STUK

GUIDE **YVL 5.2** / 23 JANUARY 1997

ELECTRICAL POWER SYSTEMS AND COMPONENTS OF NPPS

This Guide is in force as of 1 March 1997 until further notice.

First edition
Helsinki 2002
Tummavuoren Kirjapaino Oy

ISBN 951-712-478-3 (print)
ISBN 951-712-479-1 (pdf)
ISBN 951-712-480-5 (html)
ISSN 0783-2400

STUK • **SÄTEILYTURVAKESKUS**
STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

Osoite/Address • Laippatie 4, 00880 Helsinki
Postiosoite / Postal address • PL / P.O.Box 14, FIN-00881 Helsinki, FINLAND
Puh./Tel. (09) 759 881, +358 9 759 881 • Fax (09) 759 88 500, +358 9 759 88 500 • www.stuk.fi

Authorisation

By virtue of section 55, second paragraph, point 3 of the Nuclear Energy Act (990/87) and section 29 of the Government Resolution (395/91) on General Regulations for the Safety of Nuclear Power Plants, the Radiation and Nuclear Safety Authority (STUK) issues detailed regulations concerning the safety of nuclear power plants.

YVL guides are rules an individual licensee or any other organisation concerned shall comply with, unless STUK has been presented with some other acceptable procedure or solution by which the safety level set forth in the YVL guides is achieved. This guide does not alter STUK's decisions, which were made before the entry into force of this guide, unless otherwise stated by STUK.

Translation. Original text in Finnish.

1 General

The electrical power systems and components of the nuclear power plant on the one hand generate electrical power and supply it to the external grid and on the other hand supply electrical power to the plant's systems from external and internal power units. The reliable operation of these systems is important for plant safety, accident management and the mitigation of the consequences of accidents.

The Government Resolution (395/1991) presents general regulations for NPP safety, which include provisions for the electrical power systems of NPPs as well. These requirements are stated more precisely in Guide YVL 1.0, which sets forth safety principles to be applied in NPP design.

Guide YVL 1.1 describes how STUK controls the design, construction and operation of NPPs. Guide YVL 5.2 gives detailed design bases and safety requirements for electrical power systems and components. Chapter 3 of this Guide YVL 5.2 describes how STUK controls the electrical power systems and components of NPPs.

The instrumentation and control systems and components of NPPs are dealt with in Guide YVL 5.5, pump motors in Guide YVL 5.7, valve actuators in Guide YVL 5.3, diesel generators in Guide YVL 5.1, air conditioning systems and components in Guide YVL 5.6, and hoisting appliances and fuel handling equipment in Guide YVL 5.8. Provision against earthquakes is addressed in Guide YVL 2.6 and fire protection in Guide YVL 4.3. Where electrical power systems or components containing programmable technology are concerned, Guide YVL 5.5 is to be complied with, when applicable. Guide YVL 7.18 deals with radiation protection aspects to be considered in the design and layout of NPP systems and components.

In addition to this Guide, NPPs are subject to electrical safety legislation, which is enforced by other authorities.

2 Design bases of electrical power systems and components

2.1 General design bases

Redundancy, separation and diversity principles

In accordance with the third paragraph of section 18 of the Government Resolution (395/1991), *systems which perform the most important safety functions shall be able to carry out their functions even though an individual component in any system would fail to operate and additionally any component affecting the safety function would be out of operation simultaneously due to repairs or maintenance* (the redundancy principle).

Safety systems which back up each other as well as parallel parts of safety systems shall be separated from each other so that their failure due to an external common cause failure is unlikely (the separation principle).

In ensuring the most important safety functions, systems based on diverse principles of operation shall be used to the extent possible (the diversity principle).

In accordance with Guide YVL 1.0, *the on-site electrical power supply system serving the safety functions shall be capable of carrying out its functions during anticipated operational transients and postulated accidents even in the event of a single failure, although any component affecting the safety function would simultaneously be inoperable due to repair or maintenance.*

The electrical separation of safety classified electrical power systems shall be designed to render unlikely the failure of parallel sub-systems owing to the same electrical disturbance.

