Design Provisions for Station Blackout at Nuclear Power Plants

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Abstract

A station blackout (SBO) is generally known as "a plant condition with complete loss of all alternating current (AC) power from off-site sources, from the main generator and from standby AC power sources important to safety to the essential and nonessential switchgear buses. Direct current (DC) power supplies and uninterruptible AC power supplies may be available as long as batteries can supply the loads. Alternate AC power supplies are available".

A draft Safety Guide DS 430 "Design of Electrical Power Systems for Nuclear Power Plants[4]" provides recommendations regarding the implementation of Specific Safety Requirements[5]: Design: Requirement 68 for emergency power systems. The Safety Guide outlines several design measures which are possible as a means of increasing the capability of the electrical power systems to cope with a station blackout, without providing detailed implementation guidance.

A committee of international experts and advisors from numerous countries is currently working on an IAEA Technical Document (TECDOC) whose objective is to provide a common international technical basis from which the various criteria for SBO events need to be established, to support operation under design basis and design extension conditions (DEC) at nuclear power plants, to document in a comprehensive manner, all relevant aspects of SBO events at NPPs, and to outline critical issues which reflect the lessons learned from the Fukushima Dai-ichi accident.

This paper discusses the commonly encountered difficulties associated with establishing the SBO criteria, shares the best practices, and current strategies used in the design and implementation of SBO provisions and outline the structure of the IAEA's SBO TECDOC under development.

1. Introduction

As far back as 1985, the IAEA published a TECDOC on this subject — *Safety Aspects of Station Blackout at Nuclear Power Plants* (IAEA-TECDOC-332). That TECDOC focused mainly on safety aspects of SBO. Owing to the date of publication, it needs to be revised to account for lessons learned from past SBO events, as well as from the Fukushima Daiichi accident.

The IAEA, in cooperation with Member States, is currently developing a Technical Document on the "Design Provisions for Station Blackout for Nuclear Power Plants".

This paper describes design philosophy, station blackout recovery strategies, as well as guidance for existing plant designs that has been observed in Member State Countries participating in the development of the TECDOC.

[4] It will supersede the Safety Guide "Design of Emergency Power Systems for Nuclear Power Plants", Safety Standards Series No. NS-G-1.8, IAEA, Vienna (2004).

[5] Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. SSR-2/1, IAEA, Vienna (2012).

The TECDOC aims to provide a common international technical basis to be considered when establishing the various criteria for SBO events in line with recommendations from DS 430, Chapter 8 Alternate AC power source, regarding the design of electrical power systems for DEC and to provide technical guidance for the design provisions to deal with SBO events at NPPs. This involves a description of current plant practices and design provisions already implemented at some NPPs, as well as proposals for improvement of current design bases and qualification requirements to better deal with an SBO event, in order to further improve robustness of the plant electrical design.

The TECDOC provides a description of current plant practices and design provisions for SBO events already implemented at some NPPs, as well as proposals for improvement of existing plant design and qualification requirements to increase the robustness of the plant electrical design for contending with SBO events.

2. Classification of SBO event

While a Loss of Off-site Power (LOOP) is considered to be within the design basis for all plants and is managed through a range of redundant and diverse means, SBO is considered for most of existing NPP designs as a design extension condition (DEC).

International operational experience has shown that loss of off-site power supply concurrent with a turbine trip and unavailability of the emergency alternating current (AC) power system is a credible event. Lessons learned from the past and recent station blackout events, as well as the analysis of the safety margins performed as part of the ‘stress tests’ that have been conducted on European NPPs as a response to the Fukushima Daiichi accident, have identified the station blackout (SBO) event as a limiting case for most NPPs.

In the Fukushima Daiichi accident in 2011, the common cause failure of electrical power supply systems due to flooding resulted in the melting of the core of three reactors at the Fukushima Daiichi NPP, and severely restricted heat removal at the spent fuel pools for a long period of time. In addition, the flooding caused the loss of DC power supply. The plant was left without essential instrumentation and controls, and this made accident management for the plant operators very difficult. The operators remained without information on the critical plant parameters until the power supply was restored from portable batteries. The readings were discontinued, difficult to obtain.

Although the Fukushima Daiichi accident went well beyond SBO, many of the lessons learned from that accident still remain to be addressed. The design of the electrical power systems for both operating plants and new builds should account for both SBO and the full loss of all on-site AC and DC power. Criteria for the two types of events will necessarily be different, as we want to limit the consequences of SBO within the design basis envelope because the historical frequency of SBO is higher, while a total loss of AC and DC for a prolonged period as at Fukushima Daiichi represents a design extension condition.

