their interpretations, the safety standards KTA 3701 through KTA 3705 specify requirements for the power supply of the safety system.

(3) In the present safety standard, it is presumed that conventional requirements and technical standards (e.g. Accident Protection Requirements, DIN-Standards, VDE-Regulations) are adhered to under consideration of the safety-related requirements specific to nuclear power plants.

(4) General requirements for the electrical power supply in nuclear power plants are specified in safety standard KTA 3701. These also pertain to electronic modules and converters.

(5) Requirements for emergency power generating facilities with diesel generator units in nuclear power plants are specified in safety standard KTA 3702.

(6) Requirements for emergency power generating facilities with batteries and rectifier units in nuclear power plants are specified in safety standard KTA 3703.

(7) Requirements for switchgears, transformers and distribution networks for the electrical power supply of the safety system in nuclear power plants are specified in safety standard KTA 3705.

(8) In KTA safety standards the emergency power facilities are considered as ending at the connection terminals of the power loads. Requirements for the power loads are, therefore, specified in the equipment related safety standards KTA 3501 and KTA 3504.

(9) Basic requirements regarding quality assurance are specified in safety standard KTA 1401.

(10) Requirements regarding the design of nuclear power plants against seismic events are specified in KTA 2201.4.

1 Scope

This safety standard applies to emergency power facilities with static or rotary converters having alternating-current output ports, and it applies to switching power supply units and multi-unit switching power supplies having direct-current outputs used for providing the uninterruptible emergency power supply in stationary nuclear power plants. The scope of the present safety standard is exemplarily shown in **Figure 1-1**.

2 Definitions

(1) Switching power supply unit

A switching power supply unit is a type of converter that contains one or more transformers and one or more electronic circuits and that uses switching semiconductor components to convert electrical energy into various voltages. The internal operating frequency and wave shape are different from the supplied frequency and wave shape; the internal operating frequency is higher than 500 Hz but no higher than 100 MHz. Switching power supply units have direct-current/direct-voltage output ports.

(2) Multi-unit switching power supply

A multi-unit switching power supply is comprised of multiple switching power supply units connected in parallel, and of the corresponding protective and monitoring equipment.

Note:

Multi-unit switching power supplies may be collectively placed in power supply cabinets.

(3) Converters

Converters are devices that convert electrical energy into different voltages and different frequencies.

Note:

A converter may be a rotary converter, a static inverter, a switching power supply unit (DC/DC converter, AC/DC converter).

(4) Converter facility

Converter facilities are rotary converters or static inverters together with the corresponding switch-over devices in a single or multi-train design.

3 General Requirements

(1) The design of converters, switchgear, distribution systems and power loads shall be coordinated with each other such that the static and dynamic limits of the admissible supply voltages for the power loads are not exceeded.

(2) The effects that failure inducing events within the converter facilities or within single converters may have on the nuclear power plant shall be analyzed.

(3) Failure of one converter may not inadmissibly affect any parallel connected converters.

4 Design

4.1 Circuit Design Concept

4.1.1 Circuit design concept for converter facilities

(1) When specifying the circuit design, special consideration shall be given to the redundancy of the supplied systems, and to the effects that component failure of the converter facility have on the reliability of the supplied systems.

(2) Converter facilities supplying train-correlated power loads shall themselves, including their auxiliary equipment, be designed in functionally and spatially separated trains.

(3) Regarding the spatial separation of the train-independent standby converter, the requirement of Section 4.6, para. (2), applies.

(4) Every converter within a specific train shall be supplied from the direct current switchgear of the same train to which the converter belongs (cf. **Figure 1-1**).

(5) Every converter shall feed into the same converter emergency power switchgear of the same train to which the converter belongs (cf. **Figure 1-1**)

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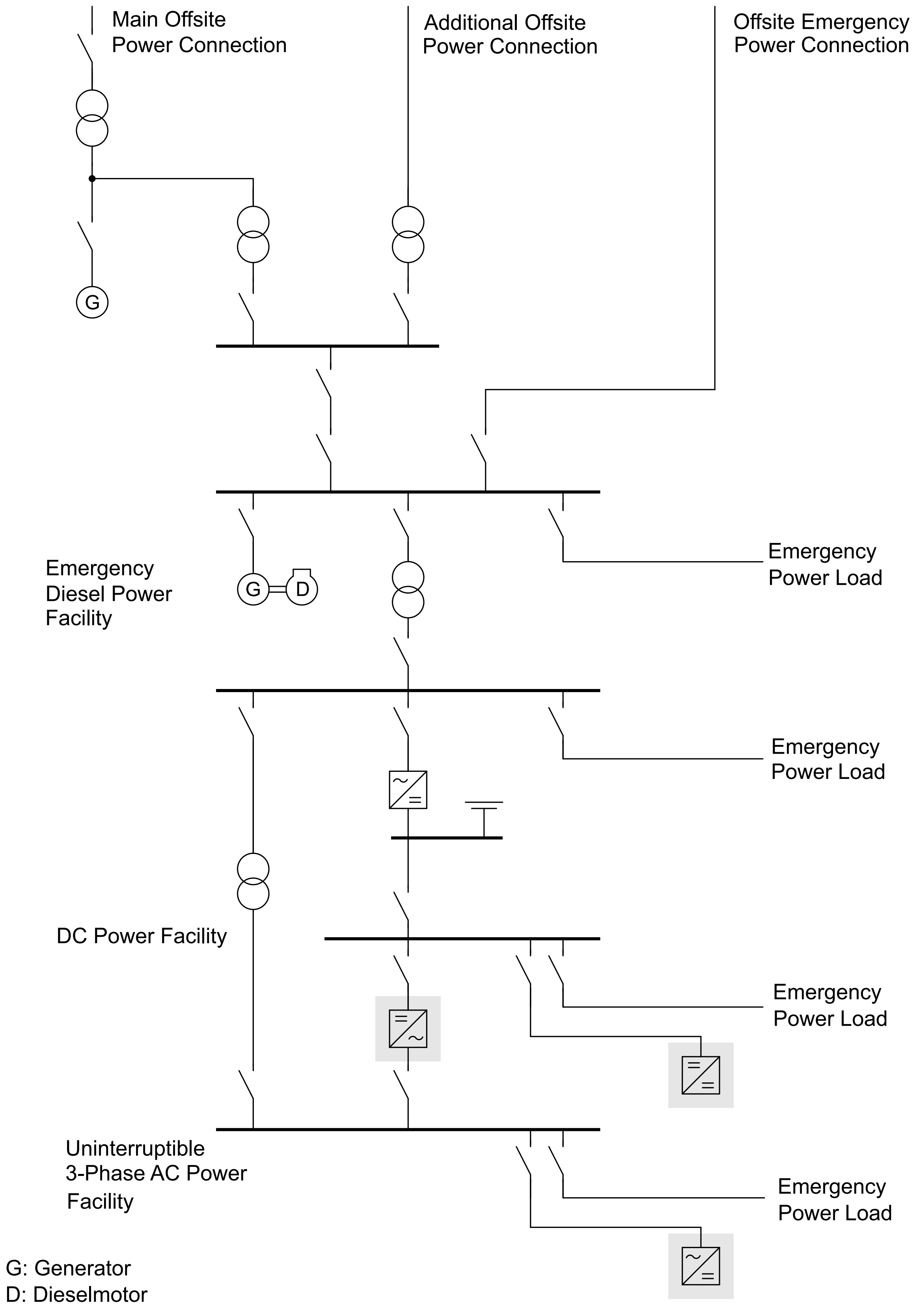