It shall be ensured by design that the failure of an EYT system (not important to safety) does not endanger the operation as designed of a safety classified system.

Safety classification and quality assurance

In accordance with the first paragraph of section 21 of the Government Resolution (395/1991), *the functions important to the safety of the systems, structures and components of a nuclear power plant shall be defined and the systems, structures and components safety classified according to their safety significance.* Detailed instructions for safety classification are given in Guide YVL 2.1.

In accordance with section 5 of the Government Resolution (395/1991), *advanced quality assurance programmes shall be employed in all activities, which affect safety and relate to the design, construction and operation of a nuclear power plant.* The general principles of quality assurance are described in Guides YVL 1.4 and YVL 1.9.

In accordance with the second paragraph of section 21 of the Government Resolution (395/1991), *the systems, structures and components important to safety shall be designed, manufactured, installed and operated so that their quality level and the inspections and tests required to verify their quality level are adequate considering any item's safety significance.*

Electromagnetic interference

The electrical power systems and components of the nuclear power plant shall be reliably protected against the effects of electrical and magnetic interference fields, mains interference, radio interference and disturbances caused by telecommunications.

Electrical components shall be designed in such a way that they themselves do not cause any harmful electromagnetic interference in their operating environment.

Earthing systems and lightning protection systems shall be designed to effectively protect people, buildings, equipment as well as electrical and I&C systems against overvoltages, overcurrents and any other possible electromagnetic interference due to climatic factors.

Overvoltage protection

The nuclear power plant's earthing and overvoltage protection systems shall be designed to effectively prevent harmful internal and external overvoltages in the plant's electrical and I&C systems.

Environmental qualification

The structures, materials and installations of electrical components and cables needed in accidents shall be of such design that, for their entire designed service life, the operating capability of the components will be in compliance with requirements applicable to design basis accidents.

Electrical components and cables, which are to remain operational even in postulated accidents, shall be tested to ensure their performance. In a uniform series of tests, the same test specimen shall be subjected to the design basis environmental stresses in question. A test simulating a postulated accident shall include exposure to radiation and stresses caused by temperature, pressure and humidity levels equivalent to the accident conditions as well as sufficiently rapid changes in the conditions representing these situations. The consistency of the water used in the test shall be equivalent to that in the accident conditions in question. If a component could be submerged during a postulated accident and must even then maintain it operating capability, the component's operability in the situation shall be demonstrated as well.

The accelerated ageing of components or cables shall be carried out in a way that, with sufficient confidence, represents actual ageing. Ageing is usually carried out such that a test specimen is

first thermally aged and then subjected to radiation. After that it undergoes a mechanical tolerance test and finally the aforementioned tests simulating a postulated accident. The tests shall demonstrate, with sufficient confidence, that the components and cables will, for their entire design service life, maintain their operating capability in postulated accidents.

Seismic tests and analyses shall be conducted in accordance with Guide YVL 2.6.

The capacity of electrical components that must operate during severe accidents shall be appropriately demonstrated. In case electrical components inside the containment must operate in accidents during which hydrogen fires are possible, it shall be demonstrated that the components will maintain their operating capability in accidents during which hydrogen fires are possible.

Supply of on- and off-site electrical power

In accordance with the fourth paragraph of section 18 of the Government Resolution (395/1991), *a nuclear power plant shall have on-site and off-site electrical power supply systems. The execution of the most important safety functions shall be possible by using either of the two electrical power supply systems.*

In accordance with Guide YVL 1.0, *the plant shall be provided with systems, which enable power supply from the main generator to the plant's safety significant systems in case the connection to the external transmission grid is lost.*

The plant's electrical power supply units shall be so designed that the loss of the remaining power supply units in case of the loss of a single power supply unit or caused by the same reason is highly unlikely.

