AREVA
Safety Alliance
Products, Services and Solutions
Introduction

Since March 11th, 2011 we at AREVA, along with all of our global utility customers have been closely monitoring, evaluating and responding to the unfolding events associated with the historic earthquake and resultant tsunami in Japan. We have all been taken aback by the sheer magnitude of the human toll and the forecast of an extended recovery and rebuilding of their communities and infrastructure. And of course, we are all striving to understand and respond to the implications of the “beyond design basis” events at the Fukushima Daiichi nuclear station. Each of us are trying to find ways to both meaningfully help our Japanese associates as well as understand and develop measured, responsible, and balanced actions for our own facilities.

AREVA has initiated an early and sustained level of interaction with key nuclear industry regulators, technical, and utility contacts and working groups. We are committed to proactively work as a team with our utility customers to help develop and deliver the most adapted and optimal solutions to the challenges that we are facing now and in the future are likely to emerge. AREVA stands ready to assist you with the type of industry leadership, technical and licensing strength and customer commitment to reduce the burden and to strengthen the response of our utility partners.

Safety Alliance

AREVA has implemented an immediate initiative to realign some of our businesses to be more responsive to the emergent needs of our industry. More than ever our industry’s leadership has to work closely together, communicate openly and frequently and has to coordinate our actions to ensure the most efficient and beneficial approach.

To this end, we have selected and organized a catalog of existing AREVA products, services and solutions that can contribute to achieve the three main imperatives of our Industry Safety Approach:

- Resistance to Major Hazards
- Robustness of Cooling Capability
- Prevention of Environmental Damage

AREVA is committed to team up with you and your other partners in a unified response to this challenge to ensure that our industry will become stronger, safer and more reliable than ever before.
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- Continuous Measurement of Boron Concentration (COMBO)
- Vibration Monitoring System SÜS
- Hardening of Steam Generator Secondary Heat Sink

### 3 Prevention of Environmental Damage

**Safety Analyses**
- Safety Analyses

**Safety Upgrades**
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- Radiological Emergency Response
- Post-accident Characterization and Response
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- Liquid Level Measurement Solutions
- Hardening of Primary System Depressurization

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- Severe Accident Management Guidelines – OSSA
- Nuclear Simulators
- Training for Reactor Operations in Accidental Conditions

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**AREVA Safety Alliance**
Resistance to Major Hazards

Safety Analyses

- Safety Analyses
- Fire Protection & Hazard Analysis
- Seismic Margin Assessment

Safety Upgrades

- Analysis and Upgrades of Physical Protection Elements
Safety Analyses

The AREVA Safety Alliance expertise for enhanced Utilities Safety Analyses dedicated to Resistance to Major Hazards.

The challenge
To perform the requested Safety Analysis in order to demonstrate the resistance of nuclear power plants to major initiating events.

The solution
The AREVA Safety Alliance Approach to Safety Analysis covers the most comprehensive spectrum of licensing requirements about hazards and regulatory standards worldwide.

Technical Features

Accident Analysis concerned by the Safety Analysis Report
- Internal and external hazards consideration is a part of safety review
- Provisions taken in the design basis concerning extreme external hazards

Seismic Analysis evaluating the NSSS equipment behavior
- Seismic Margin Assessment and seismic PSA
- development of seismic input
- evaluation of reactor coolant system, piping and supports
- recommendation of needed design
Safety Analyses

Multinational experience

**Licensing / standard compliance:**
- US/NRC
- France/ASN
- China/NSSA
- Finland/STUK

**References: AREVA Worldwide Experience**
- Many Safety Analysis Reports: OL3, Daya Bay and Ling Ao Chinese PWR, Ulchin units 1 and 2 in Korea
- Global review of Safety Analysis Report: OL3, some Chinese PWR,
- Seismic analysis of primary components, steam generators and auxiliary systems for French PWR fleet (EDF contracts), steam generator replacement (Belgium, USA).

**Your benefits at a glance**

- Demonstrate the compliance of nuclear power plants to new Safety Standards
- A standard approach to Safety Checks-related Analysis
- Access to a wider range of Safety Analysis competences:
  - Protection against hazards Analysis
  - Seismic Analysis

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Fire Protection & Hazard Analysis

A comprehensive range of Fire Protection & Hazard Analyses from investigations to optimized solutions.

The challenge
To demonstrate the power plants’ safe shutdown capability and availability of critical protection systems in the event of fires due to internal and external events, including natural disasters.

The solution
AREVA is adept at developing comprehensive and integrated solutions to demonstrate safe shutdown capability for design basis and severe accident mitigation:
• Evaluate separation and isolation of redundant safety trains.
• Perform Fire Hazards Analysis and Fire Risk Analysis to evaluate adequacy of train separation, installed fire protection systems and building design and layout.
• Evaluate on-site response capabilities such as fire fighting equipment and fire brigades.
• Develop severe accident mitigation methods and modified fire protection systems to protect vital Plant systems and ensure decay heat removal capability for reactor systems and spent fuel pool.

Technical Features
• Fire safe shutdown systems and circuit analysis
• NFPA code compliance assessment and analysis
• Safe Shutdown Analysis System (ARTRAK) software
• Fire hazards assessment and analysis
• Fire suppression and detection systems design and testing services
• Computerized combustible tracking and control programs
• Fire barrier design, evaluation and testing services
• Smoke and heat effects analysis
• Fire PRA and modeling services
• Fire brigade training
• Accident mitigation analysis and equipment tracking database (DataTRAK)
Fire Protection & Hazard Analysis

Multinational experience

Licensing / standard compliance:
AREVA personnel have experience in all aspects of evaluation, development and implementation of nuclear fire protection programs to satisfy licensing requirements and applicable codes and standards. We actively participate in industry initiatives and standard/code development to best serve the interests of our customers and the industry at large.

References:
AREVA has performed fire protection and safe shutdown analyses for the AREVA plants e.g. in France, Germany, China, Finland, Switzerland, Netherlands, Brazil and other existing plants in Europe, Asia and the USA.

Your benefits at a glance

• Comprehensive investigation for safety, personal and investment protection
• Benefit of the combination of the best system design specialists
• Provision of optimized solutions

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Seismic Margin Assessment

Assess the safety of the plant and the margins in case of earthquake

The challenge
In many countries, the Safety Authorities have reviewed their requirements with respect to seismic assumptions, either to reevaluate the design requirements or to request analysis of the consequences of beyond design basis seismic conditions. In particular, utilities are requested to provide margin assessments taking into consideration possible cliff-edge effects.

The solution
The seismic margin methodology is designed to demonstrate sufficient margin over the safe shutdown earthquake (SSE) to ensure plant safety and to find any “weak links” that might limit the plant’s capability to safely withstand a seismic event larger than the SSE. Based on the fragility of seismic structures and components and fault trees/event trees approach, the High Confidence of Low Probability of Failure (HCLPF) value can be assessed. AREVA’s experience combines expertise in nuclear industry and capability to use state of the art probabilistic approach.

Key features
- Probabilistic safety assessment for key structures, systems and components:
  - Civil works
  - Primary circuit
  - Safeguard system
  - Pumps
  - Tanks
  - Spent fuel pool
  - Electric and I&C systems
  - Fire fighting equipment
  - Internals and fuel
- Margin assessment demonstrating robustness against beyond design earthquakes
- Key systems strength and weakness analysis
- Specific tools: calculations are performed with SASSI, ANSYS, SOFISTIK, SYSTUS, SYSPipe
- Option: a full seismic Probabilistic Safety Assessment can also be used to assess the core damage frequency calculation based on existing probabilistic hazard curves
Seismic Margin Assessment

**Strong Expertise and solid references**

**References:**
- Nuclear power plants: Grohnde, Neckarwestheim 1
- New build: Olkiluoto, Taishan, UK EPR™ Generic Design Assessment
- Fast Breeder Reactor: Phenix
- Enrichment plant: Georges Besse 1

**Our core expertise in seismic design**

**Dedicated teams for:**
- System and heavy equipment
- Piping and auxiliary components
- Civil work
- Seismic reassessment
- Fuel assemblies

**Methods:**
- Compliance with international codes and standards: ASME, IAEA

Structural fragility evaluation: Identification of critically loaded structural members by nonlinear (static and dynamic) analysis

**Your benefits at a glance**

- Accurate assessment of the margins required to document safety authorities expectations
- Identification of strengths and weaknesses for the key systems
- Combination of nuclear and seismic expertise required to perform state-of-the-art evaluation for NPPs
- Experience in relevant data collection and analyses
Resistance to Major Hazards

Safety Analyses
- Safety Analyses
- Fire Protection & Hazard Analysis
- Seismic Margin Assessment

Safety Upgrades
- Analysis and Upgrades of Physical Protection Elements
Analysis and Upgrades of Physical Protection Elements

Improve the external and internal physical protection of your buildings and openings thanks to tailored and cost-effective analysis, licensing and safety upgrades.

The challenge
Nuclear power plants, interim storage facilities and permanent disposal sites as well as nuclear research facilities must be optimally protected against the consequences of residual risks, such as natural disasters, and other interferences caused by individual events.

The solution
AREVA offers you integrated and comprehensive protections against extreme natural events and individual risks by developing a concept for you tailored to your individual requirements to reinforce building structures, entrances and internal doors. We will deliver and install the necessary hardware and support you in the licensing process.

Tailor-made project scope
- Safety Analysis
- Upgrade/backfitting proposal
- Licensing and qualification support
- Hardware modification or implementation
  ... for a full turnkey project

Hardware Upgrades or backfitting
... are possible for all types of reactors to increase protection against:
- High water and floating debris
- Flying debris from tornadoes/hurricanes
- Earthquakes loads
- Fire and smoke propagation
- Security-related events
- Kerosene impermeability
- Explosion pressure waves
- Radiation

Door of a building with special requirements
Physical protection gate, double-leaf
Widely used technologies

Licensing / standard compliance:
AREVA teams of experienced experts are familiar with most licensing/qualification and standard compliance requirements of Safety Authorities in France (ASN), the US (NRC), China (NSSA), or Finland (STUK) to give a few examples.

