45A/893/NP

NEW WORK ITEM PROPOSAL

Proposer	Date of proposal
SWEDEN	2012-10-04
TC/SC	**Secretariat**
45A	France
Date of circulation	**Closing date for voting**
2012-10-12	2013-01-11

A proposal for a new work item within the scope of an existing technical committee or subcommittee shall be submitted to the Central Office. The proposal will be distributed to the P-members of the technical committee or subcommittee for voting on the introduction of it into the work programme, and to the O-members for information. The proposer may be a National Committee of the IEC, the secretariat itself, another technical committee or subcommittee, an organization in liaison, the Standardization Management Board or one of the advisory committees, or the General Secretary. Guidelines for proposing and justifying a new work item are given in ISO/IEC Directives, Part 1, Annex C (see extract overleaf). **This form is not to be used for amendments or revisions to existing publications.**

The proposal (to be completed by the proposer)

Title of proposal
Nuclear power plants – Electrical systems – Electrical Power System Analyses

☒ **Standard** ☐ Technical Specification

Scope (as defined in ISO/IEC Directives, Part 2, 6.2.1)
This standard establishes requirements for analyses of electrical power systems in nuclear power plants. The standard will include identification of hazards, guidance on analyses to be performed to determine the design bases and verification that the design meets these bases. The standard covers both AC and DC power systems and apply to all nuclear power plants.

Purpose and justification, including the market relevance, whether it is a proposed horizontal standard (Guide 108)[1)] and relationship to Safety (Guide 104), EMC (Guide 107), Environmental aspects (Guide 109) and Quality assurance (Guide 102) . (attach a separate page as annex, if necessary)
The need of a standard on electrical power system analyses in nuclear power plants was recognized by the OECD/NEA work DIDELSYS (defence in depth of electrical systems) after the Forsmark incident in 2006. The same need was also recognized during drafting of an updated IAEA safety guide on design of electrical power systems. See further Annex A and Annex B.

Target date	for first CD 2014-06	for IS/ TS
Estimated number of meetings 3	Frequency of meetings: per year	Date & place of 1st meeting: 2013-06, Moscow
Proposed working methods	☒ E-mail	☐ Collaboration tools

Relevant documents to be considered

Relationship of project to activities of other international bodies
IAEA Safety Standard NS-G-1.8 Design of Electric Power Systems for Nuclear Power Plants (presently DS-430)

Liaison organizations	**Need for coordination within ISO or IEC**

Preparatory work
Ensure that all copyright issues are identified. Check one of the two following boxes

☐ A draft is attached for comment* ☒ An outline is attached

* Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

We nominate a project leader as follows in accordance with ISO/IEC Directives, Part 1, 2.3.4 (name, address, fax and e-mail):
Lars Fredlund Ringhals AB 43285 Väröbacka Sweden; lars.fredlund@vattenfall.com

1) Other TC/SCs are requested to indicate their interest, if any, in this NP to the TC/SC secretary.

Concerns known patented items (see ISO/IEC Directives, Part 2) ☐ Yes. If yes, provide full information as an annex ☐ no	**Name and/or signature of the proposer** Thoma Korssell, Swedish NC secretariat

Comments and recommendations from the TC/SC officers
1) Work allocation ☐ Project team ☒ **New working group** ☐ Existing working group no:
2) Draft suitable for direct submission as ☐ CD ☐ CDV/ DTS
3) General quality of the draft (conformity to ISO/IEC Directives, Part 2) ☐ Little redrafting needed ☐ Substantial redrafting needed ☒ **no draft (outline only)**
4) Relationship with other activities In IEC In other organizations
5) Proposed horizontal standard ☐ [1] Other TC/SCs are requested to indicate their interest, if any, in this NP to the TC/SC secretary.
Remarks from the TC/SC officers This proposal related electrical systems is totally consistent with the approach discussed in IEC SC 45A since 4 years and with the will of IEC SC 45A to set up a new Working Group to cover in particular the issue of reliability of NPP electrical systems developping a new series of standards. The decision of IEC SC 45A to set up the new Working Group is a follow up of the OECD/NEA/DIDELSYS expert recommandation to have standards developed on the subject of electrical systems. It has to be noted that this topic is covered by the current scope of IEC SC 45A. SC 45A officers invite the National Committees to appoint new eletrical experts to take part to the technical debate on this new topic. SC 45A officers fully support this project and given the project is approved will diligently organize the set up of the Working Group before the IEC SC 45A meeting to be held in June 2013 in Moscow.

Approval criteria:

- Approval of the work item by a simple majority of the P-members voting;
- At least 4 P-members in the case of a committee with 16 or fewer P-members, or at least 5 P-members in the case of committees with more than 17 P-members, have nominated or confirmed the name of an expert and approved the new work item proposal.

Elements to be clarified when proposing a new work item

Title

Indicate the subject matter of the proposed new standard or technical specification.

Indicate whether it is intended to prepare a standardor a technical specification.

Scope

Give a clear indication of the coverage of the proposed new work item and, if necessary for clarity, exclusions.

Indicate whether the subject proposed relates to one or more of the fields of safety, EMC, the environment or quality assurance.

Purpose and justification

Give details based on a critical study of the following elements wherever practicable.

a) The specific aims and reason for the standardization activity, with particular emphasis on the aspects of standardization to be covered, the problems it is expected to solve or the difficulties it is intended to overcome.
b) The main interests that might benefit from or be affected by the activity, such as industry, consumers, trade, governments, distributors.
c) Feasibility of the activity: Are there factors that could hinder the successful establishment or general application of the standard?
d) Timeliness of the standard to be produced: Is the technology reasonably stabilized? If not, how much time is likely to be available before advances in technology may render the proposed standard outdated? Is the proposed standard required as a basis for the future development of the technology in question?
e) Urgency of the activity, considering the needs of the market (industry, consumers, trade, governments etc.) as well as other fields or organizations. Indicate target date and, when a series of standards is proposed, suggest priorities.
f) The benefits to be gained by the implementation of the proposed standard; alternatively, the loss or disadvantage(s) if no standard is established within a reasonable time. Data such as product volume of value of trade should be included and quantified.
g) If the standardization activity is, or is likely to be, the subject of regulations or to require the harmonization of existing regulations, this should be indicated.

If a series of new work items is proposed, the purpose and justification of which is common, a common proposal may be drafted including all elements to be clarified and enumerating the titles and scopes of each individual item.