2.1 SBO coping time

A coping time for an SBO event of a specific NPP design determines the safety margin that the plant has in response to the SBO event. A textbook definition of coping time is a “*time available from loss of all AC power to the safety bus until onset of core damage if no counter measures*”.

The SBO coping time determines whether the effective countermeasures can be implemented to prevent the core damage. For some NPP design the SBO coping time is very short (e.g. less than one hour), which makes it difficult to implement effective measures to either restore the power supply or ensure the heat removal function. Besides that, plant SBO can challenge performance of the systems and components; e.g. integrity of reactor coolant pump seals, loss of equipment due to loss of ventilation, etc.

SBO coping capability in term of design and organizational provisions currently implemented at NPPs in Member States (MS) varies from country to country; some countries rely on additional diesel generators or mobile means available on site; other countries have incorporated specific SBO provisions into the design as a second protection level (e.g. bunkered systems qualified to anticipated external events). Sizing of additional power sources to be used for SBO, and their qualification requirements are still subjects of discussions.

2.2 SBO coping capability

The plant SBO coping capability determines a time during which the pant withstand SBO without fuel damage. It also involves necessary design provisions, appropriate procedures and personnel training.

The Fukushima accident has showed that the external event which goes beyond the original plant design basis could result in extended loss of all AC power sources. In this case, the important consideration is how long can the plant cope without AC power to prevent core melt scenario.

3. SBO Management

This section describes challenges associated with SBO event, as well as design philosophy, and station blackout recovery strategies that have been observed in Member State Countries participating in the development of the TECDOC.

The objective of SBO management is to provide alternate AC power source to power necessary loads in order to bring the plant to a safe controlled state and to maintain it in the controlled state to prevent a core melt accident.

The SBO event management depends on several aspects, such as whether:

- the plant was operating at full power before the SBO event; or
- the plant was in the shutdown state for refuelling (including mid-loop operation); or
- the AC power can be restored quickly; or
- the restoration of AC power requires several hours but can still be accomplished within the coping time.

The following three SBO cases are discussed;

1. SBO event which can be recovered from within the coping time.
2. Extended SBO event.
3. SBO event that leads to a core melt scenario.

3.1 SBO recovery within coping time

This case is characterized by a short recovery period; i.e. alternate AC power supply can be started and connected to the plant safety bus(es) within 10-30 minutes. Regardless of the plant design, the heat removal function should be accomplished by non-AC powered loads.

SBO coping times varies between the different plant designs; therefore the coping strategies reflect the initiating event that caused the SBO conditions, plant response to the SBO condition, and available means, preferably stationary, which can be used.

For those plants equipped with turbine driven pumps for providing feedwater either to the SGs (PWRs and PHWRs) or reactor vessel (BWRs), the heat removal continues without interruption after the SBO event. The Uninterruptible Power Supply (UPS) buses provide enough power to ensure control and monitoring functions needed for heat removal.

For those plants without turbine driven means, i.e. which depend fully on AC power supply, a fast connection of alternate AC power or restoration of the grid is critical.

During the short duration SBO, the following challenges should be considered:

- Reactor coolant inventory (RCS) is sufficiently maintained;
- Re-criticality does not occur;
- Integrity of reactor coolant pump seals is not challenged;
- Battery capacity is sufficient to power necessary DC/AC loads;
- Alternate AC power source mission time is sufficient;
- CST has enough capacity;
- Spent fuel pool (SFP) heat up is a slow process.

The following steps are recommended during short SBO event (to be performed in parallel):

- Start up and connect the alternate AC power source to a safety bus;
- Ensure SG (PWR) make up from Condensate Storage Tank (CST);
- Ensure reactor vessel make up (BWR) from a suppression pool;
- Try to recover the grid;
- Try to recover at least one division of stand-by AC power sources.

The mission time for PWR the turbine driven feedwater pumps which provide the SGs with water from CST is typically several hours and therefore there is no concern with respect to heat removal in these cases. However, for BWR a rapid depressurization of the BWR could cause starvation of the steam supply to the feed pumps, causing them to trip. The mission time for the alternate AC power source is typically several days, and therefore this mission time does not limit its operation during short duration SBO events.

Continuity of DC power supply is typically needed for several hours, and thus alternate AC power supply can be restored before station battery banks are depleted.

It was observed that sizing of alternate AC power supply sources typically depends on the plant design; for example, plants with turbine driven capabilities (e.g. feedwater can be provided by turbine driven means into the SGs or reactor pressure vessel (BWR case) which means the alternate power source does not have to be sized to power the feedwater pumps, or fully electric plants which means that sufficient electrical power supply is necessary to power feedwater pumps. For PHWRs where SG makeup can be provided by mobile means, the alternate power supply source is only required to power critical instrumentation and monitoring loads.