Total loss of alternating current power

In accordance with Guide YVL 1.0, *in nuclear power plant design, the possibility of the on-site and off-site power supply units being simultaneously lost shall be considered. As provision against such a situation, the plant shall have available a power supply unit which is independent of the electrical power supply units designed for operational conditions and postulated accidents. It must be possible to introduce this power supply unit into operation quickly enough and its capacity shall be sufficient to remove reactor decay heat, to ensure primary circuit integrity and to maintain reactor sub-criticality.*

Unit-to-unit power supply

The electrical power systems of units located on the same plant site shall be designed to make possible the feeding of electrical power from one unit to the safety important systems of the other during an accident. The design of power supply connections shall render unlikely the spreading of electrical disturbances from unit to unit via the connections as well as the unplanned taking into service or engagement of the connections. The connections shall be available promptly and reliably enough where necessary.

Overcurrent protection

The electrical power systems shall be provided with reliable, selectively operating safety devices that in short-circuit or overload situations remove from service only the failed component or section of the electrical power network. The protective devices shall operate selectively in all planned connection circumstances of the electrical power systems. Fault currents shall be broken rapidly enough to avoid hazards and to minimise disturbances. All switchgears important to the plant's safety and undisrupted operation shall be provided with reliable arc protection where necessary.

Repairs and preventive maintenance

The plant's design shall make possible the carrying out of operational actions as well as the periodic inspection, maintenance, testing and repair of electrical power systems and components in a way that ensures plant and personnel safety and minimises any plant inoperability caused by the actions.

Component identification symbols

In accordance with Guide YVL 1.0, *a clear marking system shall be planned to identify components.*

To facilitate component identification and to avoid human error, the components and cables of the plant's electrical power systems shall be provided with identification symbols made of durable materials, freely accessible during inspection, maintenance and troubleshooting. In addition, the cables and their paths shall be documented in sufficient detail.

2.2 Main grid connections

In accordance with Guide YVL 1.0, *for electrical power supply, there shall be two separate, independent grid connections from the external grid to each parallel section of the on-site electricity distribution system. These grid connections shall be so designed that during operational conditions and postulated accidents, the simultaneous loss of both is unlikely. It must be possible to start operation of both grid connections quickly enough after the plant main generator has been separated from the grid.*

Plant design shall consider variations of voltage and frequency that occur in the main grid and affect the electrical systems and components of the nuclear power plant. Main grid connections and their auxiliary systems shall be dimensioned as well as physically and electrically separated from other electrical power systems in such a way that design basis disturbances in the main grid do not jeopardise the operation of safety significant components during plant operational transients and accidents.

The design of the main grid connections shall make unlikely the simultaneous failure of both of them owing to the same cause during operational transients and postulated accidents. Plant design shall also consider all component failures and fires that could be caused by short circuits in the grid connections. In addition, auxiliary systems important for the operability of the connections, e.g. auxiliary voltage supplies and automatic switching devices, shall be designed in a way that makes the connections as independent as possible.

The main grid connections shall be provided with reliable, automatically starting change-over equipment. Change-over shall be possible to carry out also from the control room. Every power transformer coupled to external grids shall be provided with automatic and manual voltage control systems to protect against the effects of voltage variations in the main grid and to assure the plant's electrical power systems are operable during postulated main grid voltage variations.

2.3 Non-secured electrical power systems

Non-secured electrical power systems shall be designed such that their failure or malfunction does not endanger the operation of electrical power systems important to plant safety. Non-secured power systems and their auxiliary systems shall be reliably physically and electrically separated from power systems important to plant safety, making it unlikely that their malfunction would result in the failure of any safety significant power system.

2.4 Secured alternating current power systems

The operation of safety significant alternating current components shall be assured by securing their supply of electrical power by sufficiently efficient, independent onsite emergency power supply systems.

Secured alternating current power systems shall be provided with sufficiently reliable, efficient and automatically engaging feed systems of the stand-by power to assure uninterrupted power supply or power supply if a voltage break of permissible duration has occurred, in case regular power supply is disrupted in a way that endangers the operability of the components. It shall be possible to reliably take the stand-by power supply systems into service even from the control room and from emergency control posts.

The stand-by power supply systems shall be designed in a way that assures the availability of secured alternating current power systems important to plant safety according to the operating time requirements set to them.

The design of the stand-by power supply systems shall make them capable of reliably starting, engaging, receiving loads and feeding electrical power even during the most demanding loading situations and environmental conditions. The quality of the alternating current fed shall be kept such that the operating capability of the components to which power is supplied is not compromised. Requirements that apply to the diesel generators of NPPs are discussed in more detail in Guide YVL 5.1.