Figure 1-1: Diagram exemplarily showing the scope (greyed background) of the present safety standard

(6) In each train, one interconnection shall normally be provided between the converter emergency power switchgear and the diesel emergency power switchgear of either its own train or of a neighboring train (**Figures 4-1** and **4-2**). This interconnection shall normally be activated by a switch-over device after failure of the power supply from the converter taking the requirements specified under Section 4.5.4 into account. Interconnections to a neighboring train shall be constructed such that no failure possibility to be assumed can cause the failure of more than one train. If the frequency deviations of the diesel emergency power switchgear are not admissible for certain power loads (e.g. the power supply to process computers), it is admissible to provide one interconnection to the station service equipment.

(7) In order to maintain the availability of the converter facility while carrying out maintenance work, a standby converter independent of any specific train may be installed. In case of demand, this standby converter shall normally be switched on, replacing the train-correlated converter, such that it is correlated to both the input and output sides of the train of the converter which it is replacing. All necessary switching procedures shall be carried out manually and shall be interlocked such that, at both ends, only this same train can be connected. Other circuit design concepts shall be agreed upon by the proper nuclear authority or its appointed authorized expert (under Sec. 20 AtG).

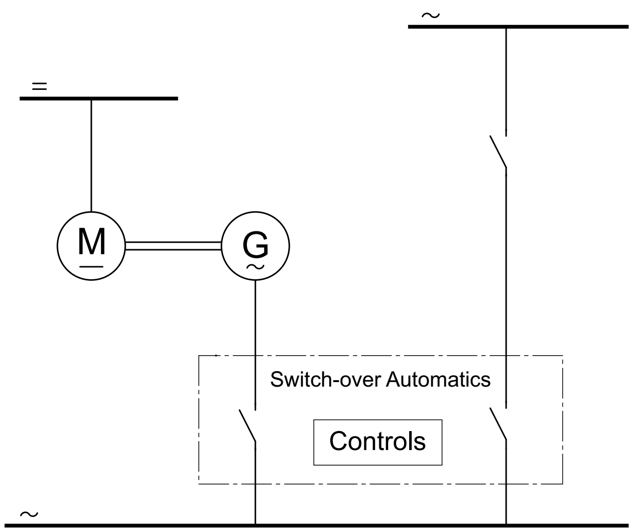

Figure 4-1: Example of a circuit design concept for one train of a converter facility with rotary converters

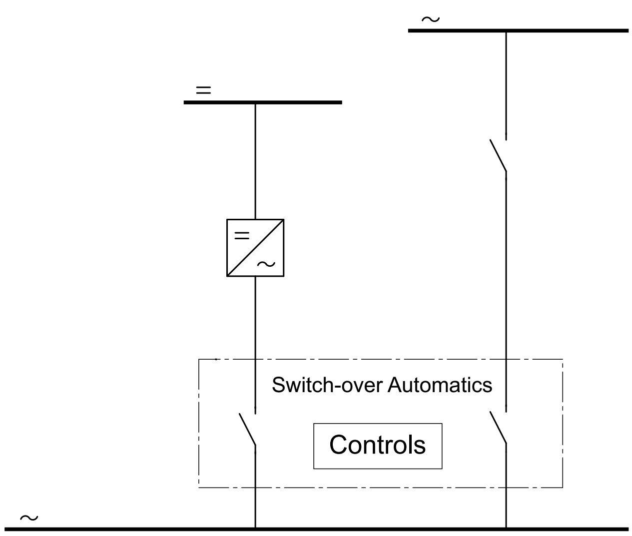

Figure 4-2: Example of a circuit design concept for one train of a converter facility with static inverters

