Format and Content of the Safety Analysis Report for Nuclear Power Plants - Core Set -

2013
Learning Objectives

After going through this presentation the participants are expected to be familiar with:

• Related IAEA Standards: GSR Part 1, GS-G-4.1

• Contents of SAR
  • Introduction, General plant description, Management of safety, Site evaluation, General design aspects
  • Description & conformance to the design of plant systems, Safety analyses, Commissioning, Operational aspects, Operational limits & conditions
  • Radiation protection, Emergency preparedness, Environmental aspects, Radioactive waste management, Decommissioning & end of life aspects
References

1. Governmental, Legal, Regulatory Framework for Safety, GSR Part 1

2. Format and Content of the Safety Analysis Report for Nuclear Power Plants, GS-G-4.1
1. Introduction
2. Baseline of a SAR
3. Chapters and Content of a SAR
4. Summary
1. Introduction
1. Introduction

- Requirement 24: Demonstration of safety for the authorization (GSR Part 1)
  - Authorization stages in the lifetime include:
    - Site evaluation, design, construction, commissioning, operation, shutdown and decommissioning
    - Management of radioactive waste and the management of spent fuel
  - Prior to granting of an authorization, the applicant shall submit a safety assessment associated with facilities and activities.
  - The regulatory body shall issue guidance on format and content of the documents to be submitted by the applicant for an authorization.
1. Introduction

- Requirement 25: Review and assessment of information relevant to safety (GSR Part 1)
  - The regulatory body shall review and assess relevant information to determine whether facilities and activities comply with regulatory requirements.
  - Technical and other documents submitted by the applicant shall be reviewed and assessed by regulatory body.
  - The regulatory body shall assess all radiation risks associated with facilities and activities.
2. Baseline of a SAR

- General Considerations of SAR (GS-G-4.1)
  - To demonstrate how the design will contribute to the prevention of accidents & to the mitigation of the consequences

- Initial (preliminary) SAR or, pre-construction SAR (PCSAR)
  - Application for siting and/or construction

- Updated (intermediate) SAR or, pre-operation SAR (POSAR)
  - Application for authorization to operate

- Finalized (final) SAR or, station SAR (SSAR)
  - Revisions to intermediate report before first routine operation
2. Baseline of a SAR

- Contents of SAR (GS-G-4.1)
  - PCSAR
    - Safety principles & objectives
    - Detailed design information & supporting calculations
    - Safety features incorporated into the design
    - Possible challenges to the plant
  - POSAR
    - More specific information on the topics outlined in initial SAR
    - Finalized detailed plant design & demonstration of its safety
  - SSAR
    - Revisions to the intermediate SAR following commissioning
    - Periodic updating of the SAR (living SAR)
2. Baseline of a SAR

- Results of Review & Assessment by Regulator

- Basis for the evaluation & the evaluation results
- Comparison with similar (reference) facilities
- Contents of documentation for the results of review & assessment
- Conformance with regulatory requirements & guides
- Independent analysis performed by regulatory staff
- Conclusions & reasons for the decisions on license
- Any additional conditions to be fulfilled by operator
2. Baseline of a SAR

- Results of Review & Assessment by Regulator
  - Records of information exchange between regulatory body & operator
    - Requests for additional information (RAI) by regulatory body
    - Questions by regulatory body & responses by operator
    - Records of meetings between regulatory staff & operator
Chapter & Content of SAR (GS-G-4.1)

- Chapter I: Introduction
- Chapter II: General plant description
- Chapter III: Management of safety
- Chapter IV: Site evaluation
- Chapter V: General design aspects
- Chapter VI: Description & conformance to the design of plant systems
- Chapter VII: Safety analyses
- Chapter VIII: Commissioning
- Chapter IX: Operational aspects
- Chapter X: Operational limits & conditions
- Chapter XI: Radiation protection
- Chapter XII: Emergency preparedness
- Chapter XIII: Environmental aspects
- Chapter XIV: Radioactive waste management
- Chapter XV: Decommissioning & end of life aspects
Chapter I: Introduction

- General Consideration
  - The main purpose of the SAR
  - The existing authorization status
  - An identification of the designer, vendor, constructor and operating organization of the NPP
  - Any similar (or identical) NPPs already reviewed and approved and a statement of the specific differences and improvements
  - The main information on the preparation of the SAR;
  - A description of the structure of the SAR
Chapter II: General Plant Description