References:
Similar hardware are already installed in several NPPs, research and storage facilities in France, Germany, the Netherlands, the United States, Japan, Finland, Brazil, Argentina, Switzerland. For instance, AREVA recently installed such physical protection equipment in the Oskarshamn and Goesgen nuclear power plants in the frame of turnkey installation contracts.

AREVA experts in civil design/calculation and construction management have worked on a large range of New Builds projects but also for several modernization/backfitting measures on existing plants.

Example of physical protection elements with additional requirements

Hardening of an exterior wall with attachment elements

Your benefits at a glance

- High planning and consulting expertise, including detailed safety and security analyses
- International expertise in erection for upgrade projects with a broad experience in handling the interfaces between involved parties
- High competence in internationally required certification
- All products are designed in line with the highest international quality standards
Robustness of Cooling Capability

Safety Analyses

• Safety Analyses
• Safety Margin Reassessment
• Analyses of UPS & I&C Power Supply

Safety Upgrades

• Flooding Protection
• Flood Proof Motors
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• Continuous Measurement of Boron Concentration (COMBO)
• Vibration Monitoring System SÜS
• Hardening of Steam Generator Secondary Heat Sink
Safety Analyses

The AREVA Safety Alliance expertise for enhanced Utilities Safety Analyses dedicated to Robustness of Cooling Capability.

The challenge
To perform the requested Safety Analysis in order to demonstrate the resistance of nuclear power plants to major initiating events.

The solution
The AREVA Safety Alliance Approach to Safety Analysis covers the most comprehensive spectrum of licensing requirements about hazards and regulatory standards worldwide.

Technical Features
- Accident Analysis included in the Safety Analysis Report
- Identification of potential cliff-edge effects especially for external events
- Analysis of robustness of the facility design to maintain its safety functions beyond the design basis
- Use of Probabilistic Safety Analysis (PSA) studies

Radiological Analysis
- shielding, radioactive release calculations
- safety documentation packages
- activity calculations
- radioisotope inventories
- neutron and gamma flux calculations
Safety Analyses

Multinational experience

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Your benefits at a glance

• Demonstrate the compliance of nuclear power plants to new Safety Standards
• A standard approach to Safety Checks-related Analysis
• Access to a wider range of Safety Analysis competences:
  • Accident Analysis
  • Radiological Analysis
Safety Margin Reassessment

The AREVA Safety Alliance customized methodology for Safety Checks.

The challenge
To assist nuclear utilities performing Safety Margin Reassessment in order to:
• identify potential weak points systematically, including cliff edge effects
• propose mitigation plans
• increase grace period if necessary using cost/safety benefit analyses

The solution
The AREVA Safety Alliance customized methodology for Safety Margin Reassessment is based on worldwide experience, ensuring consistency with WENRA and other international requirements while addressing the safety requirement specificities of the studied plants.

Features and Work Plan
A 2.5 month project:
1. Off site preparation
   • A first questionnaire is sent to the customer prior to site audit for each technical area with questions that will be addressed during the safety checks
2. On site audit
   • 5 days mission is organized on site to perform walkdowns and interviews
   • Each day a common debriefing is organized

Output
• Preliminary report is issued onsite
• A detailed report will complete the mission

A dedicated expertise at your service:
• Team of AREVA experienced worldwide experts in the different fields linked to Fukushima scenarios (extreme external hazards such as seismic + flooding)
• Systems, procedures, electrical and I&C, layout and building, seismic, accidental studies, severe accident management
• Expertise in the performance of safety checks (AREVA has participated to the German safety checks)
• Expert counterparts for each field of expertise are appointed within customer’s organization
Safety Margin Reassessment

A best-in-class combination of expertise

Team of AREVA experienced experts
- Systems (fluid, HVAC)
- Equipment
- Severe accidents (simulation and management)
- Electrical systems
- Lay-out, impact flooding
- Seismic margin assessment
- Operating Procedures

Your benefits at a glance
- Access to the best combination of experts
- Benefit from a consistent approach (cf. EPRI/NEI Leadership Model document in the US)
Analyses of UPS and I&C Power Supply

Improve your UPS and I&C power supply using AREVA’s experience with state-of-the-art new plant design and our nuclear process know-how.

The challenge
New loads and/or regulatory requirements require increased capacity. Modified plant processes require different load scenarios and transients.

The solution
AREVA assesses your UPS power balances and evaluates the existing design. Based on the result and current requirements, we provide suggestions for improvement and turn-key implementation of all needed component and system modifications. To achieve the exact fit solution for your particular needs, we combine the best products from a range of proven quality manufacturers.

Analyzing and improving a UPS system is a complex task. It requires the expertise of an experienced provider dedicated to the nuclear industry. Mastering UPS system design needs not only hardware know-how but also requires knowledge of the plant’s operating conditions, correct consideration of all interfaces, optimized design to withstand transients and to protect the connected safety loads and knowledge of potential common cause failures.

Technical Features
- Detailed analysis of the existing UPS power balance and I&C power supply concept, determination of strengths and weaknesses
- Consideration of increased disturbance scenarios and experiences obtained from incidents
- Elaboration of optimization potential regarding capability of the entire UPS and I&C power supply system
- Increase of battery capacity
- Analysis and modification of the redundancy concept to extend the availability
- Implementation of current limiting devices for battery chargers protects the UPS against transient events
- Detailed and sophisticated approach to power balance, adapted to the process engineering of the plant

Battery Room in a NPP (Example for OCSM type batteries)
Analysis of UPS and I&C Power Supply

Licensing / standard compliance:
- We have worked to KTA, YVL, RCC-E
- IEC type hardware was provided so far, but other types are also possible.

References / example of application:
- Entire UPS system and I&C power supply system: Oikiluoto 3 (Finland), Taishan and Ling Ao (China), Belene 1+2 (Bulgaria)
- I&C power supply system: Flamanville 3 (France), Mochovce 3+4 (Slovak Republic)
- Replacement of rotary converters by static inverters: Emsland, Gundremmingen, Philippsburg 1+2 (Germany), Gösgen (Switzerland)
- Modernization of UPS: OKG2 PLEX (Sweden), Neckar 1, Isar 1 (Germany), Mühleberg (Switzerland)
- Implementation of transient limiters for battery chargers: Emsland (Germany), Gösgen (Switzerland)

Using our established & proven process, we implement significant UPS system improvements for many different plant types and licensing environments all over the world.

(Frank Marquardt,
Head of Electrical System’s Emergency Power Supply Department)

Your benefits at a glance
- Fulfillment of the latest technical developments
- Increases ability to safely resist power failures
- Individual fit to the plant design
- Complete engineering portfolio from basic design to erection and commissioning

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Robustness of Cooling Capability

Safety Analyses

- Safety Analyses
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- Analyses of UPS & I&C Power Supply

Safety Upgrades

- Flooding Protection
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AREVA Safety Alliance
Flooding Protection

Evaluation, analyses and countermeasures responing to potential flooding risks.

The challenge
Depending on the location, water courses in immediate proximity to nuclear power plants bear flooding risks.

The solution
AREVA realizes systematic evaluation of on site characteristics supported by studies and analyses of the nuclear power plants’ potential water risks and supplies countermeasures for flooding risks.

Technical Features

Typical proceedings and measures are:

- Engineering studies
- Safety analyses
- Securing the flood-protected feed of the Reactor Pressure Vessel (at least one train)
- Procurement of flooding-proof engines (service water & emergency cooling)
- Train disconnection in the reactor building (service water) via leak detection with automatic train shutdown and installation of new non-return valves in the recirculation
- Underwater tests

AREVA’s portfolio comprises studies, analyses and tests
Flooding Protection

Applicable countermeasures to all nuclear power plants

References:

• Philippsburg 1 (BWR)
• Isar 1 (BWR) types are also possible.

Licensing and standard compliance:

• Applicable to all reactor types

Your benefits at a glance

• Prevents the loss of the ultimate heat sink in case of flooding
• For all types of reactors: Pressurized Water Reactors (PWR) including Russian type VVER, Boiling Water Reactors (BWR), and CANDU plants
Flood Proof Motors

Prevent the loss of vital pumps. Ensure sufficient cooling in case of flooding and even under severe accident conditions.

The challenge
Plants want to prevent the loss of important drives after a large cooling pipe break and in case of externally caused flooding.

The solution
Use AREVA’s scalable drive system solutions to prepare your system for a flooding of at least 6 meters. The system consists of waterproof motor, cabling and junction boxes. Get a complete solution from one supplier: Our experienced engineers take care of the initial task analysis, system design, testing, delivery, installation and commissioning.

We are your reliable partner for both new installations and modernizations.

AREVA can also provide the related pumps, piping, leak detection and automatic train shutdown, non-return valves, etc. Please refer to product information “Flooding Protection”.

Technical Features

- Tested and approved design for safety related low and medium voltage motors of 110 - 400 kW
- Use of LOCA-qualified materials. Motors will be tested for operability under LOCA conditions: humidity > 95 %, pressure 1.1 bar absolute, duration 2 h
- Approved system (pump + motor + cable) for operating even under severe flooding conditions. Protection class IP 68-h6 (6 m)
- Water-jacket-cooled motors eliminate heat dissipation from the motor into the room
- Testing was done under water with 80 °C for 3 days, then 11 days at 30 °C
- Analytic functional proof available for continued operation under induced vibration conditions
Your benefits at a glance

- Important pumps in emergency systems stay operable even under water and after LOCA
- Reduced risk of losing cooling pumps due to flooding
- A specialized team with very recent experience ready to implement new installations and upgrades of installed pumps
- Beyond the right hardware, AREVA provides a complete solution covering all engineering disciplines and considering your plant’s special requirements

Licensing / standard compliance:

- Motors are IEC type, testing has been made to KTA requirements.
- Ask us regarding availability of a suitable solution for your special requirements in a non-KTA licensing environment.