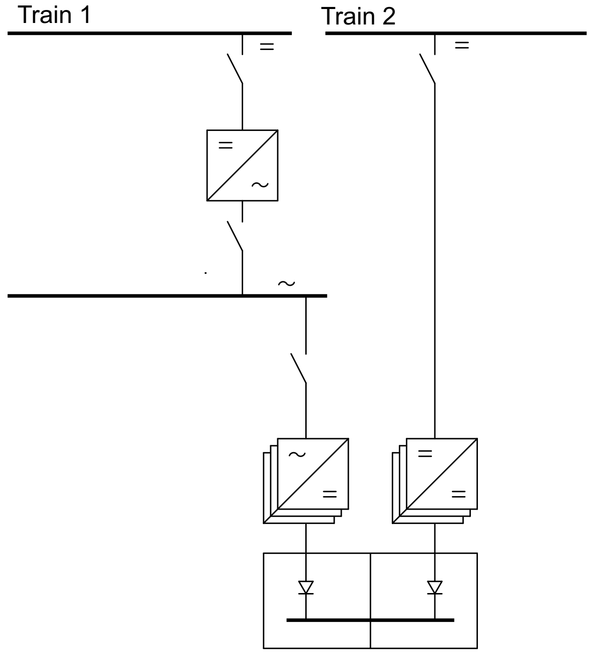

Figure 4-3: Example of a circuit design concept with redundant multi-unit switching power supplies for supplying instrumentation and control equipment

4.1.2 Circuit design concept for the switching power supply units

(1) If switching power supply units are used to supply safety-related power loads then the multi-unit switching power supplies shall be designed such that they do not define the overall reliability of the power supply.

Note:

This can be achieved, e.g., by a circuit design concept of redundant multi-unit switching power supplies, each one to be supplied from two uninterruptible emergency power switchgears of different trains (cf. **Figure 4-3**).

(2) Within a single multi-unit switching power supply a failure of a single switching power supply unit shall be controlled.

(3) If the power supply stems from two multi-unit switching power supplies, these supplies shall be dimensioned such that the selectivity of the overcurrent protective devices on the input or output side is ensured even if only one multi-unit switching power supply is available. Regarding this selectivity consideration, no further failure of a single switching power supply unit within a multi-unit switching power supply needs to be considered.

4.2 Power Balance and Limit Values

4.2.1 General requirements

The power requirements shall be determined separately for each train considering the operating conditions and the accidents to be assumed for the nuclear power plant as well as their time sequence. This shall include, as a function of time, the power requirements of all power loads which can be connected to a single train under the assumed operating and accidents conditions.

4.2.2 Determining power requirements

(1) In order to determine the real power at the output port of a converter, the balance of the real power of the power loads to be supplied shall be calculated for every load case to be considered. In this context, all power loads which can be supplied

from the converter shall be determined including the electrical transmission losses.

(2) In the case of intermittently operated power loads or power load groups, the nominal electrical power multiplied by a to-be-specified simultaneity factor shall be applied. If an actuation can occur simultaneously, the simultaneity factor shall equal 1.

(3) In order to determine the apparent power of a static inverter or of the generator of a rotary converter the apparent power balance shall be determined for each train of a converter facility and for each load case to be considered.

(4) Dynamic load changes shall be considered in the design of the converter such that the dynamic limit values specified under Section 4.2.4, para. (2), are not exceeded.

(5) In the case of three-phase converters the power loads of the single-phase power loads shall be distributed as evenly as possible among the three phases.

4.2.3 Safety margin of the power balance

A safety margin shall be added to the power requirement determined. The safety margin shall be at least 10 % at the point in time when the real power of the converter is specified. During operation, this reserve shall not be fully used up.

4.2.4 Limit values

(1) The design of the converters, their associated protective and monitoring equipment, the switch-over devices and the cable network shall all be well coordinated such that the limit values admissible for the power loads are not exceeded even in the case of the most unfavorable ambient conditions and the highest operation and accident related loads.

Note:

Operation related loads are, e.g., load shedding to station service power, or offsite power supply related voltage transients.

(2) The voltage and frequency behavior of the converter shall stay within the limit values listed in **Table 4-1**.

(3) For the power loads such as computer systems that require more stringent tolerances than they are specified for the converter, individual power supply possibilities shall be provided.

4.3 Suitability of the Converter Facility and the Multi-Unit Switching Power Supplies

(1) The suitability of the converter facility and the multi-unit switching power supplies deployed in nuclear power plants shall be demonstrated by a type test and by a demonstration of proven performance.

(2) A converter may be assumed to be suitable if

a) a type test on this converter type has been successfully carried out as specified under Section 5.3,and

b) the proven performance has been demonstrated for 10 converters of this series with each one having been in service for at least 3 years.

Note:

Converters belong to the same series if, with graduated nominal power, they are built following the same design principle and are identical with respect to circuit design, controls and monitoring.

(3) In case of an indication of over-loading of components, of the wrong choice of material or of common mode failures, it shall be demonstrated that the error source has been removed.

(4) If the converter to be used in a nuclear power plant contains individual components which differ from those in the series for which proven performance has been demonstrated, a separate suitability proof for these parts is admissible in well substantiated cases.

(5) If for the deployment in nuclear power plants additional safety-related characteristics are required which were not included in the demonstration of proven performance or in the type test specified under Section 5.3, additional suitability proofs shall be performed.

(6) The type and extent of the suitability proofs specified under paras. (4) and (5) shall be agreed upon by the proper nuclear authority or its appointed authorized expert (under Sec. 20 AtG). In this context, the operating periods of the converter prior to first criticality of the nuclear power plant may be taken into account.

4.4 Design of the Converters

4.4.1 Converter power loading

The converter power loading shall be specified on the basis of the power balance determined for each train as specified under Section 4.2.2 increased by the safety margin specified under Section 4.2.3; the resulting load shall be used as basis for the converter design.