- Applicable regulations, codes and standards
  - A list of all relevant regulations, codes and standards that provide the design criteria
  - A separate and complete justification of any relaxation of a specific requirement

- Basic technical characteristics
  - Principal elements of NPP, including No. of units, type of plant, NSSS, containment structure, thermal power level, and net electrical power output.
  - List of selected characteristics in an appendix.
3. Chapters and Content of a SAR

Chapter II: General Plant Description

- Information on Layout and other Aspect
  - General layout drawings for the entire plant and site

- Operating Modes of NPP
  - All possible operating modes, including startup, normal operation, shutdown, refueling and any other allowable modes of operation

- Material incorporated by Reference
  - List of topical reports
Chapter III: Management of Safety

- Consideration of Safety Culture
  - Strategy to encourage safety culture
  - Indicators of safety culture and program to monitor such indicators

- Quality Assurance (QA)
  - Principal aspects of QA system
  - QA arrangement throughout plant lifetime.

- Monitoring and Review of Safety Performance
  - Adequate audit and independent safety review system
Chapter IV: Site Evaluation

- Site Reference Data
  - Site location and surrounding area
  - Population distribution
  - Disposition of public and private facilities (airport, harbor, railway, industrial site, hospitals, etc.)

- Evaluation of Site Specific Hazards
  - Natural & human induced hazards (external event)
  - Screening criteria and expected impact.
  - Target probability levels
Chapter IV: Site Evaluation

- Proximity of Industrial, Transport and Military Facilities
  - Evaluation of any threat in the vicinity of the site

- Activities at the Plant Site
  - Any activities might influence the safe operation
  - Site protection (ex. dams) and modification measures (ex. soil substitution)
Chapter IV: Site Evaluation

- Hydrology, Meteorology and Seismology
  - Flooding, reservoirs, drainage, tsunami, etc.
  - Temperature, wind speeds, snow loads, etc.
  - Seismic and tectonic characteristics

- Radiological Conditions due to External Sources

- Site Related Issues in Emergency Planning and Accident Management

- Monitoring of Site Related Parameters
Chapter V: General Design Aspect

- Safety Objectives and Design Principles
  - Defense in depth: design concept of the plant
  - Safety functions: control of reactivity, removal of heat from the core, confinement of radioactive materials and limitation of accidental release.
  - Deterministic design principles and criteria: adequacy of safety margins
Chapter V: General Design Aspect

- Safety Objectives and Design Principles (continue)
  - Single failure criterion: redundancy, diversity and independence
  - Other safety requirements or criteria: simple design, passive safety features, fault tolerant system, operator friendly system, etc.
  - Probabilistic design criteria: PSA
  - Radiation protection: ALARA
3. Chapters and Content of a SAR

Chapter V: General Design Aspect

- Conformance with the Design Principles and Criteria
- Classification of SSCs
  - Categorization and classification of SSCs: a list of safety relevant SSCs
- Civil Engineering Works and Structures
  - Range of structural loading, seismic classification
  - Containment building: leak-tightness, mechanical strength, pressure resistance, etc.
Chapter V: General Design Aspect

- **Equipment Qualification and Environmental Factors**
  - A complete list of equipment items

- **Human Factors Engineering**
  - Principles of human factors engineering
  - Human-machine interface issues

- **Protection against Internal and External Hazards**
  - The general design measures for the protection
3. Chapters and Content of a SAR

Chapter VI: Description and Conformance to the Design of Plant System

- General Considerations depend on Type and Design of Reactor
  - System description: objective, functional design, human factors consideration, operational aspects and detailed elements of system design
  - Engineering evaluation: table of specific technical requirements, industrial codes and standards and regulatory requirements
  - Safety assessment: functions of system, demonstration of safety function, single failure analysis and reliability analysis
Chapter VI: Description and Conformance to the Design of Plant System

- Reactor
  - Summary description: mechanical, nuclear, thermal and hydraulic behaviors of fuel, reactor vessel internals, reactivity control system, and I&C system
  - Fuel design: design limit and functional characteristics
  - Reactor internals: thermohydraulic, structural and mechanical aspects of fuel bundles, supporting elements and provisions to monitor the neutronics and temp. of the core
Chapter VI: Description and Conformance to the Design of Plant System