The permanent pre-alignment of the alternate AC power source is desirable as this permit a shorter connection time. The alternate AC power supply source should be connected to the safety bus(es) only after it has been disconnected from other power supplies to prevent the alternate AC power source from becoming overloaded.

The alternate AC power source power capacity is limited and cannot supply large loads (e.g. cooling the turbine condenser, or ensuring residual heat removal from suppression pool of BWR); this is not an issue during the short SBO event, because the alternate power source is meant to be a temporary solution until the power supply is recovered either from the grid or standby AC power sources.

3.2 Extended SBO

In a situation, where the alternate AC power source was connected, but it was neither possible to recover the grid nor standby AC power sources, the plant enters the extended SBO condition which can last from hours to several days.

During extended SBO events, the Reactor Coolant Pump (RCP) integrity may be challenged if injections pump which provides water to the RCP seals remains unavailable. If RCP seals fail, the RCS leak rate will be equivalent to a small break LOCA. If RCS seal failure occurs maintaining the RCS inventory and sub-cooling margin may be a challenge. The autonomy of Condensate Storage Tank (CST) is limited and typically will last for several hours; however the CST will need replenishing from the external source, consequently, mobile equipment may be necessary.

The suppression pool heats up as steam is discharged into it and the residual heat removal system is no longer in operation because it requires more power than the alternate AC power source is capable of providing. High suppression pool temperatures may challenge the capability of the injection pumps (BWR).

For PWRs or PHWRs, the decay heat produced in a SBO event is removed from the core through natural circulation. A combination of two effects, i.e. shrinkage of RCS inventory due to temperature decrease and expected leakage from the RCS, cause a drop in the RCS pressure. The rate of this pressure decrease depends on the particular reactor design but is typically about 1MPa per hour. Maintaining the RCS inventory and sufficient sub cooling margin is therefore important to avoid formation of a bubble below the reactor pressure vessel (RPV) head which could potentially lead to loss of natural circulation.

During extended SBO, Spent Fuel Pool (SFP) cooling is necessary. If the alternate AC power source has insufficient capacity to power loads in the SFP cooling chain, a contingency cooling strategies via mobile pumps may be necessary.

3.3 SBO resulted in a core melt

There are several possible SBO scenarios which could lead to a severe accident, for example:

- Neither the grid nor stand-by AC power sources could successfully be restored within the coping time;
- The alternate AC power source cannot be started and/or connected to the safety bus within the coping time;
- The alternate AC power source was able to connect within the coping time, but it fails to operate in long-term (e.g. insufficient diesel fuel, damage due to extreme external events, etc.)
- If the entire grid, standby and alternate AC power sources are unavailable, and mobile means were unable to deploy with the coping time.

These scenarios may be caused by a combination of events including: multiple failures of plant equipment and severe external events (e.g. earthquake, flooding beyond design bases, severe weather conditions, airplane crash, etc). In addition to the reactor core, the on-site SFPs also require heat removal capability.

The stationary equipment, including alternate AC power source remains unavailable. From an electrical point of view, it may not be possible to provide power supply to the loads via the plant distribution system and therefore certain predefined loads would require direct power supply connection (via provisional cable connection).

4. Establishing Design Criteria for designated SBO equipment

This section describes SBO related design considerations as observed in countries participating in the development of the SBO TECDOC. These are applicable for alternate AC power sources of different voltage and power output, specific design features to better serve its purpose, i.e. mobility, connectivity, accessibility to a specific load to be powered, and capacity to allow for starting and operating required loads.

4.1 Safety classification

The alternate AC power sources, which provides for diversity, are classified, but not necessarily in the same class as the standby AC power sources. The equipment which makes it possible to connect alternate AC power source, including the connecting point to the plant buses have the same safety class as the alternate AC power source. Mobile AC power sources are typically not safety classified; demonstrating the functions associated with a safety class may be difficult.

4.2 Sizing criteria

The alternate AC power supplies have sufficient capacity to operate systems necessary for coping with a station blackout for the time required to bring the plant to and maintain it in a controlled state. A combination of postulated internal initiating events (e.g. LOCA) concurrent with a SBO is typically not considered.

If an alternate AC power source serves more than one unit at a site where safety standby AC power sources are shared between units, the alternate AC power source is designed to have sufficient capacity to operate systems necessary for coping with a station blackout for the time required to bring all units that share the safety AC power sources to, and maintain them in a controlled state. The alternate AC power source for one unit is normally connected neither to the on-site power system of that unit nor off-site power systems.