Relevant documents

List any known relevant documents (such as standards and regulations), regardless of their source. When the proposer considers that an existing well-established document may be acceptable as a standard (with or without amendments), indicate this with appropriate justification and attach a copy to the proposal.

Cooperation and liaison

List relevant organizations or bodies with which cooperation and liaison should exist.

Preparatory work

Indicate the name of the project leader nominated by the proposer.

<u>NWIP Nuclear Power Plants – Electrical Systems – Electrical Power System Analyses. Purpose and justification</u>

1 Purpose

This standard establishes requirements for

1) identification of hazards that challenge the performance of electrical power systems in nuclear power plants
2) analyses to determine the design bases for the electrical power systems and connected equipment
3) analyses to verify that the design meets the design bases

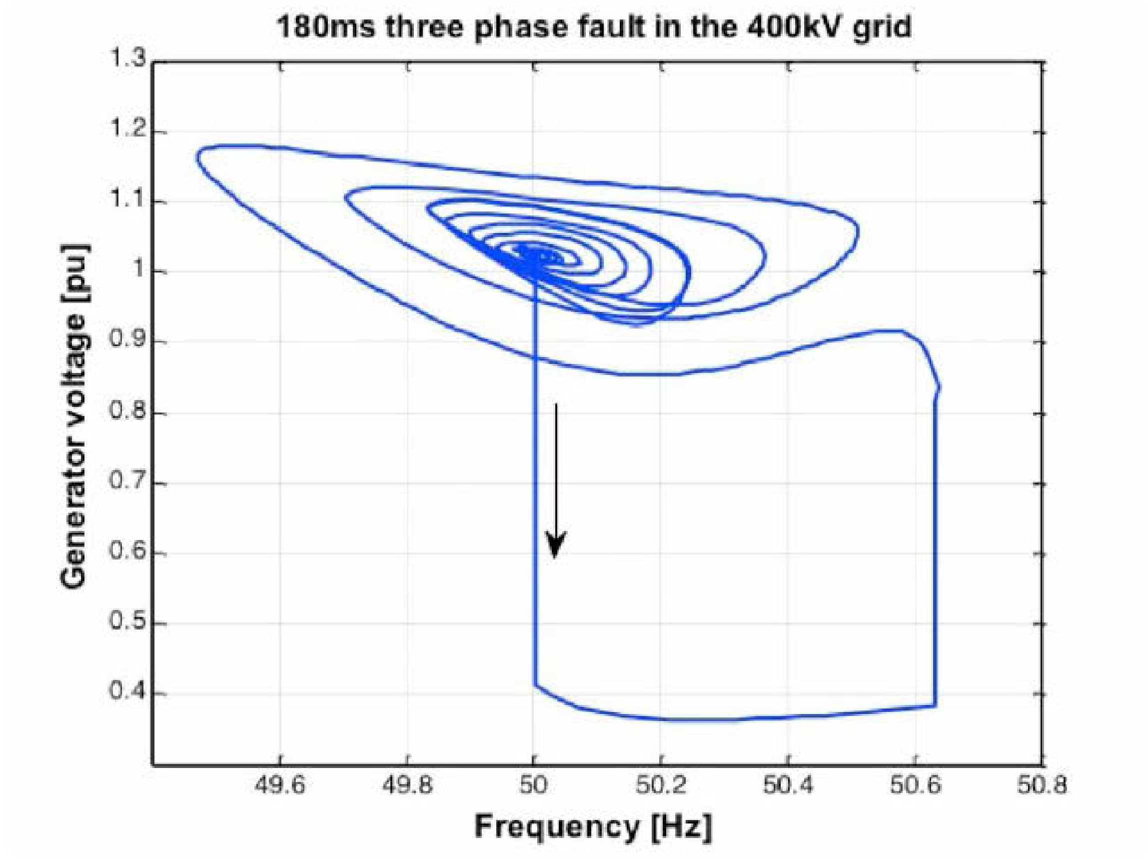
2 Justification for a specific standard on electrical power system analyses

Electrical systems in nuclear power plants have from an electrical point been treated as support system. Experience from various events, captured in the OECD/NEA DIDELSYS work (defence in depth of electrical systems), indicate that there is a lack of guidance how to design and analyze these support systems. The main part of the need for specific analyses required are driven by the fact that a nuclear power plant is a large production facility with special transient and dynamic response to different electrical events.

During the final step of the DIDELSYS work the need for engineering standards was investigated and six broad categories were identified. This standard will cover four of the categories

1) <u>Hazard analyses</u> that shall be performed for identification of possible fault conditions, including characterization of the conditions that can exist in the plant's electrical power system
2) Confirmation of the <u>robustness</u> of the electrical power systems under the full range of possible conditions
3) <u>Setpoint determination</u> for those electrical protective devices whose settings involve considerations that are unique to nuclear safety
4) <u>Coordination</u> between the plant operator and the transmission system operator, but limited to design aspects

The standard is not only useful for new build. In many nuclear power plants electrical equipment is getting obsolete and will be replaced. Experience shows that the original design bases, based on the hazard analyses, often are lost or not updated and commercially available equipment does not meet the challenges in power plants.



Example of on-site voltage (y-axis) and frequency (x-axis) variations during fault clearing on the transmission system

3 References

IAEA Draft Safety Guide DS-430 (supersedes NS-G-1.8) Design of Electrical Power Systems for Nuclear Power Plants. Available at http://www-ns.iaea.org/committees/comments/default.asp?fd=1151

IAEA Technical report NG-T-3.8 Electric Grid Reliability and Interface with Nuclear Power Plants

NEA/CSNI/R(2009)10 Defence in Depth of Electrical Systems and Grid Interaction.

NWIP, Nuclear Power Plant – Electrical Systems – Electrical Power System Analyses. Outline

The text provided below is intended as a suggestion of the structure of the Standard and of what kind of information that should be included. Figures are included in order to explain what information shall be covered by the standard. Part of the provided text should be part of an informative annex to the standard.

Table Of Content

1 SCOPE AND OBJECT

1.1 General

This standard provides the engineering standard for analyses of electrical power systems in nuclear power plants. The standard includes identification of hazards, guidance on analyses to be performed to determine the design bases and verification that the design meets these bases. The standard covers both AC and DC power systems and apply to all nuclear power plants.

1.2 Use of this Standard

To be added later

2 NORMATIVE REFERENCES

To be completed later

This standard is related to IAEA Safety Standard NS-G-1.8 Design of Electric Power Systems for Nuclear Power Plants (presently DS-430)

3 TERMS AND DEFINITIONS

To be added later

4 SYMBOLS AND ABBREVIATIONS

To be completed later

TSO Transmission system operator

Alternate AC power source. Dedicated power source that could be used as power supply to the plant during total loss of all non-battery power in the safety power systems (station blackout) and other design extension conditions.