The stand-by power supply systems shall be provided with sufficiently comprehensive, alarming surveillance to promptly observe and localise failures causing unavailability of the systems.

For the duration of their functional testing, maintenance and repair, it shall be possible to safely disconnect from other electrical power systems those units that belong to the stand-by power supply systems. If necessary, it shall be possible to reliably replace the power supply units of battery-backed alternating current systems with stand-by power supply connections that make it possible to safely carry out measures relating to the power supply units.

In cases where there is reason to believe that a common cause failure could compromise the reliable operation of a secured alternating current system or that of its section, solutions based on diverse operating principles shall be employed in system design to the extent possible.

Automatic features (e.g. automatic start-up and switching devices) vital for the operation of redundant sub-systems and auxiliary systems (e.g. auxiliary voltage, air conditioning, cooling, fuel, lubrication and compressed air) shall be designed according to the same principles as the sub-systems proper. The auxiliary systems shall be so dimensioned that they are capable, in accordance with the set operating time requirements, of assuring the operating capability of safety significant secured alternating current systems in all plant operating conditions and postulated accidents.

Cross-connections between redundant sub-systems shall be avoided, unless it can be demonstrated that they improve system reliability. Their design shall render unlikely the occurrence of human errors in connection with their start-up and operation. The spreading of a malfunction from one sub-system to another via a cross-connection shall be reliably prevented.

2.5 Direct current power systems

The direct current power systems important to safety shall be designed to be as independent of other power systems as possible. They shall satisfy, where applicable, the aforementioned design principles that apply to secured alternating current systems.

Direct current power systems important to safety shall be designed such that their availability can be continuously and reliably monitored.

Storage batteries shall be dimensioned to reliably assure the operating capability of direct current and alternating current power systems important to plant safety in accordance with system-specific operating time requirements. In accordance with Guide YVL 1.0, *batteries backing up the operation of electrical systems important to safety shall maintain their capability to operate at least for two hours under any circumstances.*

Charging devices shall be capable of simultaneously feeding direct current to the loads and of charging storage batteries. A charging device shall be dimensioned such that its performance is not endangered even during the most demanding loading situations and environmental conditions. It shall be capable of feeding the necessary direct current to the loads even if the storage battery has been disconnected. And even in such a case, the quality of the direct current supplied shall not cause malfunctioning of the loads.

3 Regulatory control

3.1 Pre-inspection of electrical power systems

STUK pre-inspects Safety Class 2 and 3 electrical power systems.

During the processing of construction and operating licence applications, systems pre-inspection is carried out by reviewing the Preliminary and Final Safety Analysis Reports and the related topical reports. The pre-inspection of a system that is modified or added during NPP operation is carried out by reviewing a separate set of documents pertaining to the modification. The system's safety class determines the scope and contents of the pre-inspection documents.

The pre-inspection documents of an electrical power system shall include
- the system design bases
- a technical description of the system
- a description of the operation of the system
- a safety analysis of the system.

The quality management methods applied in the system's design and implementation shall be described.

The system's design bases shall give the regulatory guides and standards applied in the system's design and implementation. In accordance with Guide YVL 1.2, *it shall explicitly appear from the document what regulations and guides pertaining to radiation and nuclear safety specifically apply to the matter in question and how possible deviations from their requirements are made.*

The system's technical description shall include at least
- diagrams and descriptions representing the control, measurements and monitoring of the system
- schematics for electrical protection and a description of selectivity
- block diagrams for main and auxiliary voltage feeds.

The description of the operation of the system shall state its operation during operational conditions and accidents. The necessary diagrams and drawings shall be appended to the description as well as a description of how the system's operability depends on its auxiliary systems (e.g. cooling, auxiliary voltage). In addition, a qualitative failure analysis (e.g. a failure mode and effect analysis) of the system shall be made, whose level and depth shall be equivalent to the system's safety classification.