References:

- NPP ISAR 1 (Germany): Installation of four motors + delivery of two spare part motors:
  - Two high voltage motors of the residual heat removal system + one spare part motor (6 kV / 400 kW)
  - Two low voltage motors of the secured closed cooling system + one spare part motor (380 V / 110 kW)
- NPP PHILLIPSBURG 1 (Germany):
  - Offer of seven motors
  - Two high voltage motors of the residual heat removal system + two spare part motors (6 kV / 350 kW)
  - Two low voltage motors of the secured closed cooling system + one spare part motor (380 V / 110 kW)
- NPP GOESEGEN (Switzerland):
  - Offer of seven high voltage motors (6 kV / 255 kW)

We have successfully implemented our flooding protection upgrade. Working with the highly committed AREVA team was a great pleasure.

Dr. Frank Becker,
Project Manager of EoN Hannover for the Isar 1 NPP Upgrade

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Motor testing temperature curve

Flood Proof Motors

AREVA NP GmbH

Your contact: plant-studies-germany@areva.com
Additional Connections for Mobile Power Sources

Diversify your means for providing power to your plant's vital loads in case of a severe accident with Station Blackout.

The challenge / introduction
Severe events can cause failure of all fixed external and internal power sources of a NPP, with potentially grave consequences. The time until connection of mobile power sources needs to be as short as possible.

The solution
Easy connectivity for mobile power sources and pre-installed connections from an erection pad with hook-up point to the critical loads speeds up plant recovery after a Station Blackout (SBO).

AREVA's long-lasting experience in implementing complex electrical upgrades allows us to provide your tailor made solution.

Mobile power sources are available – connection to your essential loads will take days without pre-installed connection points.

Technical Features
- Position of connection point: outer face of the building
- Use for important loads: battery charger, pumps/valves, lighting, measurements
- **Case 1: supply of 1 or a cascade of switchgears**
  - permanent cable connection to the switchgear
  - infeed into switchgear via load breaker (breaker may be moved from other infeed)
  - prior to use: need of manual disconnection of the switchgear from the original source(s)
  - no protection devices with need of auxiliary voltage
  - possibly the entry point of the 3rd grid may be used
- **Case 2: direct supply of an single important pump**
  - permanent cable connection to the pump (parallel to the original one, both powered)
  - prior to use: need of manual disconnection from the original source
  - direct supply of the pump without I&C control
  - Standard voltage level
  - Mechanically predesigned connection to the output of the mobile power source (with or without plug)
Your benefits at a glance

- Mobile power source are widely available. Pre-arranged power connection points speed up plant recovery
- AREVA provides a comprehensive multi-disciplinary solution, covering all aspects from civil construction to electrical design as well as efficient project management for turn-key implementation

Licensing / standard compliance:

Compatible to all nuclear standards because of
- being unpowered or protected during normal operation.
- being activated in events beyond design basis only.

References:

German Konvoi plants:
- Feedwater building
  There is a protected opening in the wall to allow a flexible cable connection from outside (mobile source) to the four emergency switchgears. The cable is not prepared but the infeed to the switchgear.
- Switchgear building
  There is space in cable sealing frames going from outside to inside.

AREVA NP Electrical Systems is a one-stop shop for solutions that require more than just hardware know-how. Our solutions combine the suitable OEM hardware with advanced engineering capabilities to provide you a superior and economic solution.

Heiner Dornburg,
Director Electrical Systems AREVA NP

Pre-installed openings for use in emergency situations and prepared switchgear (not shown). Very simple today, it can make a big difference in a severe incident situation.
Hardened Emergency Diesel Generator Upgrade existing EDGs Beyond Design Conditions

Implement selective design modifications or a full upgrade solution for a significant, plant-specific and cost-effective safety level improvement.

The challenge
Worldwide, there is an increased focus on emergency power supply for both new build projects and existing nuclear plants. Existing accident scenarios are being questioned and new and tightened safety levels are likely to be imposed by regulatory bodies.

The solution
In case of external events (e.g. airplane crash, flooding or hurricanes) not only the external grid might not be available, but also the plant Emergency Diesel Generators (EDG) might be damaged and therefore not available. In case of plant shutdown, this might lead to a Station Blackout (SBO).

AREVA is your complete solution provider for all EDG related matters:
Complete systems, EDG control systems (safety and non-safety related portions, generators, generator protection, excitation and voltage regulation, synchronization and more: everything you need from one partner.

Technical Features:
- Generator bearings without external oil supply system (passive cooling)
- Modular analogous excitation system
- Mechanical speed controller (or encapsulated electronic one)
- Generator with closed cooling circuit (encapsulated), water or air cooled (air ducts or cooling water supply necessary)
- Protection of tank rooms including pumps against flooding
- Protection of air intake and exhaust openings against shockwaves
- Electrical cabinets moved to higher levels or sealed for emergency operation under water
- Separate encapsulated battery (with separate engine driven charger) for black start capability

NPP Phillipsburg 1 (Germany): Bunkerized Independent Accident and Sabotage Protection Subsystem building provided by AREVA.
Your benefits at a glance

- Upgrade of existing EDGs / subsystems or design improvement of new EDGs to reach a more rigid design:
  - Less susceptible to harsh environmental conditions
  - Better mastering of beyond design accidents
  - Easier repair after impairment of serviceability
  - Black start capability

Licensing / standard compliance:

- AREVA NP has delivered more than 300 EDG systems worldwide and is currently implementing numerous complete system deliveries and modernizations of EDG systems.
- In cooperation with our extensive supplier network, the described solutions can be made available within one year.

References:

- Our solutions are applicable for all plant designs: German (KTA) or US (IEEE) or French (RCC-E) nuclear standards.

You can rely on AREVA’s vast experience with over 300 diesel systems worldwide for your specific upgrade solution.

Philippe Samama,
Executive VP, Installed Base BU.
Alternative Power Supply
Example of the H₂/O₂ PEMFC as a Backup Power Solution

Increase your Station Blackout (SBO) coping capabilities with diversified energy solution.

The challenge
In case of Station Black-Out the plant operation will require alternative power supply in order to power vital function.

The solution
AREVA supplies containerized autonomous fuel cell backup power systems. The H₂ and O₂ tanks are commonly used at the power plant for various applications. Additional dedicated trailers can be installed to increase the energy autonomy. An electrolyzer can be proposed as an option to refill the tanks.

MISTRAL H₂/O₂ Fuel Cell
- Pure H₂ & O₂ PEM FC
- Power: 100 kVA / Unit
- AC tri-phased or DC output
- Weight: 5 t (w/o gas storage)
- Can be delivered within its container or installed in a building
- Up to 6 Mistral in parallel

ELECTROLYZER (Optional)
- Hydrogen flow: 10 to 40 Nm³/h
- Pressure: 35 barg
- Operating range: 10 - 100 % Pₘₐₓ
Alternative Power Supply Example of the H₂/O₂ PEMFC as a Backup Power Solution

A mobile power solution for high performance applications

References:
A 30 kVA PEMFC backup system has been tested by the French “Commissariat à l’Energie Atomique et aux Energies Alternatives” (CEA) for more than 80 hours of active operation and over 30,000 hours of stand by.

A 100 kVA system has been in use for more than 6 months at an AREVA facility in Aix-en-Provence.

Our core expertise
Over 40 recognized experts in Fuel Cell development:
- Architecture and design process
- Electrochemistry and test facilities
- Electrical and control systems
- Mechanical and structural engineering
- Safety environment
- Qualification and system improvement
- Installation, commissioning and maintenance

Your benefits at a glance
- A diversified back-up power solution based on fuel cell technology
- Very high start-up reliability
- Independence towards ambient conditions (polluted environment, waterproof)
- Very low self discharge and long lifetime thanks to the inerted mode
- Low maintenance requirements
- A modular solution in terms of installed power and energy autonomy
Hardened 3rd Grid Connection

Increase your power supply options through installing a rigid 3rd grid connection – or improve the availability of the existing solution.

The challenge
All off-site and on-site AC power sources may fail.

The solution
A hardened 3rd grid connection can help preventing the occurrence of a severe plant accident by providing power when all other AC sources have failed.
Based on our experience with new plant design and modernization, AREVA can provide a complete solution including initial study, design, delivery and installation/commissioning.

Technical Features:
- External Emergency Power Supply
- Power supply installation is independent from the emergency power generating facilities of the power plant
- Minimum power: for one residual heat removal train including all necessary I&C and auxiliary equipment
- Connection of the 3rd grid connection is done manually only
- Connection can be hardened against external events like sabotage (e.g. connection by cabling)

Partial Single Line Diagram showing the 3rd grid connection. OL3 (Finland).
Design by AREVA NP
Hardened 3rd Grid Connection

Your benefits at a glance

- Diversity in offsite power supply means increased safety
- If sufficient power is foreseen: long term substitution of the Emergency Diesels
- In case of adequate realization (e.g. cable connection to an hydro-electric power plant): power supply in case of loss of the Emergency Diesel supply

Licensing / standard compliance:

- AREVA can implement hardened 3rd grid connections for all kinds of nuclear power plants
- Existing solutions have been made per requirements e.g. of KTA 3701

References / examples of application for 3rd Grid Connections (NB or retrofit):

- OL3
- CN Trillo
- Kernkraftwerk Emsland
- Kernkraftwerk Isar 2
- Bohunice
- Other power plants

Severity of natural disasters increases. It may be time to harden existing 3rd grid connections or install new ones.

Heiner Dornburg, 
Director Electrical Systems AREVA NP

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Transport of Used Fuel to Reprocessing Plant or to Centralized Storage

Safely transport used fuel to reprocessing plant or to centralized storage to reduce used fuel inventory at NPP sites.

The challenge
Reactor pools are necessary to cool down used fuel after unloading. Many electrical utilities maximize existing storage capacity with pool re-racking. In cases of a severe accident, risks are increased. If safety authorities impose stronger restrictions concerning the capacity or duration of storage, utilities will face challenges for unloading their pools.

The solution
AREVA is the world leader in used fuel transport with almost 50 years of experience. Shipments of used fuel can be made to a reprocessing facility or to a centralized storage to reduce your pool inventory.