Preferred power supply. The power supply from the transmission system up to the safety classified electrical power system. It is composed of transmission system, switchyard, main generator and distribution system up to safety classified electrical power system. Some portions of the preferred power supply are not part of the safety classification scheme.

Station blackout (SBO). Plant condition defined as the complete loss of all AC power from off-site sources, from the main generator and from standby AC power sources important to safety. DC power and uninterruptible AC power is present as long as batteries can supply the loads. Alternate AC power can be available.

5 GENERAL REQUIREMENTS FOR ELECTRICAL POWER SYSTEM ANALYSES

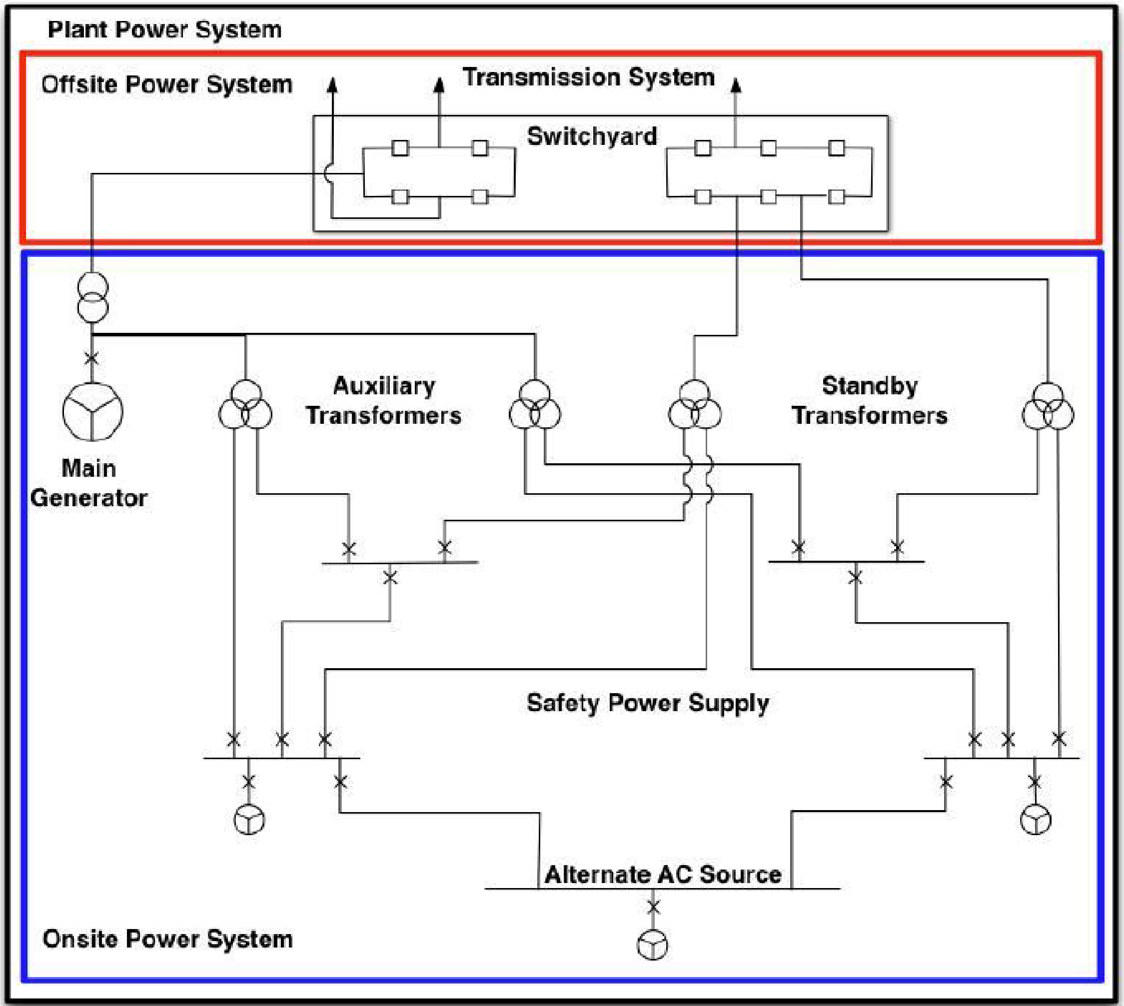
5.1 General

Analytical studies shall adequately demonstrate design margins and robustness of the Electrical Power System in a nuclear plant. It shall be used for protective relay settings and to verify the operability of plant equipment during normal, abnormal and transient conditions of the plants electrical power system. The analyses shall be verified and validated by test or operating experience.

This standard describes the key elements of electrical power system analyses in nuclear power plants. The standard describes what shall be analyzed as a minimum but does not give details on how the analyze shall be carried out.

The main part of the required analyses are driven by the nuclear power plant being a large production facility with special transient and dynamic response to different events, not by nuclear aspects. Electric power system analyses are independent of redundancy, diversity and probability.

The nuclear power plant is during shutdown a large load on the grid with demands on reliable power supply in order to support the nuclear safety functions. This mode of operation shall be analysed.



Note This figure is only an example. Varrious arrangements of buses, loads, generators, and interconnections will meet the requirements of SSR 2/1. Furthermore, many elements of the plant power system, such as buses that are not important to safety, and DC power systems are not shown.

Special purpose, "stand-alone" power supplies, such as separate power for security systems, are not included in the scope of this guide.

Fig 1 Relationship of the plant power system, the offsite power system and the onsite power system (from IAEA DS-430)

5.1.1 Robustness

Robust and reliable on-site power systems are essential for supporting the safety functions of the plant.

Robustness means that the plant equipment has sufficient margins and built in conservatisms such that equipment ratings, capabilities and capacities required to meet intended goals are not easily challenged. Equipment protection schemes and setpoints shall be chosen to accommodate anticipated variations in operation of on-site and off-site power systems. Protective actions are initiated, when needed, in order to preserve the functionality of the Safety Power Systems during normal operation. Protection schemes shall be designed for high reliability.

Simple and transparent design adds to the robustness. Use of proven design is preferred.

5.1.2 Analyses process

In order to achieve the robustness a clear analyses process shall be used.