4.3 Qualification of SBO equipment

Equipment qualification includes functional qualification, qualification for the effects of internal events, and qualification for the effects of external events. Qualification for the effects of internal events and external events aims to ensure that these events do not result in common cause failure of alternate AC power source.

4.4 Storage of equipment

Plants in some Member States employ stationary alternate AC power sources. In these cases the stationary AC power sources are housed in bunkers or the AC power source are hardened so that there are adequately protected from external events.

Portable alternate power source(s) are stored in a location or locations such that it is reasonably protected such that no one external event can reasonably damage all the portable AC supply source(s). Reasonable protection is provided for example, through provision of multiple portable AC supply sources stored in diverse locations or through storage in structures designed to reasonably protect from applicable external events.

5. Differences for the new and existing plants

The integration of alternate AC Power sources is obviously easier and can be accomplished without compromise for a new plant compared to a retrofit application at an existing plant. If design and performance criteria are taken into consideration already in conceptual design of the plant, searching for suitable place where alternate AC power source can be installed, providing additional connecting points, additional spare batteries, raceway and sheltered locations for mobile power sources can be avoided. These design features can be accomplished already into the early design phase.

6. Design provisions to increase robustness of existing plants

The improvement measures to further enhance the robustness of the plant electrical systems require implementation of a complex solution, i.e. it should not be based just on supplying one additional alternate AC power source. The SBO design provisions should be seen in greater perspective, i.e. from initiating even or combination of events that actually caused SBO condition, protections against those events, availability alternate AC power source with pre-installed connecting points, both qualified for anticipated external events, availability of mobile power generating means that can be deployed on place, considering possible site devastation.

The Final peer review report[6] on the Stress Tests performed on European nuclear power plants underlined the “Necessary implementation of measures allowing prevention of accidents and limitation of their consequences in case of extreme natural hazards is a finding of the peer review that national regulators should consider. Typical measures which can be considered are bunkered equipment to prevent and manage severe accident including instrumentation and communication means, mobile equipment protected against extreme natural hazards, emergency response centres protected against extreme natural hazards and contamination, rescue teams and equipment rapidly available to support local operators in long duration events. Such possible measures, as identified by the peer review, are detailed in the report”.

6.1 Design provisions implemented to cope with SBO

By analysing different member states solutions to cope with SBO event in different nuclear power plant designs, the following common level of defence were observed:

- A reliable (normal) power supply from the high voltage grid;

[6] Final peer review report on the Stress Tests performed on European nuclear power plants, April 2012

- House load capability of the turbine and generator island;
- At least two feeds from a backup grid (independent from the output grid);
- Standby AC power sources (redundant);
- A small generating nearby plants DGs (used for frequency control such as hydro, diesel generator station, gas turbine with a power output around 30 MW);
- Alternate (dedicated) AC power source designed and qualified for anticipated external events;
- Mobile diesel generators (high or low voltage);
- High capacity station batteries;
- Backup (charged) batteries stored on site.

The above level of defence appear to be sufficient to (i) minimize the occurrence of SBO event, or if SBO event occurs (ii) to prevent fuel damage by providing technical means and organizational measures to cope with SBO event and to prevent the fuel damage.

In order to cope with extended SBO duration, the following additional means or provisions have been considered to enhance the plant SBO coping capability:

- Medium size generators to re-energize battery chargers;
- Emergency diesel engine driven pumps to replenish water sources, i.e. CST make-up;
- Medium size generators and injection pumps to restore RCP seal cooling;
- RCP Shutdown seal package designs to limit seal leakage;
- Hardened wet well venting systems and suppression pool make-up with cold water (BWR);
- Pre-plan and pre-stage more emergency equipment to make manual actions easier and train more personnel to use it.

It is obvious that for extended SBO duration, it may be necessary to use alternative means of cooling including alternate heat sinks. SG gravity feeding, or using other sources of water, supply from stored condenser cooling water, alternate tanks or wells on the site, or water sources in the vicinity (reservoir, lakes, etc.) is an additional way of enabling core cooling and prevention of fuel degradation.

6.2 Design provisions for non-electric equipment

It has been discussed already that nether either alternate or mobile AC power source itself, despite their qualification to external events, may be insufficient to ensure a power supply function to designated SBO mitigation equipment. The AC/DC power distribution system, connecting points, cables, etc. should also be protected against effect of external or internal events.