Technical Features
- Transportation of a wide range of used fuel (UOX, MOX, Materials Testing Reactor Fuel)
- Cask capacity up to 28 PWR or 69 BWR fuel assemblies
- Thermal output up to 64 kW
- Initial enrichment up to 5 % U235
- Burn-up of used fuel up to 70 GWD/MTU
- Wide range of casks and baskets to meet specific customer requirements: fuel type, fuel geometry, NPP interfaces...
- Global solution including handling, operation (tools) and transport equipment
- Transport authorizations and cask licensing by safety authorities
Transport of Used Fuel to Reprocessing Plant or to Centralized Storage

Wide-ranging technology

**Licensing / standard compliance:**
Transport licenses in Western Europe and Japan.

**References:**
More than 200 backend shipments per year, almost 50 years of international transport activities.

Your benefits at a glance

- Evacuation solution can be quickly implemented
- Fuel can be evacuated as early as 180 days after downloading from the reactor
- Safe and secure used fuel evacuation:
  - Proven transport risk management
  - Vast international experience in used fuel transport
- Integrated solutions: loading, transport (by road, train or maritime shipment) and unloading

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Dry Storage at NPPs:
- Canister Systems: NUHOMS®, TN NOVA™
- Dual Purpose Casks: TN®24 Family

Reduce inventory of used fuel in pools with dry storage on NPP sites.

The challenge
Reactor pools are necessary to cool down used fuel after unloading. Many electrical utilities maximize existing storage capacity with pool re-racking. In cases of a severe accident, risks are increased. If safety authorities impose stronger restrictions concerning the capacity or duration of storage, utilities will face challenges for unloading their pools.

The solutions
AREVA is the world leader in used fuel dry storage. Two families of customized solutions can be proposed to reduce pool inventory: canister systems and dual purpose casks (transport and storage).

Technical Features
- Dual purpose or canister systems
- Capacity: 24 to 37 PWR assemblies, 52 to 69 BWR assemblies
- Typical cooling time: 5 to 10 years
- Resistant to external hazards: aircraft crashes, earthquakes, tornados, flooding...
- Passive system
- Horizontal (NUHOMS®) or vertical storage (TN NOVATM, TN®24)
- Burn-up: up to 70 GWd/MTU
- High level of radioactive protection (low doses)
Dry Storage at NPPs: NUHOMS®, TN NOVA™ and the TN®24 family

Wide-ranging technology

Licensing / standard compliance:
• Long-standing relationships with Nuclear Safety Authorities.
• Numerous transport casks, licensed internationally for a wide variety of radioactive materials, including transport of used fuel to the AREVA La Hague reprocessing facility.

References:
• World leader for almost 50 years
• More than 1000 casks supplied by AREVA
• 50% of the US market share

Our core expertise
• Engineering (design & manufacturing)
• Licensing
• Transport
• Services (loading & maintenance)

Your benefits at a glance
• Used fuel can be loaded after 5 years to reduce pool inventory and meet regulatory requirements
• In case of reactor shut down, used fuel can be unloaded in only 2 years provided that capacity optimization is performed
• Vast experience in licensing with multi-national safety authorities
• Flexible solutions to meet site requirements: concrete or metal, vertical or horizontal storage
• Resistance to external hazards: earthquakes, fire, flooding, airplane crashes
• Totally passive equipment

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High Sensitivity Leakage Monitoring for Components and Compartments (FLÜS)

Monitoring leakages to strengthen the safety of the plant

The challenge
In case of occurrence of major hazards like earthquakes, even minor leakages must be detected promptly. Moreover the Leak Before Break (LBB) approach to detect minor leakages at a very early stage for equipment can help to detect and to remedy minor cracks and consequently increase the robustness of the cooling system in case of future stress. For these reasons, we can expect Safety Authorities to be more and more demanding in the future with respect to leakage detection.

The solution
The FLÜS system can detect and localize minor leakages on components underneath the insulation or inside compartments. The equipment consists of robust temperature and radiation resistant monitoring lines equipped with “humidity measuring points” (sensor tubes) installed close to the components. The monitoring lines pick up local humidity and convey these air samples to a central humidity analyzer.

Key Features:
- Radiation-hard and temperature-resistant monitoring lines for humidity measurement
- Up to 6 lines per system
- Additional temperature sensors and air cooler condensate flow sensors are available for diverse measuring
- Periodic measuring cycles
- Response time: typically 20 to 60 minutes
- Sensitivity: 1 kg/h for components
- Automatic self-testing functionality
- Dry instrument air can be supplied by the plant or by a dedicated air supply unit
High Sensitivity Leakage Monitoring for Components and Compartment (FLÜS)

**Your benefits at a glance**

- High-sensitive humidity measurement and detection of minor leakages
- Accurate localization of the leakages due to installation close to the components/pipes
- Credited for Break Preclusion Concept and Leak Before Break approach due to detection and localization of minor cracks
- Maintenance-free and long lifetime due to the robustness of the equipment
- High reliability and availability of the system (self-test)

**Licensing / standard compliance:**

All plants

**Selected References:**

<table>
<thead>
<tr>
<th>Reactor Type</th>
<th>Reference Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPR</td>
<td>OL3, TSN, FA3</td>
</tr>
<tr>
<td>PWR</td>
<td>German PWRs, Davis Besse</td>
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<tr>
<td>VVER</td>
<td>Kozloduy, Kalinin, Mochovce</td>
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<tr>
<td>BWR</td>
<td>Oskarshamn 2, Ringhals 1</td>
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<tr>
<td>CANDU</td>
<td>Point Lepreau, Gentilly 2</td>
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</tbody>
</table>

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Continuous monitoring to assess the operating capability of the plant’s valves and actuators

The challenge
The reactor trip operations induced by an earthquake or other severe events involves a large number of valve and actuators operations under stress conditions. Being able to rapidly and quantitatively assess the thrust margin of all critical valves operated is an asset that enables to anticipate and remediate to the possible consequences of an aftershock. Furthermore, providing the system responsible with additional status information for example actuator runtime or thrust at failure, is crucial to accurately capture the overall post event plant status.

The solution
The ADAM®/SIPLUG® continuous condition monitoring and diagnostic system acquires data during each operation of the valve, even during events, without interfering with the actuator. The data is first stored in the acquisition device itself (SIPLUG®) and is kept safely there until it has been successfully transmitted to the evaluation system (ADAM®). This method shows it’s full relevance during operation in degraded conditions (post event) where the network availability can become an issue. The automatic evaluation capabilities of the ADAM® software will then provide a precise status information of actuator and valve. Those information are provided summarized in a traffic light style intelligible display and adapted to an usage under time pressure.

Key Features:
- Remote monitoring from the Motor Control Center (MCC) using active power measurement
- Non-reactive against the actuator and other subsystems
- High precision data acquisition and high sampling rate
- Available for motor and solenoid operated valves
- Powered through the power supply of the switchgear feeder (if the MCC is powered, the monitoring unit is also powered)
- Non-volatile internal storage resistant to sporadic network or power outages. Measurements remain in internal flash memory even if power fails
- Networking using proven industrial class Ethernet hardware
- Compatible with most switchgear designs

Robustness of Cooling Capability

Key Features:
- Remote monitoring from the Motor Control Center (MCC) using active power measurement
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- Networking using proven industrial class Ethernet hardware
- Compatible with most switchgear designs
Condition Monitoring ADAM®/SIPLUG® for Valves and Actuators

**Your benefits at a glance**

- Continuous online monitoring allowing real-time assessment of the valves’ condition as well as event analyses.
- Monitoring from the switchgear panel outside the containment: data available in post-event conditions; no dose in normal conditions
- No risk of impact on the switchgear system in case of failure
- Reduced outage time through condition based maintenance
- Prevent valve failures thanks to trending capabilities
- User-friendly interface designed for non-specialists and emergency situations (dedicated valve diagnostic software)

**Licensing / standard compliance:**

All plants; in line with RCC-E C3321, 3322 and GL 89-10/96-05

**Selected References:**

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPR</td>
<td>OL3, TSN</td>
</tr>
<tr>
<td>PWR</td>
<td>Isar 2, Neckarwestheim 1&amp;2, Borssele</td>
</tr>
<tr>
<td>BWR</td>
<td>Krümmel</td>
</tr>
</tbody>
</table>

**SIPLUG® 4 CO for cable outlet installation**

**SIPLUG®/ADAM® Feeder deployment example**

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Ensuring the primary circuit leaktightness to guarantee plant operation and safety

The challenge
In case of Station Black-Out, Reactor Coolant Pumps (RCP) stop, leading to the leakage of significant quantities of water through the seals (typically several cubic meters per hour for each pump). The primary circuit leaktightness function is therefore key to preclude Loss Of Cooling Accidents (LOCA) that could ultimately lead to core melt.

The solution
A new technology of RCP seals that can withstand high pressure and temperature profiles in case of Station Black Out (SBO) has been developed by AREVA, taking into account the high expectations from our customers and from Safety Authorities. This RCP Seal aims at withstanding extended SBO (ultimate qualification in progress).

This technology can be implemented on both operating RCPs for installed base, and new RCPs for new builds projects.

Key technical features
- A three stage shaft seal
- Reactor coolant system pressure equally divided through each stage of the seal
- Each stage is conservatively designed to withstand the full primary pressure
- All 3 stages are identical
- Increase resistance in case of failure: the RCP can operate until the next outage in case of failure of one stage and during 24 hours in case of failure of two stages
- Lifetime estimated to 10 years

Hydrodynamic shaft seal

Robustness of Cooling Capability

Safety Upgrades
**Strong expertise and solid references**

JSPM has 40 years of experience in the maintenance of shaft seals. Indeed, AREVA JSPM teams take part in the maintenance programs of over 400 RCP’s worldwide. Every year over 100 leak tightness systems are assessed and repaired in SOMANU’s hot workshop. The considerable experience thus built up has enabled AREVA JSPM engineers and technicians to acquire outstanding know-how that they have turned to good account by increasing the reliability of the seals and reducing their impact on the scheduling of outages.