Based on the loads to be supplied and on the identified events that could challenge the electrical power systems, the first steps of the analyses will determine the design bases on the plant level which will be broken down to system level and finally component level. Based on the actual design, and the components chosen, further analyses will verify that the design fulfils the design bases

5.1.3 Qualification of analytical tools

5.2 Operating area

The design base of the plant shall define a voltage and frequency operating area for continuous and transient/ dynamic operation. This constitutes the base for loads that are connected to the plant's electrical systems and gives the acceptance criteria for the electrical analyses.

The operating area shall take into account the various electrical events the plant shall be able to cope with, the impact of these events on the electrical systems derived from the analyses, as well as the design bases (frequency and voltage) from the thermohydraulic and nuclear safety analyses. See figure 2.

The operating area is part of the design bases for the plant. Incomplete design bases, resulting in equipment not qualified for the intended function, cannot be solved by redundancy or diversity.

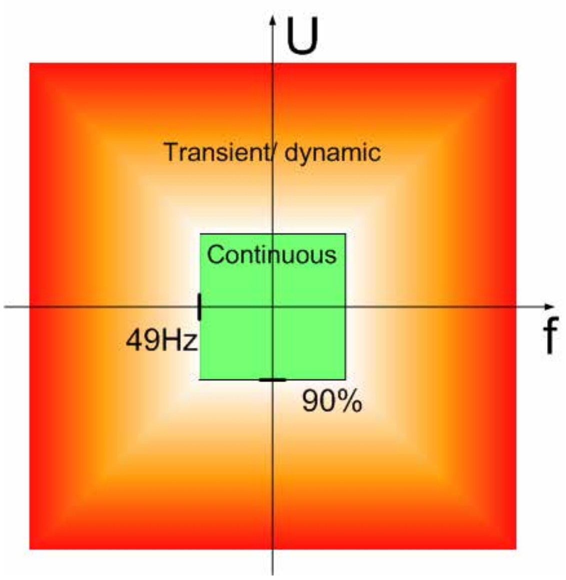


Fig 2 Operating area (example, levels to be omitted)

5.3 Identification of hazards

The design of the power systems in the plant shall consider all possible events that could occur in the electrical systems associated with the plant (see fig 3). These events can cause symmetrical and asymmetrical perturbations in the plant and can be initiated:

- In the transmission system(s) with the plant on line, off line and shutdown, or as a consequence of the plant separating from the grid due to anticipated faults or voltage and frequency variations beyond an acceptable level.
- By the main generator tripping leaving the on-site power systems connected to the off-site or on-site power sources.
- In the on-site power systems as a result of an electrical event such as motor starting, phase to ground fault or switching surges.

The impact of such events on all the onsite electrical power systems (AC and DC) (see Figure 3) shall be evaluated and confirmed that the allowable voltage and frequency requirements are not exceeded and the protection system is adequate.

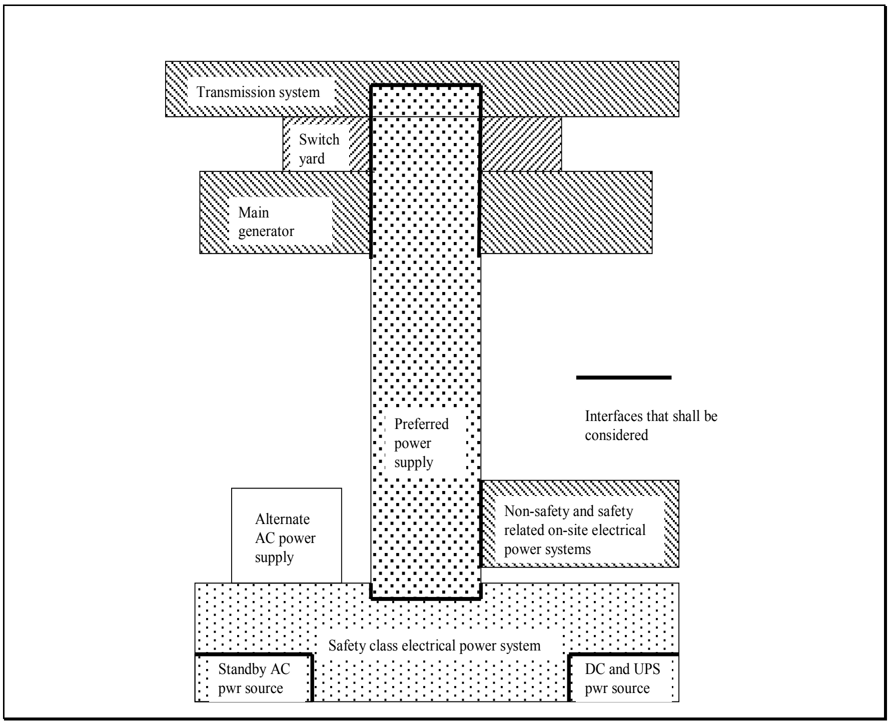


Fig 3 Interfaces to be considered in the analyses (based on IAEA DS 430)

5.3.1 Events originating from the grid/ preferred power supplies

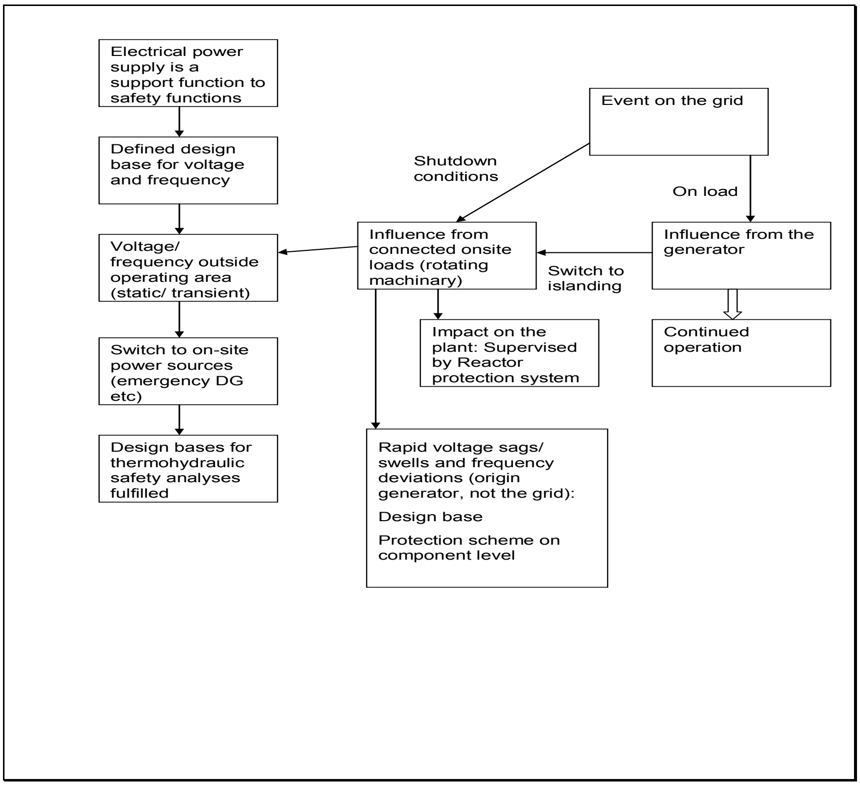


Fig 4 Events originating from the grid. (Atmospheric disturbances not included).