4.4.2 Design of rotary converters

(1) The drive motor of the rotary converter shall be designed as follows:

a) The specification of the nominal rating of the drive motor shall be based on the maximum real power required as specified under Sections 4.2.2 and 4.2.3, plus the generator losses. It shall be possible to achieve the required motor power rating even at the lower static limit value of the direct-voltage input.

b) The drive motor and its speed control shall be designed such that size and duration of the sudden loading when the largest of power load group is switch-connected remains within the admissible overload limit of the drive motor, and that the admissible frequency limit values listed in **Table 4-1,** No. 2.2.2, are not exceeded. In this context, the influence of the inertia moment of the overall mechanism shall be considered.

(2) The generator of the rotary converter shall be designed as follows:

a) The nominal apparent power of the generator, its reactance and its voltage control shall be specified such that, even in the case of dynamic load changes, the output voltage remains within the admissible dynamic limit values listed in **Table 4-1,** No. 2.1.

b) The magnitude and duration of the short circuit current shall be specified in conformance with the protective devices of the power loads such that a selective activation of these protective devices is possible.

c) Three-phase alternating current generators shall normally be thermally designed to withstand the following unbalanced loading of the phases:

   ca) one non-loaded phase and two phases at 100 % nominal current,

   cb) two non-loaded phases and one phase at 100 % nominal current.

4.4.3 Design of the static inverters

(1) The static inverter and its control equipment shall be designed such that the limit values listed in **Table 4-1** are not exceeded.

(2) The magnitude and duration of the short circuit current shall be specified in conformance with the protective devices of the power loads such that a selective activation of these protective devices is possible even without support from other alternating voltage sources.

(3) Three-phase static inverters shall normally be thermally designed to withstand the following unbalanced loading of the phases:

a) one non-loaded phase and two phases at 100 % nominal current,

b) two non-loaded phases and one phase at 100 % nominal current.

4.4.4 Design of the multi-unit switching power supplies

(1) Multi-unit switching power supplies shall be designed such that the limit values listed in **Table 4-1** are not exceeded.

(2) The magnitude and duration of the short circuit current shall be specified in conformance with the protective devices of the power loads such that a selective activation of these protective devices is possible.

(3) The multi-unit switching power supplies shall be designed such that a galvanic separation of input and output is ensured.

(4) The start-up current of multi-unit switching power supplies shall be limited. In this context, an erroneous activation of upstream protective devices shall be prevented. The start-up and switch-over procedures shall be considered.

4.5 Instrumentation and Control Equipment

4.5.1 General requirements

The instrumentation and control equipment for the operation, monitoring and protection of the converter facilities and the multi-unit switching power supplies shall correspond to train structure and train correlation of the converter facilities.

4.5.2 Monitoring

(1) Monitoring equipment shall be provided to enable identifying, by means of displays and hazard alarms, the functional availability, the operating condition and any exceeding of limit values.

(2) The arrangement of the monitoring equipment shall comply with the requirements of operation, servicing and repairs and shall normally be established as follows:

a) displays and individual alarms on-site, e.g., on the converter or at the converter control station,

b) displays and group alarms in the control room.

(3) The arrangement of the displays and hazard alarms shall enable the determination of the operating condition of the converter facility and the multi-unit switching power supplies. In this context, it is admissible to provide individual alarms on the internal modules and the group alarms on-site, e.g., on the converter itself or at the converter control station. The control room shall normally receive train-correlated group alarms.

(4) The group alarms in the control room shall be classified as Class I hazard alarms, and the individual alarms as Class II alarms, provided, their origin can be identified. The monitoring required for one converter is shown in **Table 4-2**, cols. 3 and 4.

4.5.3 Protection

(1) Protective devices shall be provided that can detect defects within the converter facility and that can perform the required protective shutdowns listed in **Table 4-2**. Additional protective shutdowns shall be evaluated regarding their necessity and reliability.

(2) The protective limit values shall be chosen such that they will lead to a shutdown only if the consequential damages of not shutting down would impair the safety of the nuclear power plant more than the non-availability of the converter.

Note:

The goal of this could be, e.g., the reusability of a component if the failure would lead to a long-term unavailability within the framework of the control of design base accident.

(3) The overcurrent protective devices shall be designed such that the selectivity within a train is ensured (cf. Section 4.4.2, para. (2), item b), Section 4.4.3, para. (2) and Section 4.4.4, para. (2)).

(3) In the case of short circuits within the static inverter up to and including the busbar of the converter emergency power switchgear, the static inverter shall be shut down by protective devices if the current limitation of the static inverter can prevent the response of the fuses in the static inverter.

Note:

Such a protective device responds, e.g., to an under-voltage at the static inverter output.

The protective devices required for a converter are listed in **Table 4-2**, column 5.

4.5.4 Switch-over devices

(1) For the switch-over of interconnections specified under Section 4.1.1, para. (6), automatic quick switch-over devices, or automatic switch-over devices with a voltage-free pause, or manual switch-over devices shall be provided considering the requirements of the power loads.

(2) An automatic switch-over device requires a line commutation of the output voltage of the converter regarding frequency and phase by the voltage of the switchgear to which the switch-over shall occur. If the frequency deviations of the diesel emergency power switchgear are not admissible for certain power loads (e.g., for the supply of process computers), the line commutation of the converter controls shall normally remain disconnected during the diesel operation.

(3) In addition to the automatic switch-overs, a possibility for switching back to the converter shall be provided.

(4) In the case of circuit design concepts with a standby converter, the switch-over possibilities specified under paras. (1) through (3) shall normally be provided even if, the standby converter is in operation instead of a train-correlated converter. In addition, the following switch-over possibilities for supplying the converter emergency power switchgear shall normally be provided:

a) from the converter of each train to the standby converter,

b) from the standby converter to the converter of each train.

(5) The switch-overs specified under paras. (3) and (4) shall normally be initiated manually and actuated by a paralleled switching device. A synchronizing device shall normally be provided for the manual parallel switching.