To check the behavior of shaft seals under normal and incidental operating conditions and to perform their qualification, AREVA has several testing means. This applies both to seals at the development stage and 100% of seals in production. A dedicated seal test bench enables to test seals and reproduce their behavior in operation in order to provide better expertise. Furthermore a static test bench in Karlstein – AREVA Technical Center – enables to test the seals in SBO conditions.

---

**Your benefits at a glance**

- Better resistance to SBO compared to other solutions: improved robustness in incidental or accidental conditions
- “Pure” hydrodynamic seal: instantaneous hydrodynamic effect
- Easily applicable to existing plants
- Improved reliability in operating conditions (possibility to operate a full cycle with one damaged stage and 24 hours in case of 2 damaged stages, easy restart of the pump in case of short loss of power supply)
- Optimized maintenance programs management and costs thanks to easier installation and inspection, easier inventory management and reduction of worker’s radiation exposure
Continuous Measurement of Boron Concentration (COMBO)

Early detection of disturbances in the concentration of Boric Acid used to prevent criticality events and improve operations

The challenge
Dissolved boric acid is one of the solutions used by the nuclear industry to prevent any criticality events in Spent Fuel Pools. In PWRs and VVERs, slow changes in reactivity are also controlled using boric acid dissolved in the coolant of the primary circuit. Today it is still standard practice to measure boric acid concentration on a non-continuous basis via chemical analysis for those usages (titration).

The solution
Continuous Measurement of Boron Concentration (COMBO) allows the early detection of disturbances on a nearly real-time basis. The measuring principle is based on the absorption of neutrons by the isotope B-10, which depends on the boron content of the coolant. Neutrons from an Am/Be source diffuse through the coolant and a portion of these neutrons is absorbed. The remaining neutron radiation is then detected by suitably positioned counter tubes.

Technical Features

System Performance
- **Measurement range:**
  - 0 – 1600 ppm Boron-10
  - 0 – 8000 ppm Boron total (20 % enriched)
  (can be adapted for specific projects requirements)
- **Reference accuracy**
  - 20 ppm for boron conc. < 1000 ppm
  - 2 % for boron conc. ≥ 1000 ppm
- **Response time** < 1 min (depending on filter type)
- **One-point calibration with reference value (e.g. titration) recommended every 3 months - Duration ≈ 1 hour**
- **Radiation** within working area
  - < 100 μSv/h (on equipment surface)
  - < 10 μSv/h (in 1 m distance)

Sensor Unit
- **Installation mounted directly on pipe without any need for welding**
- **Neutron Source: Am-Be – 3.7 x 1010 Bq**
- **Neutron Detectors: Boron-lined counter tubes**

Principle of the AREVA COMBO System
Continuous Measurement of Boron Concentration (COMBO)

**Licensing / standard compliance:**

- The COMBO system is qualified for safety-related applications.
- Type tests and seismic load test have been performed on the basis of IEC60780, IEEE 323 and KTA3505. Additionally, the used TELEPERM® XS hard- and software is qualified according to KTA3505 and IEC60880 with generic accelerations.

**Selected References:**

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Country</th>
<th>Commissioning</th>
<th>Number of Measurements</th>
<th>Monitored System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grafenrheinfeld</td>
<td>Germany</td>
<td>1996</td>
<td>1</td>
<td>Chemical and volume control system</td>
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<tr>
<td>Mochovoe Unit 1&amp;2</td>
<td>Slovakia</td>
<td>1998/99</td>
<td>18</td>
<td>Chemical and volume control system, Coolant makeup system and primary circuit</td>
</tr>
<tr>
<td>Isar Unit 1</td>
<td>Germany</td>
<td>2001</td>
<td>1</td>
<td>Fuel pool cooling system</td>
</tr>
<tr>
<td>Neckarwestheim Unit 1</td>
<td>Germany</td>
<td>2001</td>
<td>4</td>
<td>Chemical and volume control system and emergency borating pool</td>
</tr>
<tr>
<td>Callaway</td>
<td>USA</td>
<td>2004</td>
<td>1</td>
<td>Chemical and volume control system</td>
</tr>
<tr>
<td>Loviisa Unit 1&amp;2</td>
<td>Finland</td>
<td>2008/09</td>
<td>4</td>
<td>Chemical and volume control system</td>
</tr>
<tr>
<td>Sizewell Unit B</td>
<td>United Kingdom</td>
<td>2010</td>
<td>2</td>
<td>Fuel pool cooling system</td>
</tr>
</tbody>
</table>

The online COMBO monitoring system is also part of AREVA's new PWR design line EPR™ and is currently being installed in 4 EPR™ reactors in France, Finland and China.

Safety related TELEPERM® XS implementations in Loviisa 1&2 and Sizewell B.

**Your benefits at a glance**

- Early detection of disturbances in the Boric Acid concentration within the primary loop and the fuel pool cooling system
- A fully qualified system for safety related applications
- Optimized installation of the equipment and systems in the plant with no welding intervention on pipes and an easy integration in an expert system to support plant chemistry
- Easy service and maintenance by means of automatic diagnostic of all components
Vibration Monitoring System SÜS

Assessment of plant components using vibrations analysis

The challenge
In case of occurrence of hazards like earthquakes, it is crucial to ensure the structural integrity of the primary (and secondary) circuit, i.e. of the reactor pressure vessel, reactor coolant pumps, steam generators, and piping, or to detect potential structural failures.

The solution
The vibration monitoring system SÜS measures the vibratory behavior of the primary (and secondary) circuit by means of suitable sensors like displacement, pressure, and acceleration transducers. The SÜS is a fully integrated and automated system including the control of the measurement chains, data acquisition, and analyses, parameterization and trending to the point of automatic alarm generation. The system may be also used for the comparison of pre- and post-hazard vibration parameters allowing to assess the structural integrity of the monitored components.

Key Features:

- Specialized high-sensitive sensors for vibration measurements on the pressure vessel working in harsh environment (300°C, hard radiation)
- Specialized high-sensitive relative displacement sensors on loop components to measure their static and dynamic displacement
- Specialized pressure fluctuation sensors for measurement of coolant dynamics
- Automatic control of the measurement chains including automated calibration during plant operation
- Machinery protection system for reactor coolant pumps
- Periodic measuring cycles
- Automated analyses and reporting
- Large functionality for expert offline analyses

Pressur Fluctuation Sensor for intrusive measurement of coolant dynamics

High-sensitive absolute displacement sensor for applications in harsh environments (pressure vessel)
Your benefits at a glance

- Early detection of damages
- Post-hazard assessment of the plant components evolution
- High-sensitive measurements of RPV and loop vibrations
- Validation of structural integrity
- Fully automated and integrated system
- High reliability and availability of the system (self-test)
- Expert functionality for off-line analyses
Hardening of Steam Generator Secondary Heat Sink

Reinforce the Emergency Feedwater System and steam dump system to atmosphere

The challenge
In case of loss of the primary ultimate heat sink, it is required to secure the cooling of the core after the reactor shutdown. This is one of the functions of the emergency feedwater system and steam dump system to the atmosphere. This procedure called secondary "Bleed & Feed" must be secured.

The solution
Depending on the specificities of the power plant, it is necessary to assess the availability and sizing of the alternate water sources, reliability and qualification of the steam dump as well as potential weak points in the emergency cooling chain. Based on this analysis, the system can be hardened to the required extent from water reserves to pipes, pumps and valves. The use of “Bleed” (Steam dump) and “Feed” (Emergency water injection and alternate water source) approach at the secondary side of the Steam Generator can consequently be secured.

Key features
- Alternate water source
  - Analysis of existing alternate sources (fire fighting water tanks, ponds, ground water)
  - Implementation of the solution: connection through pipes, pumps if required
  - Creation of additional tanks or ponds
- Robustness of the existing emergency feedwater system
  - Analysis of risks: pumps overspeed or cavitation, reliability of pumps and turbo pumps
  - Robustness against hazards: water tight building, submersible pumps
- Robustness of the steam dump
  - Improvement of qualification, analysis of I&C and dedicated power supply
  - Compact relief and safety valve station, bleed qualified and protected against open valve failures.
- Additional dedicated train
  - Bunkered building for autarky feedwater supply with e.g. direct diesel driven emergency feedwater pump, water tank, control panel
- Capability to easily connect mobile means to the Emergency Water System

Robustness of the steam dump:
1. Main Steam isolation valve
2. Relief isolation valve
3. Safety isolation valve
4. Main safety valve
5. Control relief valve

![Diagram](image-url)
Your benefits at a glance

- Increase of the grace period before severe accident conditions in case of loss of the primary ultimate heat sink by use of the atmosphere as alternate heat sink
- Improve the reliability and robustness of the existing emergency feedwater and steam dump systems in accidental and normal operating conditions
- Increase plant’s autarky for secondary “bleed & feed” under Station Blackout and further on supported by mobile feed devices

References:

- 900 MW NPP in France (Steam dump hardening)
- PWR NPP in Germany (bunkered emergency feedwater building; diverse power)
- EPR™ Reactor Finland (secondary depressurization, feed and heat removal via feedwater tank)

Hardening of Steam Generator Secondary Heat Sink

Mobile diesel and fire fighting pump to back up the emergency diesel and feedwater pump with prepared water and AC power connections

Our core expertise in alternate cooling design relaying on own references

Bunkered emergency supply building for diverse heat removal (autarky 72h). On one axle for each safety train: Diesel – Generator – Motor alternate to the diesel - EFW Pump

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Prevention of Environmental Damage

Safety Analyses

- Safety Analyses

Safety Upgrades

- Passive Autocatalytic Recombiners
- Containment Filtering and Venting Systems
- Post-accident Sampling System PRONAS
- HERMETIS
- LOCA Proof I&C Cable ARENOPYR®
- Radiological Emergency Response
- Post-accident Characterization and Response
- Real-time Continuous Environment Monitoring
- Liquid Level Measurement Solutions
- Hardening of Primary System Depressurization

Safety Procedures

- Severe Accident Management Guidelines – OSSA
- Nuclear Simulators
- Training for Reactor Operations in Accidental Conditions
Safety Analyses

The AREVA Safety Alliance expertise for enhanced Utilities Safety Analyses dedicated to Prevention of Environmental Damage.