Events on the onsite power systems to be considered shall include, but are not limited to,

- Switching and lightning surges
- Voltage sags caused by electrical faults off-site
- Voltage interruptions caused by electrical faults off-site during shut-down operation;
- Deviating grid voltage and frequency;
- Open conductors; and
- Solar activity and geomagnetic induced currents.

For nuclear power plants with two or more independent supplies events on all supplies shall be considered and in all modes of operation.

5.3.2 Events originating from loss of load scenarios or from the main generator(s)

Events on the onsite power systems to be considered shall include, but are not limited to,

- Voltage swells caused by loss-of-load scenarios
- Frequency deviations caused by turbine speed variations;
- Transmission system faults cleared by first step or backup protection;
    - With generator connected to the grid after the event,
    - Out-of-step events, or
    - Voltage and frequency variations and transients at house load operation;
- Deviating grid voltage and frequency;
- Main generator excitation malfunctions (high and low excitation);
- Open conductors

5.3.3 Events originating from the on-site AC power sources

Events on the onsite AC power sources to be considered shall include, but are not limited to,

- Switching surges
- Voltage swells caused by loss-of-load scenarios
- Voltage sags caused by motor starts and electrical faults on-site
- Voltage interruptions caused by on-site faults;
- Frequency deviations caused by prime mover speed variations;

- Deviating power source voltage and frequency;
- Generator excitation malfunctions (high and low excitation);
- Open conductors;

5.3.4 Events originating from the on-site power systems

Events on the onsite power systems to be considered shall include, but are not limited to,

- Switching surges
- Voltage sags caused by motor starts and electrical faults on-site
- Bus transfers;
- Voltage interruptions caused by on-site faults;
- Faults in the on-site power system (all voltage levels) cleared by first step or backup protection;
- Open conductors; and
- Ground faults (low impedance to earth)

5.4 Grid requirements

The grid code of the TSO normally defines a voltage and frequency range that a thermal plant shall be able to withstand when producing power. The resulting voltage levels in the plant (which depends on the generator characteristics and limiters) shall be calculated and the impact on the plant be evaluated.

Voltage range on the grid when the plant is off-line shall also be evaluated and shown to be acceptable for the electrical safety systems. It is not acceptable that off-site power sources are not available for the plant after a trip or during shutdown.

Frequency deviations shall be evaluated. They can impact the coolant flow of the reactor and limit possible operation during disturbances.

Frequency deviations on the grid when the plant is off-line shall also be evaluated and shown to be acceptable for the electrical safety systems.

The special characteristics and needs of a nuclear power plant must be recognized by the TSO. A close cooperation between NPP and TSO is envisaged. [See IAEA NG-T-3.8, Electric grid reliability and interface with Nuclear Power Plants].

5.5 Conclusions

Normal strategy is to define a number of events that envelop the different scenarios. The most demanding events can differ depending on the operating mode of the nuclear power plant but also on initiating conditions such as power level and power factor. The impact on the onsite power systems and connected loads will also depend on the connected loads during the event.

5.6 Reaffirming system analyses

The analytical studies shall be confirmed when major replacements and major modifications of the electrical power system (on-site or off-site) are implemented and a cumulative evaluation shall be performed periodically, e.g., as part of Periodic Safety Review of the nuclear power plant.

6 AC SYSTEM STUDIES

6.1 General

Electrical systems feeding safety equipment are - directly or via transformers, switchgear and switchyards - connected to electrical systems feeding equipment without safety importance. The analyses shall cover all parts that are interconnected.

The on-site power systems are usually connected to one single preferred power supply which makes them vulnerable to common cause failures. Care must be taken to minimize the impact on safety equipment from events, normal or abnormal, in the electrical systems on-site or off-site.

6.2 Load flow studies, steady state and anticipated operational occurrences

Load flow analysis is an important part of power system calculations since it evaluates the network performance in its normal and emergency operating conditions and establishes the bounding limits for limiting conditions.

Load flow studies for AC systems shall be performed, using computer software that simulates actual steady-state power system operating conditions, enabling the evaluation of bus voltage amplitude and load angle, real and reactive power flow, and losses. Conducting a load flow study using multiple scenarios helps ensure that the power system is adequately designed to satisfy performance criteria. Specifically, load flow studies shall be used to investigate:

- Component or circuit loading,
- Bus voltage amplitude and load angle,
- Equipment voltage (voltage drop in cables)

- Real and reactive power flow,
- Power system losses,
- Proper transformer tap settings,
- Limiting conditions for system operation,
- Bus transfer schemes,
- Optimize circuit usage,
- Practical voltage profiles for postulated conditions
- Equipment specification guidelines
- Equipment sizeing (switchgear, cables etc)

Load flow studies shall consider the various power sources that can supply the electrical systems:

- The grid and alternate off-site AC source (Voltage span when the plant is not operating could be most demanding)
- The main generator supplying the onsite power systems (Voltage span of the main generator to be considered)
- Safety standby AC power sources (Voltage during sequencing is covered in chapter X).
- Alternate AC power source (Voltage during sequencing is covered in chapter X).

6.2.1 Acceptance criteria

The following general criteria for design are typically considered acceptable when used in power flow studies:

Steady state voltage drop at all buses to be within +/- 5% of the nominal rating for all operating conditions considered.

Electrical circuits shall not be overloaded for any postulated operating condition.

Reactive power flows (generation, import and export) shall be within specified limits for all operating conditions.

During specified contingency conditions, the power quality shall not be degraded.

Harmonic content shall be within set limits

6.2.2 Details on load flow studies

The following study cases shall be specifically considered in power flow studies:

Extreme operating conditions of maximum and minimum loading conditions to check the adequacy of the onsite and offsite power sources, during operation and plant shutdown.