No.	Characteristic Value	Limit Value lower	Limit Value upper	Explanatory Footnotes
1	**Input side**			a
1.1	Input DC voltage in relation to the nominal voltage U_{dN}	0.85 U_{dN}	1.15 U_{dN}	
1.2	Superimposed alternating current $I_{Ü}$ (eff.) in relation to the input current I_E under load, under nominal output voltage UAN and a power factor cos φ = 0.8	–	0.10 I_E	b, d, e
1.3	Input AC voltage in relation to the nominal voltage U_{EN}	0.80 U_{EN}	1.2 U_{EN}	k
2	**Output side**			c
2.1	Output voltage in relation to the nominal voltage U_{AN}			
2.1.1	Voltage adjustment range	0.95 U_{AN}	1.05 U_{AN}	g, h
2.1.2	Static voltage deviation within the voltage adjustment range	0.98 U_{AN}	1.02 U_{AN}	e, g, h
2.1.3	Dynamic voltage change			f
	a) when connecting the largest power load group	0.85 U_{AN}	–	
	b) when shedding the power load	–	1.2 U_{AN}	d
2.1.4	The overall settling time of voltage	–	500 ms	
2.1.5	Harmonic content of the phase-to-phase voltage and the phase voltage	–	0.05 U_{AN}	b, e, g, h, i
2.1.6	Maximum effective voltage value of individual harmonics	–	0.03 U_{AN}	b, e, g, h, i
2.1.7	The maximum oscillation width of superimposed AC voltage in switching power supply units	–	0.05 U_{AN}	
2.2	Output frequency in relation to the nominal frequency f_N			j
2.2.1	Static frequency deviation	0.99 f_N	1.01 f_N	h, g, l
2.2.2	Dynamic frequency change			
	a) when connecting largest group of power loads	0.95 f_N	–	
	b) when shedding the power load	–	1.05 f_N	d

a Limit value as related to the connection terminals on the drive motor of a rotary converter, on the input side of a static inverter or on the input side of a switching power supply unit.

b Applies only to static inverters.

c Limit value as related to the connection terminals on the generator of a rotary converter, on the output side of a static inverter or on the output side of a switching power supply unit.

d Converter power loading as specified under Section 4.4.1.

e Limit values apply to a three-phase alternating current up to an unbalanced current load of 100 % in two phases and up to a current load of 80 % in one phase, both values related to the converter power load specified under Section 4.4.1.

f The dynamic voltage changes including the static limit values of the output voltage under No. 2.1.2 shall be considered.

g Limit values apply to the tolerance range for the input DC voltage under No. 1.1.

h In the static operating range between zero-load operation and power load operation of the converter as specified under Section 4.4.1.

i Provided, the power load is linear.

N o t e :
Non-linear power loads are e.g. highly saturated transformers and rectifiers with filter capacitors.

j Does not apply to switching power supply units.

k Applies only to switching power supply units with AC voltage input.

l Does not apply to the line commutation during island operation of the emergency power generating facility with diesel generators (cf. Section 4.5.4, para. (2)).

Table 4-1: Limit values for the design of the converters

1	2	3	4	5
No.	**Measurement Value / Criterion**	**Monitoring** on site	**Monitoring** in the control room	**Protective Shutdown**
1	**Rotary Converter**			
1.1	Voltage, DC side	A, $\underline{M}$ 1)	SM	$\underline{S}$ 2)
1.2	Current, DC side	A	–	–
1.3	Voltage, AC side	A, $\overline{M}$ 1), $\underline{M}$ 1)	SM	$\overline{S}$
1.4	Current, AC side	A	–	–
1.5	Overcurrent protection of motor	M	SM	$\overline{S}$
1.6	Overcurrent protection of generator	M	SM	$\overline{S}$
1.7	Rotary speed or frequency	A, $\overline{M}$ 1), $\underline{M}$ 1)	SM	$\overline{S}$, $\underline{S}$
1.8	Switch position of the switching devices involved in the switchovers	A	A	–
1.9	Auxiliary voltage control	M	SM	–
2	**Static Inverter**			
2.1	Voltage, DC side	A, $\underline{M}$ 1)	SM	$\underline{S}$ 2)
2.2	Current, DC side	A	–	–
2.3	Voltage, AC side	A, $\overline{M}$ 1), $\underline{M}$ 1)	SM	$\overline{S}$
2.4	Current, AC side	A	–	–
2.5	Short circuit protection (voltage dependent)	M	SM	S
2.6	Frequency	A	–	–
2.7	Switch position of the switching devices involved in the switchovers	A	A	–
2.8	Auxiliary voltage control	M	SM	–
3	**Multi-Unit Switching Power Supply**			
3.1	Voltage, output side	A, $\overline{M}$ 1), $\underline{M}$ 1)	SM	$\overline{S}$, $\underline{S}$ 2)
3.2	Current output side	A	–	–
3.3	Switching power supply unit failure 4)	M	SM	–
3.4	Input voltage	$\overline{M}$ 1), $\underline{M}$ 1)	SM	$\overline{S}$ 3), $\underline{S}$ 3)
3.5	Short circuit protection (voltage dependent)	M	SM	S

A display
M alarm

SM group alarm
S protective disconnection

$\overline{M}$ alarm, upper limit value
$\underline{M}$ alarm, lower limit value

$\overline{S}$ protective shutdown, upper limit value
$\underline{S}$ protective shutdown, lower limit value

1) if the static limit values specified in **Table 4-1** are exceeded

2) if necessary, with a time delay to prevent an inadvertent shutdown in case of dynamic voltage changes caused by switch-connecting high-power DC loads (e.g., containment isolation valves)

3) automatic restart as soon as the admissible voltage range is re-established

4) in the case of switching power supply units in parallel

Table 4-2: Displays, hazard alarms and protective disconnections for one converter

4.5.5 Testability

The instrumentation and control equipment of the converter facility shall normally be designed such that the inservice inspections specified under Section 5.7 can be carried out without any manipulation of the wiring.