The challenge
To perform the requested Safety Analyses in order to demonstrate nuclear power plants ability to mitigate severe accidents.

The solution
The AREVA Safety Alliance Approach to Safety Analysis covers the most comprehensive spectrum of licensing requirements and Regulatory Standards worldwide.

Technical Features
- Severe accident design studies (in-vessel and ex-vessel)
- Grace period evaluation for extreme external hazards
- Use of Probabilistic Safety Analysis PSA level 2 studies

Radiological Analysis
- radioactive release calculations
- safety documentation packages
- activity calculations
- radioisotope inventories
Safety Analyses

Multinational experience

Licensing / standard compliance:
- France/ASN
- US/NRC
- China/NSSA
- Finland/STUK

References: AREVA Worldwide Experience
- EPR severe accident design: OL3, FA3
- EPR PSA level 2

Your benefits at a glance
- Demonstrate the compliance of nuclear power plants to new Safety Standards
- A standard approach to Safety Checks-related Analysis
- Access to a wider range of Safety Analysis competences:
  - Accident Analysis
  - Radiological Analysis
Prevention of Environmental Damage

Safety Analyses
- Safety Analyses

Safety Upgrades
- Passive Autocatalytic Recombiners
- Containment Filtering and Venting Systems
- Post-accident Sampling System PRONAS
- HERMETIS
- LOCA Proof I&C Cable ARENOPYR®
- Radiological Emergency Response
- Post-accident Characterization and Response
- Real-time Continuous Environment Monitoring
- Liquid Level Measurement Solutions
- Hardening of Primary System Depressurization

Safety Procedures
- Severe Accident Management Guidelines – OSSA
- Nuclear Simulators
- Training for Reactor Operations in Accidental Conditions
Passive Autocatalytic Recombiners

Reduce the risk of hydrogen explosion in the containment in case of a severe accident.

The challenge
During severe accident situations large amounts of hydrogen can be released inside the reactor containment. Without countermeasures these releases could lead to a significant combustible gas accumulation within the containment. An ignition of this gas mixture could exceed overpressure design values and jeopardize the integrity of the containment.

The solution
Based on the principle of catalytic oxidization, AREVA has developed a hydrogen reduction system. With a gas treating capacity of up to 1500 m³/h per PAR unit, the hydrogen concentration can be kept within certain limits even under severe accident conditions.

Technical Features
- Recombiners are composed of catalytic plates, passively inducing a reaction of hydrogen and oxygen
- Energy-independent and control-independent: no supply lines or disposal lines are necessary
- Tested under LOCA and Severe Accident conditions
- Different sizes and inlet flow rates 50 to 1500 m³/h per unit
- High proportion of precious metal content providing important design margins
Passive Autocatalytic Recombiners

**Your benefits at a glance**

- Maintain containment integrity by reducing hydrogen concentration in case of core-melt accident
- Totally passive technology: requires neither operator action nor power supply
- High hydrogen depletion and flow rate of up to 1500 m³/h per unit
- High resistance to possible poisoning of catalyst products (Successfully passed international qualification including fission product test FPT3)

**Licensing / standard compliance:**

- Severe accident qualifications.
- For all types of reactors: Pressurized Water Reactors (PWR) including Russian type VVER, Boiling Water Reactors (BWR), and CANDU plants.
- For BWR, a limited number of recombiners can help to keep the inerted conditions in the containment.
- Can be used in reactor or fuel buildings.

**References:**

Passive Autocatalytic Recombiners (PAR) systems are worldwide installed in more than 100 NPPs of in 17 countries. More than 2000 PAR and 150,000 catalytic plates are manufactured.
Containment Filtering and Venting System

Qualified filtering and venting system for reduced containment pressure.

The challenge
During severe accidents the pressure in the containment can exceed its design pressure. The pressurization of the containment – the last barrier for the radioactivity confinement – has to be reduced while purifying the gases discharged.

The solution
Containment Venting Systems are able to mitigate the consequences of severe accidents by preventing the containment from maximum pressurization. AREVA's solution combines the advantages of dry and wet filters with high loading capacity as well as high retention efficiencies for iodine, small and large aerosols.

Technical Features
- The Containment Venting System developed and qualified by AREVA is double-staged and consists of:
  - High-speed Venturi scrubber: the gas streaming out of the containment is led through conditioned water
  - Hereby the gas are smoothly dispersed and enclosed by water Therefore the radioactive aerosols and iodine are bound and not released
- Filter containment unit: allows to reach a higher separation effect, the off-gases are conducted through a metal fiber filter where residual fine aerosols are retained. Then the filtered off-gases are discharged
- Removal efficiency of > 99.999 % for large aerosols, > 99.99 % for fine aerosols and > 99.9 % for elemental iodine
- Operated at sliding pressure mode close to containment pressure allows compact design
**Containment Filtering and Venting System**

**Widely used technology**

- **Licensing / standard compliance:** Applicable to all kinds of nuclear power plants.

- **References:**
  More than 50 applications in PWR, BWR and PHWR worldwide (Germany, Switzerland, Finland, China, Canada).

<table>
<thead>
<tr>
<th>Design Pressure</th>
<th>-1/10 bar g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Temperature</td>
<td>4/180 °C</td>
</tr>
<tr>
<td>Operating Pressure</td>
<td>0.2 – 6.3 bar g</td>
</tr>
<tr>
<td>Mass flow rate</td>
<td>3.5 – 10 kg/s</td>
</tr>
<tr>
<td>Decay heat</td>
<td>&lt; 200 kW</td>
</tr>
</tbody>
</table>

**Typical system data**

**Easy to install compact design**

**Your benefits at a glance**

- Prevent from excessive containment pressure and contribute to containment integrity
- Provide excellent purification levels of gas discharges
- Easy to install in existing NPPs due to compact design
- High loading capacity
- Mostly passive operation: no electric power required
- Passed international qualification tests
Post-accident Sampling System
PRONAS

Provide precise samples of the containment atmosphere for radioactivity analyses.

The challenge
A precise understanding of the level of radioactivity inside the containment is essential to manage severe accident or loss of coolant accident.

The solution
The AREVA PRONAS System enables representative sampling of containment atmosphere (aerosols, iodine, noble gases). The analysis of the samples will provide details on the containment situation and the core damage state.

Technical Features
- Analysis of the containment gases:
  - Aerosol bound radionuclides
  - Non-aerosol bound (gaseous) iodine isotopes
  - Radioactive noble gases (Xenon & krypton)
- In situ sampling technology
- No loss of accuracy in pipes
- High dilution technology enabling easy handling of the samples
- Gases are diluted in modules and discharged from a sampling box
Your benefits at a glance

- High quality sampling, without significant losses and deposition effects
- Accurate information regarding the radioactivity level in the containment
- Easy handling of the samples thanks to high dilution factor
- Capability to derive the damage state of the reactor

Licensing / standard compliance:
Applicable to all nuclear power plants designs

References:
Installed in 15 German nuclear power plants under construction for one more BWR in Germany and three EPR™s in China and Finland

AREVA NP GmbH
Your contact: plant-studies-germany@areva.com

Licensing / standard compliance:
Applicable to all nuclear power plants designs

References:
Installed in 15 German nuclear power plants under construction for one more BWR in Germany and three EPR™s in China and Finland

Pool sampler

Sampling preparation and dilution module

Your benefits at a glance

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- Easy handling of the samples thanks to high dilution factor
- Capability to derive the damage state of the reactor
Multi-Functional Containment Atmosphere Monitoring System HERMETIS

Monitoring the level of hydrogen, steam and carbon monoxide in the containment in case of severe accident.

The challenge
In case of severe accident, it is required to monitor the level of hydrogen and other combustible gases in order to take the right decisions and maintain the containment integrity.

The solution
The HERMETIS monitoring system has been developed by AREVA to operate in the conditions of core melt accidents. It provides the necessary information for the severe accident management (SAM)/emergency planning:
• released hydrogen quantities
• distribution of hydrogen
• distribution of steam
• containment atmosphere combustion regime (locally)
• potential of hydrogen combustion
• efficiency of hydrogen countermeasures such as recombiners
• occurrence of global convection
• Indication of Molten Core Concrete Interaction (MCCI) / Failure of Reactor Pressure Vessel (RPV)

Technical Features:
• In situ Micro Sampling based on capillary pipe technology
• Superheated micro sample transport and gas analysis to prevent failure of steam analysis caused by condensation effects
• Hydrogen monitoring up to severe accidents (up to 30 vol%)
• Steam measurement (up to 70 vol%)
• Design basis and severe accident qualified hardware
• Determination of hydrogen combustion regime in different containment compartments
• Only fully metallic components in harsh environment
• No operator action required
• Easy maintenance and in-service inspection
• Entire measuring equipment outside containment
• no containment penetration valves required
• Capability for Oxygen monitoring (for BWR)
Multi-Functional Containment Atmosphere Monitoring System HERMETIS

Your benefits at a glance

• Fully qualified combustible gases monitoring for core melt accidents (Only one system for DBA and BDBA)
• Superheating of micro sample enables required accuracy for steam and H₂ measurements
• Monitors the efficiency of combustible gas control systems (Hydrogen reduction and containment mixing)
• Provide information for SAM/emergency planning (for example to maintain inerted containment conditions at high hydrogen concentrations)

Licensing / standard compliance:
All plants

References:
Worldwide references (OL3, TSN 1&2, Kozloduy 3&4)

Key technical data

• Temperature: > 250 °C
• Pressure: < 6.3 bar g
• Radiation: 5000 kGy,
• Measurement Range and Accuracy H₂
  • Range up to 30 vol-%
  • Accuracy 5 % of measurement range
• H₂O (steam) Range-up to 70 vol-%
  Accuracy 5 vol-%
The challenge / introduction
Even under loss of coolant conditions (high temperature, pressure, radiation, humidity), vital I&C connections have to remain operable for process control and monitoring and to support essential functions like reactor protection.