Contingency conditions such as outage of lines, transformers and generators for the off-site source coupled with minimum and maximum loading of plant auxiliary system including equipment required to mitigate consequences of an accident.

Optimize plant operating parameters such as transformer taps, generator excitation limits, reactive power compensations and cable sizing.

6.2.3 Bus transfer studies

Bus transfer schemes shall be analysed as part of load flow studies.

If bus transfer is carried out with the two feeders connected at the same time, this shall be considered in the short circuit studies.

The combined reacceleration currents shall be analyzed in order to decide the proper setting of overcurrent protection. If the available short circuit power is low, it might be necessary to consider a start sequence for required connected loads after bus transfer.

6.2.4 Motor starting studies

The starting current of most ac motors is several times larger than normal full load current when starting them directly on line at full rated voltage. Excessive starting current results in drop in terminal voltage and may result in failure of motor starting due to low starting torques, unnecessary operation of under voltage relays or stalling of other running motors connected to the network. Motor starting studies can help in the selection of best method of starting, the proper motor design, and the proper system design for minimizing the impact of the motor starting. This study might have to be re-evaluated after replacement of motors, depending on motor characteristics. Modern motor designs have generally higher starting currents compared with older designs.

6.2.5 Motor reacceleration studies

After a bus transfer or after voltage sag on the onsite electrical system the combined reacceleration current to all rotating equipment might be of high value. The corresponding voltage drop in transformers and cables shall be determined. Setting of overcurrent devices shall consider the combined currents.

6.3 Short circuit and ground fault studies

6.3.1 General

Short circuit calculations provide currents and voltages on a power system during fault conditions. This information is required to design an adequate protective relaying system and to determine interrupting requirements for circuit breakers at each voltage level and verify stability of system operation. Fault contributions from all operating sources at any given time shall be considered. Nuclear power plants have large motors that can provide a significant contribution to the available fault current in the plant auxiliary system. The short circuit calculations shall be confirmed when major replacements and major modifications of the electrical power system (onsite or offsite) are implemented and a cumulative evaluation performed periodically.

Short circuit studies are also one of the design base inputs for sizing of switchgears, cables etc.

Fault conditions can be balanced or un-balanced shunt faults. Faults may be caused by either short-circuits to ground or between live conductors:

- 3 phase short circuit faults
- Phase to phase faults
- Phase to phase to ground faults (or phase to ground to phase)
- Single phase to ground faults

6.3.2 Origin grid/ preferred power supplies

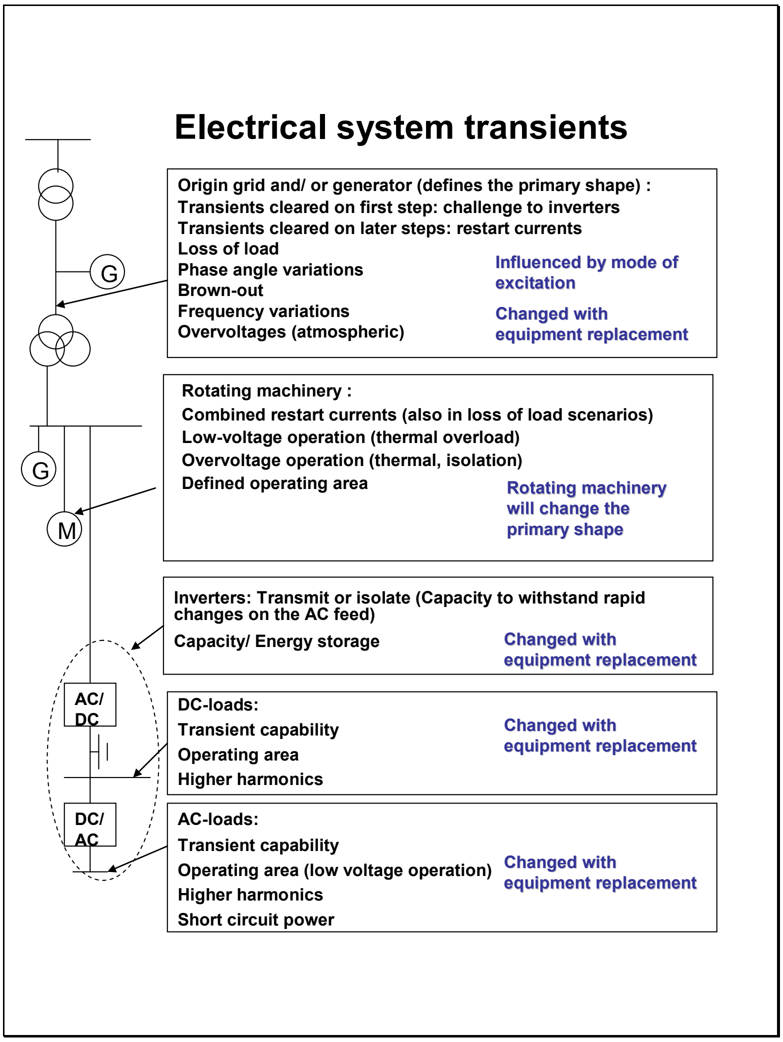


Fig 5 Electrical system transients originating from the grid

6.3.3 Origin on-site power system

6.4 Voltage studies

6.4.1 General

The returning voltage and frequency on the onsite buses in an operating generating station after an external or internal event shall be investigated. Also phase shifts (ie rapid frequency shifts) can occur, which can have an impact on connected loads and their control circuits (especially rectifiers and inverters have been reported to be sensitive to this). Examples of variations and transients on the buses that shall be considered include:

- Voltage ranges, maximum and minimum, for heavy and light load conditions;
- Frequency variation;
- Voltage and frequency transient response;
- Voltage regulation limits;

The impact on equipment (such as rectifiers and inverters) from symmetrical and asymmetrical faults on the AC supply (with origin on-site or off-site) shall be analyzed.

6.4.2 Islanding

Some nuclear power plants have the ability for islanding, i.e. convert to generating electricity only for the unit's own needs (the unit must have generator breaker and generator transformer breaker). This could be the result of a loss of load, caused by an event on the grid, or spurious opening of a breaker.

The transfer to islanding will cause variations of voltage and frequency on the generator terminals and in the onsite power systems.

During clearing of faults on the grid the returning voltage and frequency shift will show similarities to islanding.

The impact on onsite electrical equipment from variations in voltage and frequency shall be studied. Electronic equipment, such as rectifiers and converters/UPSs, has been shown to be sensitive to variations that are natural to a generating unit. Also electronic protective devices shall be studied.