Some plants have introduced improvement measures that better protects the electrical equipment from adverse effect or external natural events such as tsunami. This includes the following design improvements:

- Fastening outside transformers with anchor bolts to the grant to protect them from forces generated by tsunami or earthquake;
- Improving outdoor switchyards that are vulnerable to external natural events such as earthquake, tsunami;
- Installing water proof doors sealing the electrical compartments for stand-by and alternate AC power sources, DC batteries, and switchgear rooms;
- Sealing external cable traces to prevent water intrusion into the electrical distribution systems from the outside;

- Mounting connection points for connecting external power sources in an elevation which consider sufficient margin for the most severe flood anticipated in the design;
- Providing small floating transport means so that personnel is able to reach connecting points on site;
- Providing heavy equipment that is able to clear the road after a devastating event (earthquake, mud slides, etc.)
- Training the plant personnel for manual actions for as SBO duration increases.

6.3 Design provisions for extended mission time

The goal for SBO coping is to establish sufficient coping capability by relying upon installed equipment, onsite portable equipment, and pre-staged offsite resources to ensure fuel cooling function. The alternate as well as mobile AC power sources are deigned to operate autonomously, i.e. without need of support system provided by the plant (e.g. component cooling, instrument air, DC power, etc.). Typically, the equipment, procedures, and training necessary to implement an extended SBO consider mission time of 72 hours for core and spent fuel pool cooling and for reactor coolant system and primary containment integrity.

The alternate stationary as well as portable AC power sources typically have a capacity which does not allow powering all main and support systems needed for a standard heat removal function. For example heat, ventilation and air-conditioning system is not included among loads powered in SBO conditions. Some equipment credited in SBO cooping such as turbine driven pumps are enclosed in a small room, in which without ventilation the ambient temperature may rise to values at which the equipment is outside the design basis and which may fail to operate in a long term. Some member states implemented design provisions to power loads ensuring ventilation functions (e.g. local ventilators and chillers) for designated equipment.

7. Conclusions

This paper provides an outline of main topics that are discussed in the IAEA TECDOC on design provisions for SBO event in greater details. Furthermore, the SBO TECDOC provides examples, including illustrative figures, on design provisions that have already been implemented in participating Member State Countries.

The improvement measures to further enhance the robustness of the plant electrical systems for SBO event require implementation of a complex solution, i.e. it should not be based just on supplying one additional alternate AC power source.

The SBO design provisions should be seen in greater perspective, i.e. from initiating even or combination of events that actually caused SBO condition, protections against those events, availability alternate AC power source with pre-installed connecting points, both qualified for anticipated external events, availability of mobile power generating means that can be deployed on place, considering possible site devastation.

A mission time for SBO equipment should be carefully considered in the design, especially for extended SBO events. The only fact that the AC power sources has started and connected to the bus successfully is not sufficient.

CSNI International Workshop on
ROBUSTNESS OF ELECTRICAL SYSTEMS OF NPPs
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Design Provisions for Station Blackout for Nuclear Power Plants
IAEA TECDOC

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Contents

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- Relation with IAEA Safety Standards
- Objective
- Content of SBO Tecdoc
- Examples of SBO design provisions
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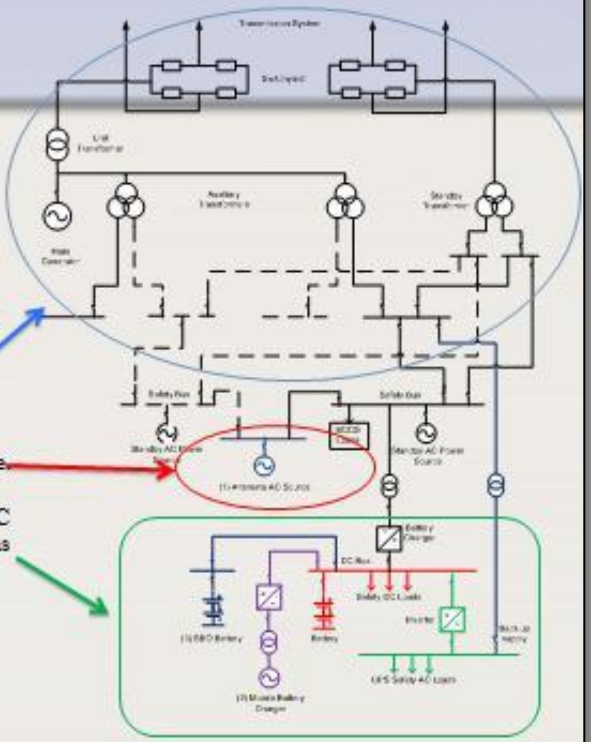
SBO Definition



A station blackout (SBO) is defined as a plant condition with complete loss of all AC power to safety and non-safety buses from off-site sources, from the main generator and from standby AC power sources important to safety.