The safety analysis of the system shall demonstrate that the system meets the requirements given in its design bases. A reliability analysis shall be appended, if necessary, to the safety analysis of a safety classified system included in the Final Safety Analysis Report and in the pre-inspection documents of a system modification.

The pre-inspection documents of a system modification shall include a description of the modification's effect on the probability of a core melt.

3.2 Pre-inspection of electrical components

STUK pre-inspects the following electrical components:
- Safety Class 2 electrical components
- electrical components needed during an accident, for which special environmental qualification requirements have been set.

The pre-inspection documents shall include
- component design bases
- description of manufacturer
- data on type tests and operating experience
- quality control and inspection plan
- description of component operation
- installation and assembly drawings.

The description of a component's design bases shall include at least its
- safety class, location and function in the electrical system
- power, voltage, current and frequency ranges
- electromagnetic compatibility within the operating environment

- conditions within the operating environment, such as temperature, humidity, radiation, pressure and vibration
- fire resistance.

The guides and standards to be applied in the design, manufacture and installation of the component shall be given.

The purpose of the description of manufacturer is to demonstrate the expertise of the component manufacturer. It shall indicate the sufficiency of the manufacturer's quality system and the related means of quality management.

The type tests of standardised components that have been used for various purposes for a long time, may, at discretion, be replaced with thorough operating experience feedback data. However, components for whose environmental qualification special requirements have been set are subject to type testing. If it is proposed that type tests be replaced with operating experience feedback data, at least the following information shall be given on the component type in question:

- number and service time of previously manufactured similar components and operating applications
- previous operating and environmental conditions
- summary of discovered failure types.

As concerns quality control and quality inspection, the inspection and testing measures performed on a component during manufacture, factory testing, installation and commissioning shall be given. In addition the performer of each inspection or test and the possible regulatory organisation shall be given. The description shall also state the methods and scope of the inspections, the approval criteria and the reporting of results.

It shall be described how the component functions in operational situations and accidents specified in the system's design bases.

3.3 Manufacturing control

As considered necessary, STUK controls by audits the manufacture of electrical power systems and components that are subject to pre-inspection. During these audits, STUK's inspectors shall be given the possibility of acquainting themselves with the manufacturers' quality systems and quality control methods as well as of verifying the implementation of quality control during the manufacturing of an electrical component.

For use during possible audits at the factory and suppliers, STUK shall be sent the manufacturing schedules of electrical power systems and components and the dates of the most important quality control measures.

3.4 Installation control

STUK controls the installation of safety classified electrical power systems and components as considered necessary,

Case by case, STUK may require the following to be submitted for information: a description of the quality system of the organisation responsible for installation, the installation schedule, the procedures followed in the documentation of installation measures and the scope of the inspections that will be carried out after the installation. This will be the case with jobs having particular safety-significance. If several organisations participate in the installation, their mutual distribution of work and spheres of responsibility shall be given as well.

STUK verifies that installation methods and inspections adhere to plans. In addition, STUK assesses by these inspections that components or equipment are in compliance with the pre-inspection documents and that a component and its cables are compatible with the conditions of the installation environment in question.

3.5 Commissioning

STUK conducts a commissioning inspection on all those electrical power systems and components whose pre-inspection documentation it has approved. For the commissioning of power systems and components modified during operation, STUK may, at discretion and on the basis of a separate application, grant inspection rights to an inspection organisation or inspector proposed by the licensee.

The items of a commissioning inspection are as follows:

- results of quality control during manufacturing
- results of quality control during installation
- results of functional tests
- status of remarks made in connection with previous control measures.

The commissioning inspection also includes the following: a visual inspection at the installation site, the witnessing of functional tests in connection with start-up operation, if considered necessary, and other possible inspections case by case that STUK may consider necessary.

STUK controls the start-up testing of electrical power systems and components in connection with tests at the site in accordance with Guide YVL 2.5. STUK witnesses the tests at the plant site as considered necessary. The start-up testing programmes and result reports of safety classified systems shall be submitted to STUK for approval.