- **Reactor (continue)**
  - Nuclear design and core nuclear performance: nuclear and reactivity control limits, core physics parameters, neutronics stability
  - Thermal and hydraulic design: design bases, analytical tools and methods and computer codes
  - Reactor materials: the properties and required performance
  - Reactivity control: demonstrate functional performance
Chapter VI: Description and Conformance to the Design of Plant System

- Reactor Coolant and Associated Systems
  - Integrity of the reactor coolant pressure boundary: analytical and numerical stress evaluation, a list of all components
  - Reactor vessel: materials, fabrication methods, inspection techniques and load combinations
  - Reactor coolant system: RCP, Prz, steam generator, RCS piping, MS isolation system, steamline and feedwater piping, pressure relief system, RHR, etc.
Chapter VI: Description and Conformance to the Design of Plant System

- Engineered Safety Features
  - Emergency core cooling system: ECCS and associated fluid system, actuation logic
  - Containment system: heat removal system of the containment, isolation system, containment spray system, control of combustible gas
  - Habitability system: main and supplementary control rooms, shielding, air purification systems, control of climatic conditions, etc.
  - Systems for removal and control of fission products
Chapter VI: Description and Conformance to the Design of Plant System

- **Instrumentation and Control**
  - Reactor trip system: trip system logic and set point, interface with actuation system for ESF, manual actuation from MCR
  - Actuation systems for ESF: Design bases for actuation system parameter, SW V&V, specification of set points, protective interlocks, manual provision
  - Safety related display instrumentation: computerized plant information system
Chapter VI: Description and Conformance to the Design of Plant System

- **Instrumentation and Control (continue)**
  - Other instrumentation systems required for safety: system for severe accident management, leak detection, vibration and loose part monitoring, etc.
  - Control systems not required for safety: non-safety-related control system for normal plant operations
  - Main control room and supplementary control room: human-machine interface, electrical design standards for equipment signals
Chapter VI: Description and Conformance to the Design of Plant System

- Instrumentation and Control (continue)
  - Electrical systems: power system, system redundancy, physical separation, independence and testability of systems, general description of utility grid and its interconnection
  - Off-site power systems: interconnection to the on-site power system
  - On-site power systems: AC power systems with system breakers and EDG, DC power system with capacity of the battery
Chapter VI: Description and Conformance to the Design of Plant System

- Plant Auxiliary Systems
  - Water systems: ultimate heat sink, condensate storage facilities, makeup system for demineralized water, etc.
  - Process auxiliaries: compressed air system, process and post-accident sampling systems, CVCS, etc.
  - Heating, ventilation and air conditioning systems: systems for MCR, spent fuel pool area, radioactive waste area, etc.
  - Other auxiliary systems: communication system, cooling water system, starting system, etc.
Chapter VI: Description and Conformance to the Design of Plant System

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Chapter VI: Description and Conformance to the Design of Plant System

- **Power Conversion Systems**
  - Requirement for the turbine generator
  - Description of main streamline piping with valves, turbine gland sealing, condenser, feedwater system, water chemistry program, etc.

- **Fire Protection Systems**
  - Material selection and physical separation for fire prevention, detection, warning, fire suppression and assessment.
Chapter VI: Description and Conformance to the Design of Plant System

- **Fuel Handling and Storage Systems**
  - Fresh fuel: accounting system, storage, criticality prevention, fuel integrity control
  - Irradiated fuel: fuel cooling, radiological protection, criticality prevention, fuel integrity control and provisions to deal with failed fuel

- **Radioactive Waste Treatment Systems**
  - Design features to control, collect, handle, process, store and dispose of solid, liquid and gaseous forms of radioactive waste
Chapter VII: Safety Analysis

- Safety Objective and Acceptance Criteria
  - Specification of acceptance criteria should be justified and documented
  - Events with severe consequences should have very low probability

- Identification and Classification of PIEs*
  - Method of identification of PIEs
  - Event classification according to their anticipated frequencies and types

* A PIE (Postulated Initiating Event) is an event identified during design as capable of leading to anticipated operational occurrences or accident conditions
Chapter VII: Safety Analysis

- **Human Actions**
  - Human actions in different type of safety analysis

- **Deterministic Analysis**
  - Evaluate and justify the plant response to PIEs in specific operational states
  - Model of computer codes and assumption concerning plant parameters, control system and operator’ actions.
  - Safety in normal operation
  - Anticipated operational occurrences and design basis accidents
3. Chapters and Content of a SAR

Chapter VII: Safety Analysis

- **Deterministic Analysis**
  - Consideration of design capability for beyond design basis accidents including severe accidents