4.6 Location and Installation

(1) The location of the converter compartments and the installation of the converters shall be in correlation with the redundancy of trains. Both location and installation shall be based on the accidents and external events to be considered for the respective converters.

(2) In case a standby converter as specified under Section 4.1.1, para. (7), is provided, this converter may be spatially allocated to one of the trains of the converter facility.

(3) The sound pressure level of 80 dB(A) shall normally not be exceeded at the converter control station.

(4) Care shall be taken to ensure easy access regarding servicing, visual inspections and repairs as well as good transport possibilities of the converters.

5 Tests and Inspections

5.1 Documents to be Submitted

(1) Documents shall be provided that demonstrate that the converter facilities and the multi-unit switching power supplies are designed, fabricated, assembled, tested and inspected in accordance with the safety-related requirements.

(2) Test instructions shall be agreed upon by the proper nuclear authority or its appointed authorized expert (under Sec. 20 AtG) as far as detailed test requirements are not specified in the present safety standard.

5.2 Electromagnetic Compatibility (EMC) Tests of the Converters

(1) The electromagnetic (conductor or field bound, and contact based) immunity against interference parameters to be expected during specified normal operation and design basis accidents at the place of installation shall be demonstrated for the converters.

(2) It shall be demonstrated that the electromagnetic (conductor or field bound) emissions of the converters will not inadmissibly affect other devices and components at the place of installation.

Note:

The testing severity levels and the limit values may be specified, e.g., in accordance with the EMC generic standards DIN EN 61000-6-2 and DIN EN 61000-6-4.

5.3 Type Tests

5.3.1 Rotary Converters

(1) The tests and inspections listed in **Table 5-1,** column 3, shall be carried out. They shall be performed on one unit each of every type of component.

(2) If converter-driven motors are used, additional type tests shall be performed on each type of the employed power converters to demonstrate their functional capability.

(3) If required for the demand case, it shall be demonstrated that the converters, within their specified requirements, will withstand any of the induced vibrations to be expected. Vibration tests on other converters and converter control cabinets that are comparable with respect to their vibrational behavior may be referenced for this demonstration.

(4) These tests shall be documented by test reports.

5.3.2 Static inverters

(1) The tests and inspections listed in **Table 5-2,** column 3, shall be performed on one unit of the respective type of static inverter.

(2) If required for the demand case, it shall be demonstrated that the static inverters, within their specified requirements, will withstand any of the induced vibrations to be expected. Vibration tests on other static inverters that are comparable with respect to their vibrational behavior may be referenced for this demonstration.

(3) These tests shall be documented by test reports.

5.3.3 Multi-unit switching power supplies

(1) The tests and inspections listed in **Table 5-3,** column 3, shall be performed on one unit of the respective type of multi-unit switching power supply.

(2) If required for the demand case, it shall be demonstrated that the multi-unit switching power supplies, within their specified requirements, will withstand any of the induced vibrations to be expected. Vibration tests on other multi-unit switching power supplies that are comparable with respect to their vibrational behavior may be referenced for this demonstration.

(3) These tests shall be documented by test reports.

5.4 Routine Tests

5.4.1 Rotary converters

(1) It shall be demonstrated that the routine tests listed in **Table 5-1,** column 4, have been carried out on each of the deployed rotary converters.

(2) In case of any deployed converter-driven motors, additional routine tests shall be performed to demonstrate their functional capability.

(3) The routine tests on the entire unit as listed in **Table 5-1,** No. 4.1 through No. 4.6, may be replaced by performing the equivalent tests on the construction site that are specified under Section 5.6.1, item f).

(4) These tests shall be documented by test reports.

5.4.2 Static inverters

(1) It shall be demonstrated that the routine tests listed in **Table 5-2,** column 4, have been carried out on each of the deployed static converters.

(2) The routine tests on the static converter listed in **Table 5-2,** No. 13 through 17 as well as Nos.19 and 20, may be replaced by performing the equivalent tests on the construction site that are specified under Section 5.6.2, item d).

(3) These tests shall be documented by test reports.

5.4.3 Multi-unit switching power supplies

(1) It shall be demonstrated that the routine tests listed in **Table 5-3,** column 4, have been carried out on each of the deployed multi-unit switching power supplies.

(2) The routine tests on the multi-unit switching power supplies listed in **Table 5-3,** No. 7 and No. 11, may be replaced by performing the equivalent tests on the construction site that are specified under Section 5.6.3, item d).

(3) These tests shall be documented by test reports.

5.5 Tests and Inspections During Assembly at the Construction Site

Tests and inspections shall be performed during assembly at the construction site that shall normally ensure that all assembly conditions, all assembly and construction conditions and all assembly dimensions that are relevant to the reliable functioning of the converter facility are met.

These tests and inspections shall essentially include:

a) checking the identity of the components based on the documents, and checking for damages during transport or storage,

b) checking the assembled unit for conformity with the valid documents (e.g. installation drawings),

c) checking that assembly instructions were followed.

5.6 Acceptane Tests and Functional Tests at the Construction Site

5.6.1 Rotary converters

Each rotary converter shall be subjected to the following tests and inspections:

a) testing of the alignment and fastening of the converter,

b) insulation test,

c) testing for smooth running,

d) functional testing of the monitoring and protective devices,

e) functional testing of the switch-over devices and interlocks,

f) functional testing with the specified static and dynamic loads and load changes, unless these tests were already performed during type testing or routine testing,

g) testing of the sound pressure level at the converter control station specified under Section 4.6, para. (3).