The solution
Together with a leading German cable manufacturer, AREVA manufactures a cable type that has been proven in practical testing to withstand LOCA and post-LOCA conditions. The cable is designed for a minimum lifetime of 60 years.

Applications
The cables are used to transmit signals and measured values in circuits of:
- Centralized process control and reactor protection systems
- Control and regulation systems, e.g. with SIMATIC, ISKAMATIC, TELEPERM® systems
- Power electronics
- Data processing, e.g. with process control computers.

Technical Features:
- Code: ARENOPYR-FRNC-BX
- Max. permissible operating temperature: 90 °C
- Max. temperature during laying, transport and storage: -15 °C to 40 °C
- Solid and stranded conductor types available
- Suitable for harsh environment
- LOCA (long term) and severe accident (mid term) proof
- Applicable for BWR and PWR plants
- Production and operation are continuously complemented by a demanding long-term ongoing qualification program

Test results after the qualification show:
- No significant degradation of initial material properties and performance including LOCA-resistance
- The initial requirements and expectations are fully verified during the qualification
- ARENOPYR cables are insensitive to the extreme loads to be considered in nuclear power plants, such as high temperature, radiation and mechanical stress
LOCA Proof Cable ARENOPYR®

Your benefits at a glance

- ARENOPYR-FRNC-BX allows systems (I&C, measurement...) to:
  - Survive severe accidents (mid term) like the effects of LOCA and post-LOCA conditions
  - Survive temperature and radiation loads caused by long term operation within a Nuclear Power Plant
  - Achieve an operational life time of 60 years minimum
  - AREVA is your full scope solution provider in the field of cabling and connections

References / example of application:
- German Power Plants (e.g. KKP, KKE, KKU; KWG ...)
- Switzerland: Gösgen
- Finland: Olkiluoto 3
- France Flamanville 3
- Argentina: Atucha II
- China: Taishan 1+2

The key benefit is the operating experience of more than 25 years. Additionally ARENOPYR offers the smallest diameter of any cable of this type and the color coding minimizes human error during installation. Therefore, many plants have made it their cable of choice.

Thomas Jäckle, AREVA NP Department Manager for Power Distribution Systems

Licensing / standard compliance:

ARENOPYR-FRNC-BX cables fulfill the following requirements:
- Fire requirements acc. to IEC 60332-3-23
- Halogen requirements acc. to IEC 60754-2-2
- Smoke emission requirements acc. to IEC 61034-2
- Radiation resistance under LOCA (long term) and severe accident (mid term) conditions acc. to AREVA ‘worst case’ specifications

References / example of application:
- German Power Plants (e.g. KKP, KKE, KKU; KWG ...)
- Switzerland: Gösgen
- Finland: Olkiluoto 3
- France Flamanville 3
- Argentina: Atucha II
- China: Taishan 1+2

AREVA NP Electrical Systems offers design and delivery for safe solutions beyond special cables:
- Cable design calculations and selection of suitable types
- Aging free glass-to-metal containment cable penetrations
- Cable trays and tray supports
- Cable raceway planning
- Cable data handling and evaluation with AREVA’s cable data system KADIS
- Complete function chains including junction boxes, wall feedthroughs, etc.

Accelerated aging cable samples mounted on a main cooling pipe. Samples are tested annually to allow long-term cable aging predictions.

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Radiological Emergency Response

Immediate real-time assessment of radiological risk following a nuclear event.

The challenge
In a radiological emergency, equipment is needed close to the scene of the incident to measure contamination to assess and minimize any radiological risk to the public and potential dose to workers and emergency response personnel. Areas must be checked to determine if limits must be placed on how long a worker can stay there. Also, contaminated items and debris must be cleaned and checked to see if they are safe to move from the immediate site. Radiation levels can change frequently, so measurements must be made continuously.

The solution
A comprehensive set of radiation measurement devices specifically designed for the rigors of emergency management. It consists of portable or transportable equipment that can evaluate radiological dose or detect contaminated areas.

Technical Features
• Worker can focus on primary task with assurance of being rapidly warned of radiation hazard change
• Wide dynamic range (up to 5 Sv/hr)
• Measures/displays radiation dose rate/accumulated dose
• Presettable two-level audio, visual and vibrating alarms
• Rugged—operates in extremes of temperature, shock, humidity, dust, immersion and radiation
Your benefits at a glance

- Rugged instruments to assess radiation hazard close to the scene of a radiation emergency
- Easy to deploy
- User-friendly software for data integration
- Reliable and accurate measurements to protect emergency responders and workers at the scene
Post-accident Characterization and Response

Characterization of areas, equipment and articles to ensure safety and prepare for post-accident site work.

The challenge
To quickly and accurately characterize areas and equipment in and around an accident site – preparing for cleanup and release to the public. Map radiation profile of affected areas.

The solution
A comprehensive set of tools designed to locate, isolate and characterize radiation sources. Systems designed for ease-of-use and ease-of-mobility. Highly accurate detection capabilities coupled with unique calibration features for measurement.

Technical Features
- Field portable medium and high resolution gamma spectrometers
- Identify and quantify radionuclide activity
- Long battery life-full day operation between charges
- Fast cool down of HPGe detector (Falcon 5000)
Your benefits at a glance

- Rugged instruments to locate, isolate and characterize radiation sources
- Flexible, allowing for multiple configurations and orientations
- Highly sensitive and accurate
- Information provided quickly or in real-time

Post-accident Characterization and Response

Cartogam

Technical Features
- Real-time acquisition and display of two dimensional picture with gamma-ray source mapping, in one image
- High detection sensitivity, better than 300 nGy/h (30 μRad/h) in under 30 minutes, with dose rate indication of hot spots up to 10 Gy/h (1000 Rad/h)
- Compact, easy decontamination detection head, allowing use in inaccessible contaminated areas

ISOCs

Technical Features
- Accurate identification and quantification classification using high resolution germanium detectors, with shielding
- ISOCs Sourceless detector specific calibrations generated by software as the sample is being counted
- Mobile detector positioning device includes 25 mm and 50 mm collimators and back-shields, and accommodates any orientation

Colibri Intelligent Survey Meter

Technical Features
- Multifunctional gamma dose rate monitor, and simultaneous read-out for multiple alpha/beta/gamma and neutron probes, with continuous display of all read-out channels
- Sophisticated dose and contamination measurement made simple
- Includes data logging/recording and GPS/mapping

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Real-time Continuous Environmental Monitoring

Early detection of nuclear incident – continuous and unattended monitoring during assessment and cleanup activities.

The challenge
It is important to continuously detect and measure releases from a radiological accident into the environment if and when they occur – and to provide early detection and warning of an unexpected incident. Weather has an important effect on the dispersal of the radiation. Once a plume is released, the wind will carry the particles in whichever way it is blowing. The stronger the wind, the further the particles will go. Precipitation also has an effect of concentrating the activity wherever it collects on the ground. Highly reliable continuous monitoring around nuclear sites is necessary to provide early indication of a radiological release and to assure safety of workers and the general public.

The solution
A range of outdoor and indoor devices designed to provide unattended monitoring of alpha/beta and/or gamma radiation in aerosols – monitoring of ambient gamma dose rate.

Technical Features
- Advanced environmental gamma radiation monitor designed to endure the most extreme conditions with unsurpassed accuracy, range and stability
- Unique “Time To Count”, counting technique for extended dynamic range
- IP67 rated aluminum enclosure
- Out of the box performance with open source platform

EcoGamma
Real-time Continuous Environmental Monitoring

Your benefits at a glance

- Highly durable instruments – designed for the environment of installation
- Increased sensitivity and minimal false alarms
- Comprehensive alarming capabilities

ECAM

Technical Features

- Proven design for outdoor monitoring of airborne alpha and beta contamination for the protection of human health
- Durable, weatherproof assembly engineered to survive in harsh environments
- Radon Compensation – algorithm strips radon interference from spectrum to increase sensitivity and minimize false alarms

iCam

Technical Features

- Sophisticated in-plant monitor for alpha/beta aerosol and gamma dose without false alarms due to radon
- Auto-adaptive spectrometric compensation for natural radon/thoron background
- Rugged steel enclosure which provides IP54 environmental protection and EMC screening.
- Comprehensive diagnostic and alarming capabilities
- Stable long-term low level measurements

AM-100 Ratemeter

Technical Features

- In-plant monitoring of ambient Gamma radiation levels
- Color touch screen interface for flexible easy operation
- Highly configurable, multi-input system with local data logging and calculation
- Rapid instrument replacement with instrument detachable from back plate

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Liquid Level Measurement Solutions

Essential measurement for greater safety in case of severe accident

The challenge
The Fukushima accident has highlighted the importance of fuel pools monitoring in case of extreme natural hazard. Several safety authorities have already demanded to install the necessary instrumentation to monitor the fuel pool parameters from the control room in case of occurrence of design-basis phenomena.

The solution
AREVA has evaluated and continues to study the different potential state-of-the-art technologies that can be used in severe conditions for level measurement. Among the multiple options, magnetic floats actuating reed contacts connected to a chain of resistors prove to be particularly robust technologies. In order to match customer’s specific requirements in terms of severe accident management policy, AREVA has developed and is qualifying two solutions depending on the monitoring height requirement.