6.4.3 Loss of voltage and degraded voltage studies

Safety equipment at nuclear plants shall be protected from a complete loss of preferred power (loss of voltage relay) to the safety buses and also from sustained degraded voltage conditions on the preferred power supply which can lead to malfunction or damage safety significant equipment. Degraded voltage could asymmetric, ie loss of one phase.

Equipment that is considered important to safety shall be protected from low voltage issues:

- Loss of voltage event which implies a sudden sharp voltage drop in the grid system. Typically a nominal delay is allowed for relay actuation to separate onsite busses from the grid if voltage does not recover to normal operating band. Loss of voltage shall provide an automatic start signal to the on-site stand-by power sources.

- Degraded voltage event that postulates sustained low voltage conditions for several seconds and subsequent recovery to normal operating band. If the offsite power system does not recover to nominal operating conditions, it is preferable to separate from the source.

- Degraded voltage events due to loss of one feeding phase.

The degraded voltage condition occurs in transmission systems that are overloaded due to generation deficiency caused by loss of a generating unit, unexpected system loads, loss of a transmission element or system faults. This protective scheme requires additional plant specific considerations. A general philosophy is outlined below:

The voltage drop/load flow studies done for evaluating offsite power/onsite power system interface shall use minimum expected voltage at the plant/grid interface node, demonstrating adequate voltage for starting and running of plant components during normal, abnormal and accident conditions.

The selection of voltage and time delay setpoints shall be determined from an analysis of the operating voltage requirements of the safety significant loads at all onsite system distribution levels.

The time delay selected shall be based on the following conditions:

The allowable time delay, including margin shall not exceed the maximum time delay that is assumed in the accident analyses;

The time delay should override the effect of expected short duration grid disturbances, preserving availability of the offsite power source(s): and

The allowable time duration of a degraded voltage condition at all distribution system levels shall not result in failure of safety systems or components.

A typical scheme for degraded voltage relay involves two separate time delay relays to deal with the following conditions:

- The first time delay shall be of a duration that establishes the existence of a sustained degraded voltage condition (i.e., something longer than a motor starting transient). Following this delay, an alarm in the control room shall alert the operator to the degraded condition. The subsequent occurrence of an accident signal shall immediately separate the safety distribution system from the offsite power system.

- The second time delay shall be of a limited duration such that the permanently connected safety loads will not be damaged. Following this delay, if adequate voltages have not been restored, the safety distribution system shall be automatically separated from the offsite power system.

Loss of one phase shall be analysed in order to determine how it can be detected in different plant conditions.

6.4.4 High voltage/ Overvoltage studies

Equipment in nuclear power plants shall be protected from overvoltages that could harm the functionality of the equipment.

The origin of overvoltages could be

- The grid
- Switching surges
- Overvoltage during loss-of-load events
- Overvoltage after grid disturbances
- Generator excitation system malfunctions

Faults on the grid, that result in loss-of-load or oscillations between grid and NPP generator, with ensuing voltage rise on the generator depending on the field current can give high overvoltage. A short rise time can also cause high overvoltage downstream rectifiers and inverters, if not correctly controlled and protected.

A typical scheme for overvoltage protection shall consists of

- Overvoltage protection on generator terminals, to protect against loss-of-load voltage and excitation malfunctions. The level shall be in line with what the loads can manage, a lower value (typically 130%) with a time delay and a higher value with no delay
- Overvoltage protection on safety system busbars to protect against emergency power supply malfunctions and overvoltages when the plant is shut down
- Overvoltage protection on loads (typically rectifiers and inverters) with no delay to protect the device against overvoltage and also to protect loads supplied from these devices.

6.5 Frequency deviation studies

6.6 Electrical protection coordination studies

6.6.1 Current

A Short Circuit / Coordination Study shall establishe the magnitude of currents flowing throughout the power system at various time intervals after a fault occurs and evaluates the size and settings of a system's protective devices, such as relays, fuses and circuit breakers, and the circuits they protect. The goal is to provide power transformers, switchgear, motor control centres, distribution panel boards and other electrical equipment with the required protection. The study also assists with selecting appropriate types, ampere ratings and device settings to ensure selective and rapid interruption of circuits under overload and short circuit conditions to minimize isolation of essential equipment.

Protective relays shall be designed to rapidly actuate equipment used to isolate the faulted portion of the system to prevent equipment damage and with minimum system disruption to ensure continuity of power to unaffected portions of the power systems. When relays designed to protect specific equipment such as containment penetrations are postulated to fail, or primary zones do not operate and clear the fault in their primary protection zone, backup relays must be able to isolate the fault, after providing sufficient time for the operation of the primary zone relays. The relays must also be able to discriminate between faulted conditions, normal operating conditions and abnormal operating conditions and function for the specific protection for which they are designed. Relay coordination calculations shall consider the operating characteristics of the relays, normal operating and withstand characteristics of plant equipment and must determine the optimum relay settings to achieve high reliability of the electrical systems.

Protective system shall also be designed to provide protection against thermal-withstand limits, motor stalling, negative sequence and direct current withstand limits, protection against abnormal frequencies, and protection against unbalance operating conditions as applicable to various plant components and operating situations Protection coordination also includes measuring principles.

Typical protective relays studies include:

- Overload phase relays,
- Overcurrent phase fault relays,
- Ground fault relays,
- Coordination with maximum load current,
- Coordination with fuse characteristics,
- Coordination with maximum motor starting current and time,

- Coordination with transformer inrush current,
- Coordination with reacceleration currents,
- Coordination with primary-back up pairs,
- Coordination with thermal withstand capabilities, and
- Coordination with safe stall limits for motors.

Ground fault protection requires unique consideration as fault current magnitudes depend on the system grounding method - solidly or low impedance grounded systems may have high levels of ground fault currents. These high levels typically require fast tripping to remove the fault from the system. Ground overcurrent and directional overcurrent relays are the typical ground fault protection solution for such systems. High-impedance ground fault detection is difficult as special relays are needed to measure the ground fault current combined with the unbalance current generated by line phasing and configuration and load unbalance.

6.6.2 Voltage

The purpose of degraded voltage protection is to prevent numerous overload trips of safety system equipment, rending them inoperable. On degraded voltage the electrical safety system shall be separated from the degraded supply and convert to it's own dedicated supply.

When voting circuits (often 2/2 or 2/3 logic) are used for voltage supervision the configuration of the equipment and the measuring principle must be able to detect the same degradation of the supply. A combination of phase-to-phase and phase-to-ground measurements shall not feed the same voting circuit for detection of asymmetric conditions.