Alternate AC power supplies are available.

DC power supplies and uninterruptible AC power supplies may be available as long as batteries can supply the loads.

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Why SBO Topic?

Year	NPP	Event
1986	Kori 4 (Korea)	SBO caused by a typhoon
1990	Vogtle 1 (Georgia, USA)	Off-site power was lost from switchyard work during a refuelling outage
1993	Narora 1 Event (India)	Ejected turbine blade caused a fire and hydrogen explosion
1993	Kola Event (Russia)	LOOP induced by high wind and failure of EDGs
2001	Maanshan (Taiwan)	Tropical storm caused loss of off-site power
2006	Forsmark 1 (Sweden)	Near SBO, Switchyard work resulted in overvoltage
2011	Fukushima (Japan)	Following a major earthquake of magnitude 9.0 on the reciter scale, a 15-metre tsunami disabled the power supply and cooling of three Fukushima Daiichi reactors, causing a nuclear accident on 11 March 2011.
2012	Byron event (USA)	Failure of insulator resulted in open phase conditions on offsite power source. The failure was not detected by the onsite degraded voltage relays. As a result, the standby sources did not start.
2012	Kori 1 (Korea)	An error in generator protective relay testing resulted in loss of off-site power to shutdown cooling.
2013	Forsmark 3	Human error resulted in two open phase conditions. The failure was not detected by the onsite voltage relays. As a result, the standby sources did not start.

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Why SBO Topic?

- More than 10 (reported) events so far
- Early recovery in most cases
- Only Fukushima resulted in fuel melt
- OEF show important precursors not to be ingored
- EU Stress tests identified SBO as most limiting
- SBO Classification

  DBA vs DEC?

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SBO vs IAEA Safety Standards

- 1985 – TECDOC 332 "Safety Aspects of Station Blackout"
- 2012 – DS 430 Design of Electrical power systems (revision of NS-G-1.8)
- 2013 – DS 462 Revision of SSR 2/1 Design
  - The design shall include an emergency power supply capable of supplying the necessary power in AOO and DBAs, in the event of the loss of off-site power. The design shall also include an alternate power source to supply, in particular, the necessary power in DEC.
- 2014 – new TECDOC "Design Provisions for SBO"

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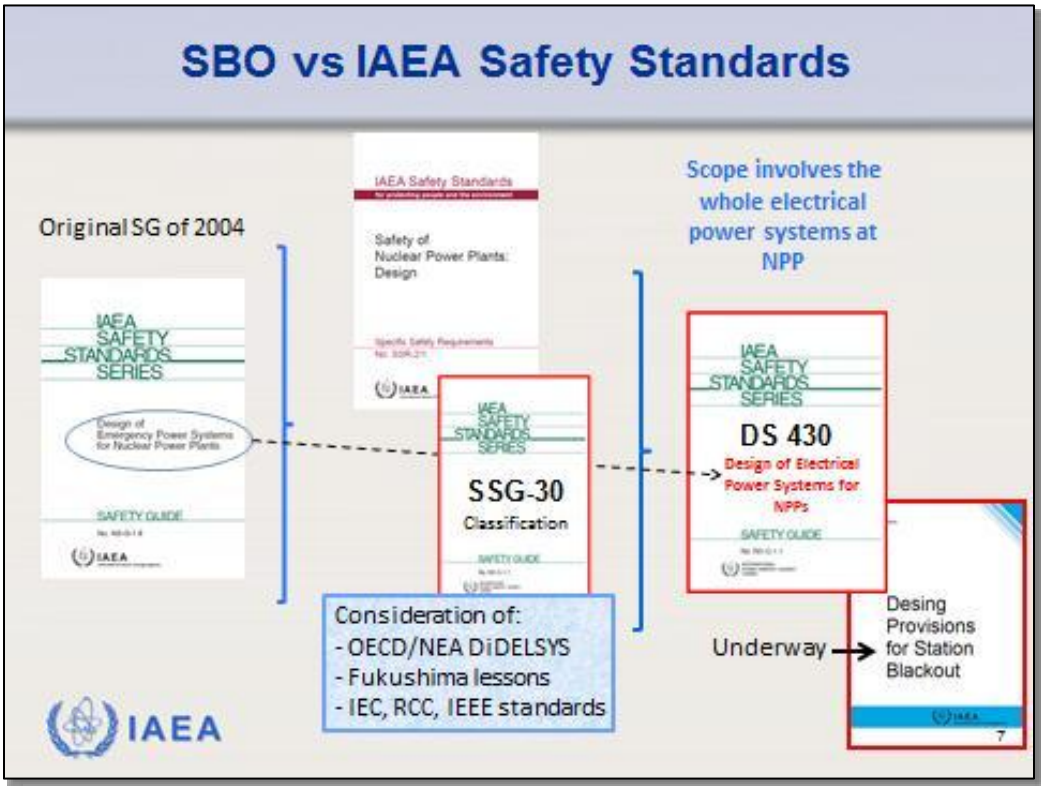