Key features
Two simple and hardened solution that resist to post-accident conditions

- **Technical solution 1**
  - Max length of measure up to 10 m
  - Max radiation 5 MGy
  - Max Pressure 12 bar
  - Max temperature 156 °C
  - Magnetic floaters in the central tube
  - On-going KTA3505 qualification

- **Technical solution 2**
  - Max length of measure up to 5 m
  - Max radiation 350 kGy
  - Max Pressure 12 bar
  - Max temperature 165 °C
  - On-going RCCE K1 qualification

Very high resistance to radiation: magnetic float moves inside the stilling wells and measuring stem is fixed outside (Solution 1)

Economic and compact design: magnetic float moves along a measuring stem (Solution 2)
Liquid Level Measurement Solutions

**Licensing / standard compliance:**

- Applicable to Spent Fuel pool
- Can be adapted to other tank or sink where level measurement is required

**References:**

- 20-year experience with implementation of level measurement in harsh conditions

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**Your benefits at a glance**

- Knowledge of the level of liquid in the equipments that are vital for safety
- Information available in the control room permitting improved control of the main functions
- Robust technology tested for seismic conditions
- High resistance to radiations matching severe accident requirements
- Passive solution (floaters actuating resistances) that does not require electrical or gazes supply
- Equipment qualification for nuclear plants in the frame of EPR projects
Hardening of Primary System Depressurization

Reinforce the capability of the pressurizer letdown to fulfill severe accident requirements

The challenge
In the extreme case of a core melt-down, it is essential to ensure that such accident does not occur under high pressure in the primary system. It is therefore necessary to open a discharge capacity to depressurize the primary system before reaching core melting conditions.

The solution
Safety and relief valves exist in all PWRs at the top of the pressurizer. However, based on the improvement of valves and valves control in the last decades, the existing depressurization system can be improved to even higher standards. Following a detailed assessment of the mechanical robustness of the existing valves and their electrical supply, a customized upgrade of the depressurization system can be implemented.

Key features
- Assessment of the existing system
  - Evaluation of existing valves: spring safety valves, pilot safety valves, pilot operated relief valves
  - Evaluation of electrical actuators if any
  - Analysis of the qualification files
- Typical Upgrades
  - Replacement of the existing valves
  - I&C modification to allow valve control by the operators
  - Reinforcement of electro magnetic actuators
  - Installation of fail-as-is to ensure the valves remain open after actuation
- Support to licensing

Installation of SEBIM valves at the top of the pressurizer

Installation of valve
Your benefits at a glance

- To improve the capability to open the pressurizer depressurization system before reaching severe accident conditions and avoid “core melting” under high pressure in the primary system
- To improve the capability to maintain open the pressurizer depressurization system during severe accident
- Additionally, in case of design basis conditions, to improve the reliability of the pressurizer depressurization system (“feed and bleed”, operating at low pressure conditions)

References:

- 900 MWe NPP in France (completed)
- 1300 MWe NPP in France (ongoing)
- Koeberg NPP, RSA
- Replacement of spring safety valves by pilot operated safety valves in Korea (Ulchin 1 and 2), Belgium (Doel 1 and 2), Switzerland (Beznau 1 and 2).
3 Prevention of Environmental Damage

Safety Analyses
- Safety Analyses

Safety Upgrades
- Passive Autocatalytic Recombiners
- Containment Filtering and Venting Systems
- Post-accident Sampling System PRONAS
- HERMETIS
- LOCA Proof I&C Cable ARENOPYR®
- Radiological Emergency Response
- Post-accident Characterization and Response
- Real-time Continuous Environment Monitoring
- Liquid Level Measurement Solutions
- Hardening of primary system depressurization

Safety Procedures
- Severe Accident Management Guidelines
  - OSSA
- Nuclear Simulators
- Training for Reactor Operations in Accidental Conditions
Severe Accident Management Guidelines OSSA: Operating Strategies for Severe Accidents

Be prepared to implement the optimal relevant operating strategies in case a severe accident would occur.

The challenge
In case of a severe accident (typically if core temperature would reach 650 °C) the operators and the crisis team must have at their disposal a clear, easy-to-use, non-redundant guideline that will help them stabilize the situation of the reactor while minimizing radioactive releases.

The solution
AREVA can propose to develop a complete integrated OSSA procedure integrating the specificities of the plant. It includes:

- Transition from Emergency Operating Procedures to OSSA
- Implementation of immediate actions
- Continuous assessment of plant conditions
- Identification of candidate strategies and implementation
- Monitoring of plant response

Structure of OSSA Package

- Technical Background Report (TBR) to provide to the technical support team with technical details and justification of severe accidents mitigation
- Support Studies Report to justify the severe accidents mitigation strategies and define the setpoints
- Operating Guidance – to present ergonomically the content of the TBR. It provides:
  - simple diagnostic tool
  - immediate actions and candidate strategies that call for system guide lines (system line-ups and limitations for severe accidents, etc.)
  - other support documents (computational aids, communication sheets, etc.)
- Options: validation of the SAMG, severe accident training of involved teams

Typical OSSA flow-chart

AREVA can also complement existing SAMG to incorporate new requirements, to extend them to the coverage of reactor shut-down states and of fuel damage in the spent fuel pool.
Severe Accident Management Guidelines
OSSA: Operating Strategies for Severe Accidents

Multinational experience

Licensing / standard compliance:
• Compliant with IAEA guides and recommendations
• Licensing of OSSA Flamanville 3 in progress at French safety authority (ASN)

References:
• OSSA Olkiluoto 3 EPR™, Finland
• OSSA Flamanville 3 EPR™, France
• OSSA Taishan 1&2 EPR™, China

Your benefits at a glance
• Avoids potential conflicts between preventive and mitigating strategies thanks to a clear independent OSSA document
• Optimized ergonomics of operating guidelines allows more simple and easier handling of stressful severe accident situations
• Minimizes repetition of system information

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AREVA NP GmbH
Your contact: plant-studies-germany@areva.com
Nuclear Simulators

Simulation tools designed to support severe accident management and facilitate safety demonstration.

The challenge
Simulation technology are widely used by most NPPs to train and license operators using Full Scope Simulators (FSS). As safety authorities become more and more demanding in their requirements to be prepared to manage severe accidents and to demonstrate safety, simulators can help.

The solution
CORYS* has designed or upgraded 30% of the NPPs simulators worldwide. Thanks to this experience, we can maintain and upgrade simulators to optimize their benefits: your FSS can be easily upgraded to simulate severe accident scenarios in real time. Beyond FSS upgrade, engineering simulators can also be developed as a key tool to support the utilities in meeting the safety authorities requirements on plant safety margin assessment.

Technical Features
- Full scope simulator
  - Enhancement of training simulator with SAM (Severe Accident Management) modeling code
  - Compliance to the reference unit
  - Development of crisis management training and SAM procedure validation
- Safety demonstration simulator
  - Integrated Nuclear Engineering simulator interfacing engineering-graded code with I&C models and auxiliary systems
  - On-line calculation and post-processing

* CORYS is a trademark registered by CORYS T.E.S.S, an AREVA (66%) and EDEV (34%) subsidiary
Nuclear Simulators

**Your benefits at a glance**

**Full scope simulators**
- Develop the capability of the operators to handle severe accident
- Validate procedures and improve communication through realistic and life-sized exercise
- Demonstrate the level of preparation of the human resources and equipments towards safety authorities

**Safety demonstration simulators**
- Facilitate safety margin assessment on plant design
- Increase the capability to deliver the safety analysis timely

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**Wide used technology**

Licensing / standard compliance:

ANSI/ANS-3.5

References:

EDF, Electrabel, VVER440 (Eastern Europe), US (70% of upgrades)

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Full Scope Simulator – EPR - Flamanville 3 (France)

Worldwide References
Training for Reactor Operations in Accidental Conditions: PHYSICA, OPERA, ERERA and ULTIMA Programs

Make sure that your staff has received state-of-the-art training on accident prevention, understanding and mitigation.

The challenge
Beyond standard trainings your staff needs to be highly trained to better understand and prevent the risks of accident during outages and operation. In the unlikely case of an accident, they have to master the physics and operational aspects of post-accidental situations.

The solution
As an experienced training provider, Areva can offer several courses to your staff that focus on the physical phenomena, systems interactions, scenario approaches, and risk mitigation in case of accident during operation or shutdown.

PHYSICA
• To understand the accident dynamics of PWRs by studying the physical phenomena and solicited systems interactions during accidental transient conditions in the NSSS.

OPERA
• To identify the main principles related to post-accidental operations of PWRs, including operating procedures.

ERERA
• To understand specifics related to operations of reactors during outages by analysing associated risks identified through lessons learned and specific safety studies.

ULTIMA
• To understand severe accident phenomenology and mitigation strategies applied during scenarios that include core melt.

4 - 5 days trainings taking place in Paris
Theory and practical exercises (use of a simulator for PHYSICA, OPERA and ERERA)
Courses in French and English
Training for Reactor Operations in Accidental Conditions: PHYSICA, OPERA, ERERA and ULTIMA Programs

Strong Expertise and solid references

Our training staff:

We train you using our specially qualified and experienced instructors or recognized experts who have knowledge in all areas of nuclear technology. Our pedagogy is active and most of our theory courses are completed with exercises on our simulator.

References:

Our center in Paris has already delivered over 20 training sessions that welcomed over 200 trainees in 2010 for the PHYSICA, OPERA, ERERA and ULTIMA programs. In total, 1300 employees from the nuclear industry and safety authorities have been trained in our center in 2010.

Our core expertise

Recognized worldwide experts in
- Neutronics,
- Thermohydraulics,
- Systems,
- Safety,
...applied in
- Reactors operations,
- Post-accident management,
- Safety analysis.

Your benefits at a glance

- Interactions with very high-level recognized specialists that will bring in-depth understanding of accident dynamics and management
- Hands-on experience thanks to exercises on a simulator that allow
  - Comprehensive modeling of systems and physics by using recent design codes
  - Practical exercises on different types of PWRs (number of loops, output etc.)
AREVA supplies solutions for power generation with less carbon. Its expertise and unwavering insistence on safety, security, transparency and ethics are setting the standard, and its responsible development is anchored in a process of continuous improvement.

Ranked first in the global nuclear power industry, AREVA’s unique integrated offering to utilities covers every stage of the fuel cycle, nuclear reactor design and construction, and related services. The group is also expanding its operations to renewable energies – wind, solar, bioenergies, hydrogen and storage – to be one of the leaders in this sector worldwide.

With these two major offers, AREVA’s 48,000 employees are helping to supply ever safer, cleaner and more economical energy to the greatest number of people.