7 TRANSIENT STABILITY STUDIES

By nature, a power system is continually experiencing disturbances. These may be include loss of production, short-circuits caused by lightning or other fault conditions, sudden large load changes, or a combination of such events. These disturbances may lead to a change in the configuration of the power system. Transient stability study of a power system is needed to determine whether the system will remain stable or not after such major disturbances. The assumed critical fault clearing time (CFCT) with a given off-site power system configuration shall be examined with various fault conditions.

The recovery of a power system subjected to a severe large disturbance is of importance to reliable and safe operation of a nuclear plant. Typically the system must be designed and operated in such a way that a specified number of credible contingencies do not result in failure of quality and continuity of power supply to the loads. This requires accurate calculation of the system dynamic behaviour, which includes the electro-mechanical dynamic characteristics of the rotating machines, generator controls, reactive power compensators, loads, protective systems and other controls. The degree of the system stability is an important factor in establishing the operating characteristics of the grid system in the vicinity of the nuclear plant. Grid perturbations that lead to loss of synchronism of the power system require separation of the disturbance in a rapid manner to avoid equipment damage or loss of system stability.

Parameters that can affect transient stability include:

- Synchronous machine parameters,
- Generator step-up transformer impedance,
- Inertia of turbo-generator,
- Transmission Line parameters,
- Circuit breaker and relay characteristics,
- System layout,
- Excitation system, power system stabilizer and generator governor characteristics,
- System grounding, and
- System Controls such as auto reclosing of circuit breakers, single pole switching, load shedding and system inertia.

Typically, transient stability analysis involves:

- Modelling generators in accordance to their steady state, transient, and sub-transient parameters,
- Simulating transient behaviour for three-phase or line-to-ground faults,
- Modelling motor and motor load torque, slip, current and acceleration curves,
- Simulating generator and motor start-ups,
- Modelling trip/close of circuit breakers, open/close of switches, and actions of relays based on the settings, and
- Plotting generator and motor speed, current, voltage, and power curves after postulated disturbances.

Breaker operating characteristics, synchronous machine behaviour and system interconnections can be optimized using computer based transient stability analysis.

The grid transient system stability analyses shall demonstrate that the plant can ride through and remain connected to the grid for perturbations that do not result in generator falling out of step.

8 SAFETY STANDBY AC POWER SOURCES STUDIES

8.1 General

Motor loads for power system analyses can be substantially higher than what is used in thermo hydraulic safety analyses. In the latter, the purpose is to show what minimum flow is needed to acheive the safety function. In electrical power system analyses the maximum load is sought for, often the case in the beginning of a sequence with run-out conditions, maximum tank levels etc.

Frequency deviations will occur during load sequencing. The impact on pump flow can generally be neglected as long as the deviations are short (see RG 1.9) and if the maximum flow used in the analyze is higher than the minimum flow in the thermo hydraulic analyze.

It is beneficial if the standby AC power sources have an overload capacity that can be used during load sequencing for rapid restoration of frequency.

The design base of the plant shall define a voltage and frequency operating area for continuous and transient/ dynamic operation. This constitutes the base for loads that are connected to the plant's electrical systems and gives the acceptance criteria for the electrical analyses. For the safety standby AC power sources it is desirable to keep them in operation even outside the operating area in order to have a power supply during emergency situations. The ultimate operating area shall be determined as part of the analyses.

Supply of consumables is outside the scope of this standard.

8.2 Load flow and load sequencer studies

Safety standby AC power sources are analysed static and dynamic. The static analyze purpose is to demonstrate that the power source has capability to supply connected loads continuously.

The dynamic analyze shall demonstrate that all loads can be connected in a pre-determined sequence and that the power source can restore voltage and frequency before the next load step is connected.

Load flow studies, as per chapter 6.2, shall be performed with the safety standby AC power source as the sole source.

8.3 Short circuit studies

Short circuit studies, as per chapter 6.3, shall be performed with the safety standby AC power source as the sole source.

8.4 Motor starting studies

8.5 Electrical protection coordination studies

8.6 Voltage studies

9 DC SYSTEM STUDIES

9.1 General

9.2 Load flow studies

Load flow analysis is an important part of power system calculations since it evaluates the network performance in its normal and emergency operating conditions and establishes the bounding limits for limiting conditions.

Load flow studies for DC systems are commonly used to investigate:

- Component or circuit loading
- Bus voltage amplitude during battery charging, trickle (float) charging and discharging
- Load voltage (voltage drop from bus to load)
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9.3 Battery characteristics

9.4 Rectifier characteristics

9.5 Short circuit studies

10 UNINTERRUPTIBLE AC SYSTEMS STUDIES

10.1 General

10.2 Load flow studies

10.3 Battery characteristics

10.4 Rectifier characteristics

10.5 Inverter characteristics

10.6 Short circuit studies

11 LIGHTNING PROTECTION AND SYSTEM GROUNDING STUDIES

A lightning protection system is a system designed to protect a structure from damage due to lightning strikes by intercepting such strikes and safely passing their extremely high voltage currents to ground. The voltage from a lightning strike rises very rapidly, typically to its peak in a few millionths of a second. This energy must be returned to ground very quickly through a low impedance path to preclude equipment damage and injury of personnel.

Most external systems for lightning protection consist of an air terminal, down conductor and grounding terminal including a network of lightning rods metal conductors, and ground electrodes connected to station ground mat to provide a low resistance path to ground for potential lightning strikes. The internal system for lightning protection will include lightning equi-potential bonding, electrical insulation of the external system and a surge protective device.

In any generating station there are generally four conceptually identifiable, but not necessarily physically distinct, grounding systems: personnel safety, lightning, electrical system and I&C - including signal grounding. All grounding systems shall be finally tied to the one grounding grid.

Typically, international standards recommend that the grounding electrode resistance of large electrical substations should be 1 Ohm or less.

Factors that affect lightning protection schemes include:

- Plant ground mat design,
- Soil resistivity, and
- Lightning rod design (copper clad, coated, other noble materials, size and depth, etc.)

A well-designed station grounding system is essential for protection of power plant equipment from ground faults and lightning strikes.

12 ELECTROMAGNETIC COMPATIBILITY STUDIES

International EMC standards on industrial environments may serve as the basis for the requirements provided that they are supplemented, where necessary, to cover the EMC environments of generating power plant components, which might be more demanding. Results of such a study would be the emission level envelope with frequency spectrum and the susceptibility level envelope with frequency spectrum.

Harmonic analyses.

GIC/ Solar flares.