Scope of the new Electrical Guide

- Describes the **whole electrical power system** at NPP
- Describes defense-in-depth concept for electrical systems
- Provides for design basis, general and detailed design guidance considering:
  - Anticipated electrical events (AOO, DBA)
  - Station Blackout
- Highlights
  - the interface with off-site power
  - the role of normal distribution systems as:
    - A source of power for many systems, and as
    - A source of power for emergency systems
  - the importance of electrical protection (breakers and their coordination)

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8

SBO TECDOC Objectives

- Further develop Chpt 8 of DS 430 on Alternate power source
- Provide common international technical basis
- Provide current regulatory basis
- Describe current plant practices and qualification requirements
- Show examples "what and how"...
- Provide proposal to further increase robustness

Our SBO Team →

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SBO TECDOC Content

- SBO management
  - within coping time
  - Extended SBO
  - SBO leading to SA
- Design criteria for SBO equipment
  - Classification
  - Sizing
  - Qualification
  - Storage
- Differences between existing and new plant designs
- Design provisions to increase robustness
- Operating experience

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SBO TECDOC Content

- Addresses SBO related issues:
  - RCP seals integrity
  - Fuel pool cooling
  - DC power continuity
  - Condensate supply to replenish EFT, or CST;
  - Instrument air
  - HVAC
  - Emergency illumination
  - Power supply for communication.

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Design & performance criteria

- Sizing?
- Qualification for external events?
- Storage and location on the site?
- Do diverse diesels have any advantage?
- What about power connections?
- How does possible failure of plant distribution systems affect alternate AC power sources guidance?
- Sharing alternate AC power sources at multi unit sites?