3.6 Inspections during operation

During plant operation STUK controls electrical power systems and components at NPPs by inspecting and reviewing the repairs and modifications of systems and individual components and by assessing the operations of licensees and the efficiency of their procedures in assuring the reliable operation of the systems and components. The licensee's operations are assessed in inspections of the periodic inspection programme that are repeated at regular intervals. In addition, STUK follows technical developments and know-how in the field as well as the collection of operating experience data, and conducts topic-specific inspections, assessments and analyses, or has them conducted.

As part of the periodic inspection programme, STUK ensures among other things that

- the operability and condition of safety classified electrical power systems and components are ascertained by periodic tests
- the ambient and operating conditions of safety classified systems and components are monitored
- the ageing of safety classified components and their installation is monitored
- data is systematically collected on the faults, repairs, maintenance and modifications of safety classified components
- the preventive maintenance, repair and spare parts service of safety classified components are appropriately taken care of.

The periodic test programmes of electrical power systems and components, the testing procedures and the condition monitoring instructions shall be sent to STUK for information. The test results shall be recorded onsite in such a way that STUK can evaluate them and compare with earlier results.

In connection with the review of the Technical Specifications of the NPP, STUK evaluates the acceptability of the operability requirements set on the facility's safety significant electrical power systems and components as well as the scope of their periodic tests.

The environmental and operating conditions of safety classified components shall be monitored by measurements at their locations. The results shall be compared with calculated values. The maintenance programmes and service life assessments of the components shall be changed on the basis of the results, if necessary. STUK checks the measurement results at the site in an extent deemed necessary.

The licensee shall monitor the ageing of electrical components and of their installation. Specific attention is to be paid to the condition of components needed in accidents as well as the condition of their cables and installations. Mechanical and electrical inspection of the samples of cables shall be performed to monitor the condition of cables located inside the containment. STUK sees to it that the condition monitoring programme of electrical power systems and components is updated on the basis of operating experience and ageing mechanism data.

3.7 System and component modifications during operation

STUK pre-inspects modifications made to safety classified electrical power systems and components during operation as described in subsections 3.1–3.4. Work on the modifications may only be commenced after STUK's approval of the pre-inspection documents has been obtained and when any requirements for the commencement and control of work, which STUK may have set in the approval, have been fulfilled. When start-up testing programmes for modified systems parts and components are drawn up, corresponding original start-up testing programmes for the systems and components in question shall be considered.

STUK's approval of modifications to Class EYT (non-nuclear) systems shall be obtained if they affect the implementation of the general design principles presented in sub-section 2.1.

Detailed requirements for modifications at nuclear facilities are given in Guide YVL 1.8.

4 Definitions

Operational conditions

Operational conditions mean a nuclear power plant's normal operational conditions and anticipated operational transients.

Normal operational conditions

Normal operational conditions mean that the nuclear power plant is operated according to the Technical Specifications and operational procedures. Normal operational conditions also include system and component tests, plant start-up and shutdown, maintenance and refuelling.

Anticipated operational transients

An anticipated operational transient means a deviation from normal operational conditions, which is milder than an accident and which can be expected to occur once or several times over a period of a hundred operating years.

Postulated accident

A postulated accident means such a nuclear power plant safety system design-basis event as the nuclear power plant is required to manage without any serious damage to the fuel and discharges of radioactive substances so large that extensive measures should be taken in the plant's vicinity to limit the radiation exposure of the population.

Accident

An accident means such a deviation from normal operational conditions as is not an anticipated operational transient. There are two classes of accident: postulated accidents and severe accidents.

Structures, systems and components important to safety

Structures, systems and components important to safety are such that

- their malfunction or breakage may significantly increase the radiation exposure of the plant's workers or the environment
- they prevent the occurrence and propagation of transients and accidents
- they mitigate the consequences of accidents.

Safety system

A safety system is a system that carries out a certain safety function.

Safety function

Safety functions are safety significant functions to prevent the occurrence or propagation of transients and accidents or to mitigate the consequences of accidents.

Severe accident

A severe accident means an event during which a significant part of the fuel in the reactor sustains damage.

Single failure

A single failure is a random failure plus its consequent effects, which are assumed to occur either during a normal operational condition or in addition to an initial event and its consequent effects. Further instructions for a single failure and how to provide against it are given in Guide YVL 2.7.