5.6.2 Static inverters

Each static inverter shall be subjected to the following tests and inspections:

a) insulation test,

b) functional testing of the monitoring and protective devices,

c) functional testing of the switch-over devices and interlocks,

d) functional testing with the specified static and dynamic loads and load changes, unless these tests were already performed during type testing or routine testing.

5.6.3 Multi-unit switching power supplies

Each multi-unit switching power supply shall be subjected to the following tests and inspections

a) insulation test,

b) functional testing of the monitoring and protective devices,

c) effectiveness of the decoupling from switching power supply units connected in parallel,

d) functional testing with the specified static and dynamic loads and the load changes, unless these tests were already performed during type testing or routine testing.

5.7 Inservice Inspections

(1) Inservice inspections shall be performed to ascertain the continued functional capability of the converter facilities and multi-unit switching power supplies. These inspections shall not normally be carried out on several trains simultaneously.

(2) Those instrumentation and control equipment which are not continuously monitored with respect to their function during operation shall be subjected to inservice inspections.

The test intervals shall be correlated with those of the other instrumentation and control equipment of the emergency power system.

(3) The test interval shall normally not exceed four years (e.g., one train per year in the case of a four-train converter facility).

5.8 Tests after Servicing or Repairs

(1) After completion of servicing or repairs which involved an interruption of functional availability, a test shall be performed demonstrating that functional availability has been restored. Depending on the type and extent of the affected parts or functions, a functional test shall be performed in agreement with the proper nuclear authority or its appointed authorized expert (under Sec. 20 AtG).

(2) If parts are installed during servicing or repairs which are modified with respect to the original configuration, the suitability of these parts shall be demonstrated.

5.9 Testers

(1) The tests and inspection specified under Sections 5.2 through 5.4 shall normally be performed by plant experts or under their responsibility. In well substantiated cases, individual tests shall be performed in coordination with the proper nuclear authority or its appointed authorized expert (under Sec. 20 AtG).

(2) The tests specified under Sections 5.5 through 5.8 shall be performed in coordination with the proper nuclear authority or its appointed authorized expert (under Sec. 20 AtG).

5.10 Test Certificates

The test and inspections performed shall be documented by test certificates. These test certificates shall contain all information relevant to the evaluation and assessment of the tests. Essentially, this includes:

a) divisions performing the test,

b) test object,

c) testing extent,

d) type of test,

e) identification number of the test instruction or, if applicable, of the standard test instruction,

f) execution of the test (e.g., planned and actual date of testing, test interval, test equipment used),

g) test results (e.g., test goal achieved, deviations, measures taken or required),

h) confirmation by the person in charge of the test execution, of the results and evaluation.

6 Operation, Servicing and Repairs

Regarding operation, servicing and repairs, the instructions of the manufacturers shall be observed.

1	2	3	4
No.	**Type of Test**	**Performed during**	
		Type test	**Routine test**
1	**Drive Motor** 1) 4)		
1.1	Overspeed test	X	X
1.2	Test of thermal behavior	X	–
1.3	Measuring the losses and the degree of efficiency	X	X
1.4	Winding test of the stator and rotor windings	X	X
2	**Generator** 1) 4)		
2.1	Overspeed test	X	X
2.2	Test of thermal behavior	X	–
2.3	Determining characteristic parameters on the basis of experiments involving idling, permanent short circuits, counter excitation and sudden short circuits	X	–
2.4	Winding test of the stator and rotor windings	X	X
3	**Flywheel** 4)		
3.1	Overspeed test	X	X
4	**Overall equipment** 5)		
4.1	Voltage setting range 3)	X	X 2)
4.2	Static deviation of output voltage 3)	X	X 2)
4.3	Dynamic change of output voltage	–	X 2)
4.4	Overall settling time for the output voltage	–	X 2)
4.5	Static frequency deviation 3)	X	X 2)
4.6	Dynamic frequency change	–	X 2)
4.7	Electromagnetic compatibility (EMC) (cf. Section 5.2)	X	–

1) It is permissible to carry out the individual tests on the overall equipment.

2) As an acceptance test on one of several identically designed rotary converters. These tests may be replaced by equivalent tests carried out on the construction site as specified under Section 5.6.1, item f).

3) Testing at 0.85, 1.0 and 1.15 times the input DC voltage.

4) N o t e: Execution of the test is detailed in, e.g., DIN EN 60034-1, DIN EN 60034-2-1 or DIN EN 60034-4.

5) It shall be demonstrated that the limit values listed in **Table 4-1** are observed.

Table 5-1: Extent of the type tests and routine tests specified under Sections 5.3.1 and 5.4.1 on rotary converters

1	2	3	4
No.	Type of Test	Performed during	
		Type test	Routine test
1	Insulation test [3)]	X	X
2	Functional test [3)]	X	X
3	Test of the protective and monitoring equipment [3)]	X	X
4	Test of auxiliary equipment [3)]	X	X
5	Test of the electric parameters at nominal power [3)]	X [2)]	X
6	Temperature-rise test [3)]	X	–
7	Determination of losses [3)]	X	–
8	Test of the overload capacity [3)]	X	X [4)]
9	Current distribution in semiconductor components connected in parallel [3)]	X	–
10	Voltage distribution in semiconductor components connected in series [3)]	X	X
11	Test of the minimum load integral at the largest load feeder fuse provided [3)]	X	–
12	Electromagnetic compatibility (EMC)	X	–
13	Voltage adjustment range [2)]	X	X [1)]
14	Static deviation of the output voltage [2)]	X	X [1)]
15	Dynamic change of the output voltage [2)]	–	X [1)]
16	Overall settling time of the output voltage	–	X [1)]
17	Harmonic content of the output voltage [2)]	X	X [1)]
18	Harmonic analysis of the output voltage [2)]	X	–
19	Static deviation of frequency [2)]	X	X [1)]
20	Dynamic change of frequency	–	X [1)]
21	Temperature dependence of the output frequency [2) 3)]	X	–

1) As an acceptance test on one of several identically designed static inverters. These tests may be replaced by equivalent tests carried out on the construction site as specified under Section 5.6.2, item d).