- **Probabilistic Analysis**
  - Method and scope of PSA

- **Summary of Results of the Safety Analysis**
  - Overall result of the safety analysis
Chapter VIII: Commissioning

- General Consideration
  - Validation of plant performance within their spec.
  - Well planned, controlled and properly documented commissioning program
  - Commissioning organization and interface between design, construction and operating organizations with qualified operating personnel at all level
  - List of test in the different commissioning phases, such as pre-operational and or startup testing, with test method and acceptance criteria
Chapter IX: Operational Aspects

- **Organization**
  - Operational org. with review body

- **Administrative Procedure**

- **Operating Procedures**
  - To operate within the operational limits and conditions during starting up, power production, shutting down, cooldown, shutdown, load changes and fuel handling.

- **Emergency Operating Procedures**
  - To diagnose and deal with emergency conditions
Chapter IX: Operational Aspects

- **Guidelines for Accident Management**
  - To prevent severe accidents and to mitigate their consequences

- **Maintenance, Surveillance, Inspection and Testing**
  - To verify the provision for safe operation
  - In-service inspection and test

- **Core Management and Fuel Handling**
  - To ensure safe use of fuel in the reactor
Chapter IX: Operational Aspects

- **Management of Aging**
  - To monitor the aging or other forms of degradation of SSC

- **Control of Modification**
  - Records of all modification should be retained to meet the requirement for configuration management

- **Qualification and Training of Personnel**
  - Qualification and training program for plant staff
  - Licensing of operators
Chapter IX: Operational Aspects

- **Human Factors**
  - Continuing review and development of measures in MCR and in the other parts of the plant

- **Program for the Feedback of Operational Experience**
  - Suitability of system for feedback of operational experience, analysing the root cause of equipment failure and human errors

- **Documents and Records Control**

- **Outage**
  - Measures during outage period
3. Chapters and Content of a SAR

Chapter X: Operational Limits and Conditions

- **General Consideration**
  - Part of SAR or separate document
  - OLCs in the form of controls, limits, conditions, rules and required actions that are formally derived from the safe operating envelope
  - Based on the safety analyses of the plant
  - Contain numerical values of limiting parameters and operability conditions of systems and components
Chapter XI: Radiation Protection

- Application of the ALARA Principle
  - Operational application of the ALARA

- Radiation Sources
  - Description of all on-site radiation sources

- Design Features for Radiation Protection
  - Shielding, features for occupational radiation protection
  - Radiation dose targets in the design specification
  - Adequate design of SSCs
Chapter XI: Radiation Protection

- Radiation Monitoring
  - Arrangement for monitoring of significant radiation sources

- Radiation Protection Program
  - Classification of work areas and access control
  - Monitoring of individuals and the workplace
  - Work planning and work permits
  - Protective clothing and protective equipment
  - Health surveillance & Training
  - Source reduction
  - Arrangements for response to emergencies
Chapter XII: Emergency Preparedness

- **General Consideration**
  - Cover the full range of accidents
  - Information on objectives and strategies, organization and management
  - Provisions of on-site and off-site exercise

- **Emergency Management**
  - Operating org.’ response to an emergency
  - Emergency arrangements for the protection of workers and public
  - Measures for ensuring the protection of plant staff
Chapter XII: Emergency Preparedness

- Emergency Response Facilities
  - On-site emergency facility
  - Supplementary control room
  - Off-site emergency facility & monitoring system

- Capability for Assessment of Accident Progression, Radioactive Release and Consequences
  - Early detection, monitoring and assessment
  - Prediction of the extent and significance
  - Prompt and continuous assessment of radiological conditions
Chapter XIII: Environmental Aspects

- Radiological Impacts
  - Limits and operational targets for discharges
  - Off-site monitoring regime
  - Environmental monitoring and alarm system

- Non-radiological Impacts
  - Identify the chemical and physical nature of releases or discharges
  - Limits and operational targets for discharges
  - Off-site monitoring regime and alarm system
Chapter XIV: Radioactive Waste Management

- Control of Waste
- Handling of Waste
- Minimizing the Accumulation of Waste
- Conditioning of Waste
- Storage of Waste
- Disposal of Waste
Chapter XV: Decommissioning and End of Life Aspects

- Decommissioning Concept
- Provisions for Safety during Decommissioning
- Differing Approaches to Decommissioning
- Planning of the Preliminary Work
4. Summary

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