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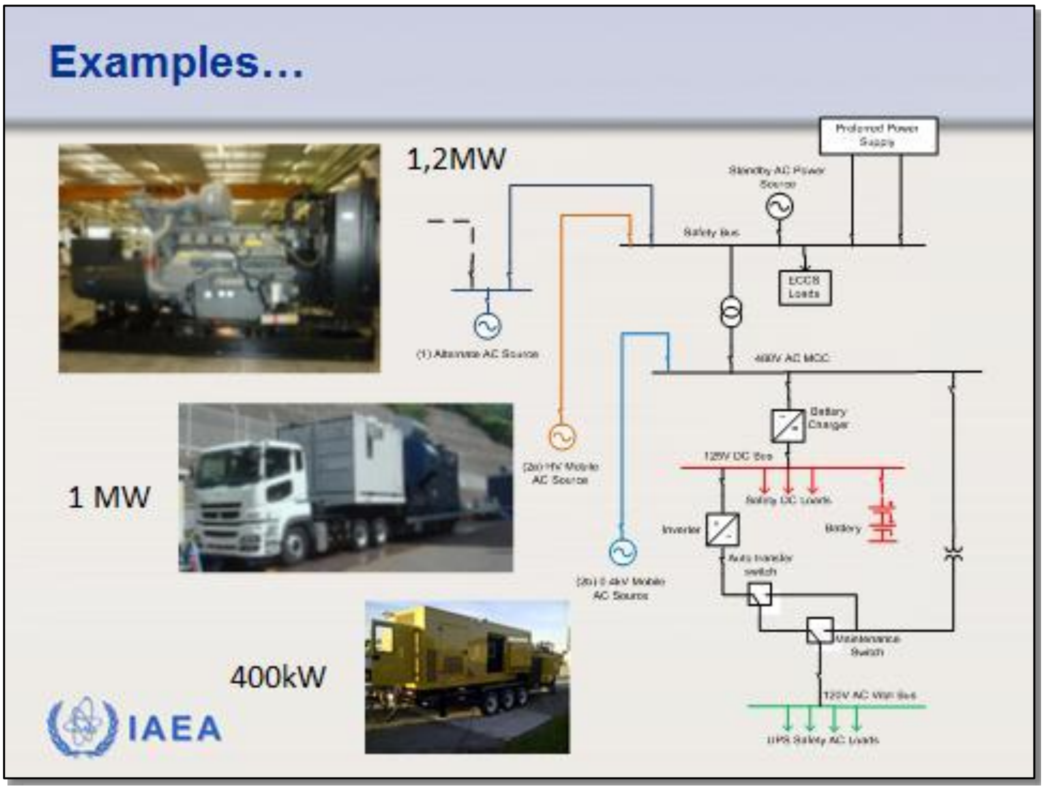
Examples…
1,2MW
1 MW
400kW
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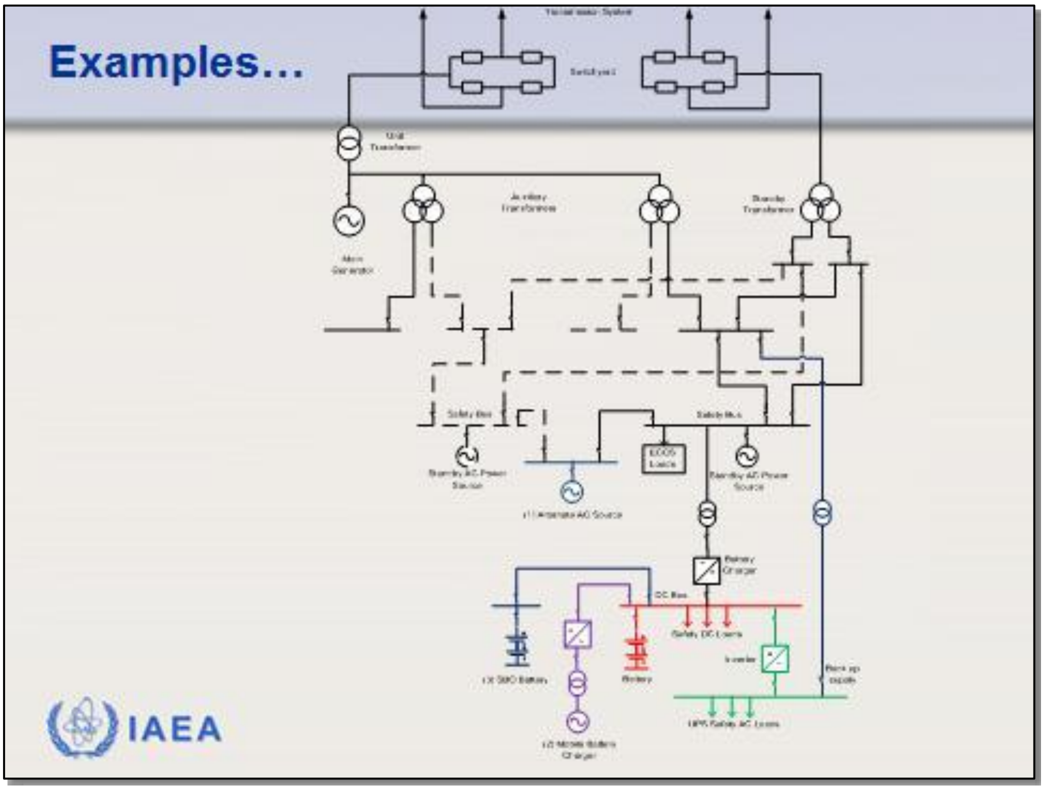
Preferred Power Supply
Standby AC Power Source
Safety Bus
ECCS Loads
(1) Alternate AC Source
480V AC MCC
Battery Charger
125V DC Bus
(2a) HV Mobile AC Source
Safety DC Loads
Inverter
Battery
Auto transfer switch
(2b) 0.4kV Mobile AC Source
Maintenance Switch
120V AC Vital Bus
UPS Safety AC Loads


Examples…
Switchyard
Unit Transformer
Auxiliary Transformer
Standby Transformer
Main Generator
Safety Bus
ECCS Loads
Standby AC Power Source
(1) Alternate AC Source
Battery Charger
DC Bus
Safety DC Loads
Inverter
Battery
UPS Safety AC Loads
(2) Mobile Battery Charger
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Preliminary results

- No solution "one fit to all"
- A complex issue, not just a new EDG
  - How to get AC/DC power to specific loads
  - Protected pre-installed connection, power distribution system, electrical protection, etc.
  - Qualification, what hazards to be considered
- A mission time not only for SBO equipment
- RCP integrity, RCS inventory

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When is it published?

- November 2013 – 1st CS meeting
- Mach 2014 – 2nd CS meeting
- June 17-20, 2014 – Technical Meeting
- October 2014 – 3rd CS Meeting
- December 2014 – Final Draft
- March 2015 – Internal review
- June 2015 - Publication

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