2) Testing at 0.85, 1.0 and 1.15 times the input DC voltage.

3) N o t e: Execution of the test is detailed in, e.g., DIN EN 60146-2.

4) Tests of the individual phases.

Table 5-2: Extent of the type tests and routine tests specified under Sections 5.3.2 and 5.4.2 on static inverters

1	2	3	4
No.	Type of Test	Performed during	
		Type test	Routine test
1	Insulation test	X	X
2	Functional test	X	X
3	Test of auxiliary equipment	X	X
4	Temperature-rise test	X	-
5	Test of the electrical parameters at nominal power	X 1)	X
6	Determination of losses	X	–
7	Current distribution in switching power supply units that are connected in parallel	X	X 2)
8	Test of the minimum load integral at the largest load feeder fuse provided	X	–
9	Electromagnetic compatibility (EMC)	X	–
10	Voltage adjustment range	X 1)	X
11	Static deviation of the output voltage	X 1)	X 2)
12	Dynamic change of the output voltage	X 1)	-
13	Overall settling time of the output voltage	X 1)	-

1) Testing at 0.85, 1.0 and 1.15 times the input DC voltage.

2) As an acceptance test on one of several identically designed multi-unit switching power supplies. These tests may be replaced by equivalent tests carried out on the construction site as specified under Section 5.6.3, item d).

N o t e: Execution of the test is detailed in, e.g., DIN EN 60146-2.

Table 5-3: Extent of the type tests and routine tests on switching power supply units and multi-unit switching power supplies as specified under Sections 5.3.3 and 5.4.3

Appendix A

Regulations Referred to in the Present Safety Standard

(Regulations referred to in the present safety standard are valid only in the versions cited below. Regulations which are referred to within these regulations are valid only in the version that was valid when the latter regulations were established or issued.)

AtG		Act on the Peaceful Utilization of Atomic Energy and the Protection against its Hazards (Atomic Energy Act) Atomic Energy Act in the version promulgated on July 15, 1985 (BGBl. I, p. 1565), most recently changed by article 1 of the act dated December 4, 2022 (BGBl. I, p. 2153)
StrSchG		Act on the Protection against the Harmful Effect of Ionising Radiation (Radiation Protection Act - StrlSchG) Radiation Protection Act of June 27, 2017 (BGBl. I, p. 1966), most recently changed by the promulgation of January 3, 2022 (BGBl. I, p. 15)
StrlSchV		Ordinance on the Protection against the Harmful Effects of Ionising Radiation (Radiation Protection Ordinance - StrlSchV) Radiation Protection Ordinance of November 29, 2018 (BGBl. I, p. 2034, 2036), most recently changed by article 1 of the ordinance dated October, 2021 (BGBl. I p. 4645)
SiAnf	(2015-03)	Safety Requirements for Nuclear Power Plants (SiAnf) of November 22, 2012, amended version of March 3, 2015 (BAnz AT 30.03.2015 B2), most recently changed as promulgated by BMUV on February 25, 2022 (BAnz AT 15.03.2022 B3)
Interpretions of SiAnf	(2015-03)	Interpretations of the safety requirements for nuclear power plants of November 22, 2012, of November 29, 2013 (BAnz AT 10.12.2013 B4), changed on March 3, 2015 (Banz AT of March 30, 2015 B3)
KTA 1401	(2017-11)	General requirements regarding quality assurance
KTA 2201.4	(2012-11)	Design of nuclear power plants against seismic events; Part 4: Components
KTA 3501	(2015-11)	Reactor protection system and monitoring equipment of the safety system
KTA 3504	(2022-11)	Electrical drive mechanisms of the safety system in nuclear power plants
KTA 3701	(2014-11)	General requirements for the electrical power supply in nuclear power plants
KTA 3702	(2022-11)	Emergency power generating facilities with diesel-generator units in nuclear power plants
KTA 3703	(2022-11)	Emergency power facilities with batteries and ac/dc converters in nuclear power plants
KTA 3705	(2022-11)	Switchgear facilities, transformers and distribution networks for the electrical power supply of the safety system in nuclear power plants
DIN EN IEC 61000-6-2 VDE 0839-6-2	(2019-11)	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments (IEC 61000-6-2:2016); German version EN IEC 61000-6-2:2019
DIN EN IEC 61000-6-4 VDE 0839-6-4	(2020-09)	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments (IEC 61000-6-4:2018); German version EN IEC 61000-6-4:2019
DIN EN 60034-1 (VDE 0530-1)	(2011-02)	Rotating electrical machines - Part 1: Rating and performance (IEC 60034-1:2010, modified); German version EN 60034-1:2010 + Cor.:2010
DIN EN 60034-2-1 (VDE 0530-2-1)	(2015-02)	Rotating electrical machines - Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles) (IEC 60034-2-1:2014); German version EN 60034-2-1:2014
DIN EN IEC 60034-4-1 VDE 0530-4	(2019-06)	Rotating electrical machines - Part 4-1: Methods for determining electrically excited synchronous machine quantities from tests (IEC 60034-4-1:2018); German version EN IEC 60034-4-1:2018
DIN EN 60146-2 (VDE 0558-2)	(2001-02)	Semiconductor convertors - Part 2: Self-commutated semiconductor convertors including direct d.c. convertors (IEC 60146-2:1999); German version EN 60146-2:2000