ABSTRACT

In the past decades the nuclear option has developed to become a measure to secure the energy supply not only of the established nuclear nations, but also of newly embarking or smaller countries without significant nuclear experience. In these small countries cooperation may work cross-border between countries or cross-corporate between manufacturers and/or utilities.

Experiences gathered in all phases of a nuclear project have to be applied on all levels to support the construction of absolutely safe and safe operation of nuclear reactors. Since the time span between decision-making for building, the licensing procedure, the detailed planning, the construction phase and commissioning can amount to several years, this leads to the urgent requirement of having to incorporate the constant experience gain on all technical and administrative levels. This has to be taken into account for the safety-related boundary conditions in the frame of a new build project as well as for any kind of updating measures for existing plants. Often neglected is the fact that this also applies to the choice of the guidelines to put into effect, to an efficient and competent authority and utility body and the integration of adequate technical specialists. Utilities face different requirements depending on whether they are situated in the country of responsible nuclear power plant utilities’ HQs or whether they are merely co-owners of a foreign plant. All these matters profit from resorting to the knowledge pool from operational experiences and experiences gained in new build projects.

AREVA serves the whole nuclear cycling including plant construction and supports its partners in all project phases, even in the development of national institutions and knowledge transfer. Any AREVA knowledge, as recent it may be, is introduced directly into corresponding application fields.

Special attention is drawn to the matter of the resulting operational experience feedback derived from events in nuclear power plants all over the world. The key is learning from mistakes made by others. By quickly adapting improvements can be implemented early in the planning stage of new build projects while at the same time defects and malfunctions in operating plants can be avoided effectively. This means the originally AREVA-internal experience
feedback grew to become a knowledge pool available to all our customers. Especially smaller or embarking countries take advantage of this offer to a greater extent since they still lack knowledge. AREVA performs the operational experience feedback for its own product portfolio, in the frame of know-how and know-why transfers and long-term stipulations with customers.

The focus of the following discussion lays on the presentation of the AREVA-internal experience gain and its benefit for our customers in daily business, e.g. by stipulations.

1 CONTENT OF THE OEF FOR THE VGB POWERTECH

The necessity for a controlled operation experience feedback as foundation for the improvement of the operational mode of a plant and for further development of components is not generally a new revelation and has always been applied in plant engineering. In nuclear engineering some essential documents on this topic exist, which deal with this special subject ([1] to [4]). Further aspects for, for instance, embarking nuclear countries are enfolded in [4] and [5], too.

By the way, in the following it is not distinguished between internal and external regulations concerning the operational experience feedback. All the processes appointed at AREVA in the frame of the operational experience feedback are defined in the frame of the contractually regulated external orders. As far as internal steps are necessary they are described in the frame of the correspondingly described order/project. In a “living” organism such a distinction in looking at the whole is not wise.

End of the 80’s the utilities of the German nuclear power plants decided together with the Siemens AG on a contract about operational experience feedback from the German nuclear installations’ operation to take better advantage of the existing resources. The contract was closed with the umbrella organization of all conventional and nuclear utilities, the VGB PowerTech (Technical Association of power and heat generators), on the one hand and the Siemens AG on the other.

Since foreign companies can join the VGB PowerTech, the operational experience feedback of Siemens plants from abroad was able to be included. The inclusion of external installations could be imaginable, too.

The evaluation of events even helps to maintain and even further improve the unquestionable high safety level of German plants. The evaluation of experience in the nuclear industry doesn’t only start in case of damage events (“accident”) but already deliberately in the run-up with the two premises:

a) Examination of “preliminary events” of potential accidents, i.e. of incidents, where additional failures or unfavorable boundary conditions could have led to the requirement of safety installations and an accident.

b) Examination of such disturbances and derogations in safety installations, which in case of a simultaneous requisition for the safety installations degrade their efficiency too much and could lead to only insufficient accident handling.

Therefore the objective of the systematic experience evaluation is:

- for a), to avoid such conditions and activities possibly leading to such an accident more reliably,

- for b), to superiorly secure the functionality of safety installations to be able to handle possibly unfolding events, which emerge in spite of the precautions according to a), even more reliably.

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The concept of operational experience feedback emanates from the following idea:

„One cannot only learn from one’s own mistakes,
but also from mistakes made by others.”

Apart from these primary goals of operational experience feedback more aspects derive which have positive effects in the further life cycle of a nuclear installation:

c) Identification of operational weaknesses without safety-technical relevance, which lead to the further development of the applied procedures and technologies (Increase in efficiency via better availability and lower error-proneness)

d) Further development of new measuring methods and technologies in the frame of R&D projects with following testing and qualification for the application in the power plant

In the frame of the 2001 company foundation of the Framatome ANP as joint subsidiary of Siemens Nuclear Power (SNP) and the French company Framatome, a subsidiary of the French Areva, the contract for operational experience feedback was transferred into Framatome ANP. On May 1, 2006 within the framework of the incorporation into the AREVA conglomerate, Framatom ANP was renamed to Areva NP with the German subsidiary AREVA NP GmbH. The AREVA NP GmbH has ever since been the contractual partner of the VGB PowerTech for the operational experience feedback from nuclear installations.

AREVA NP Germany is currently analyzing occurring national and international events regarding their relevance for more than 20 European nuclear power plants and, since 2003, Brazilian Angra 2. This enfold following nuclear plant types:

- 17 PWR-plants (13 in Germany, 3 in the rest of Europe, 1 in Brazil) and
- 6 BWR-plants (all in Germany).
Discussions about an expansion of this plant-specific operational experience feedback took place since the middle of the first decade of the 21st century. The prompt global information supply via media and international organizations following events in nuclear installations required the installation of a “warning system”, which allowed the German utilities to react to international events at short notice. AREVA NP was assigned by VGB PowerTech in 2006 to install a Clearing system that allows for evaluating international events regarding their transferability to German plants in next to no time at all. The IAEA NEWS database was defined as basis. All events equal or higher INES Level 1 listed in the database are to be evaluated. As far as transferability – even if it is just partly – is given, a quick evaluation of the event is performed in just a few days’ time, if necessary followed by an in-depth analysis.

Figure 3: Proceeding contract for international reports

The AREVA staff directly responsible for the operation experience feedback consists of a little group of experienced engineers, who on the one hand have to deal with the adminis-
Operational time and effort of such a system, and on the other hand need to be acquainted with the organization. In the frame of the operation experience feedback this group has access to the whole organization of AREVA NP Germany. Thereby an efficient processing of activities is secured and the ever renewing and constantly developed know how of the whole company is used. If the daily project work and requirements made by the operation experience feedback group conflict with each other, the timely limited legwork for the operation experience feedback group has priority. This is part of the living safety culture practice at AREVA NP and is implemented into the whole organization by respective regulations of the management.

Figure 4: Organisation und course of action of operational experience feedback

2 OPERATIONAL EXPERIENCE FEEDBACK FROM NEW BUILD PROJECTS

Apart from regulations for the operational experience feedback of German plants in operation similar regulations exist in the running new build projects to consider current findings during the construction of new builds. These procedures even more important, since direct influence on design, construction and building phases can be exerted, since the boundary condition of having to consider radiation does not exist at the beginning of the nuclear startup.

In the course of the operational experience feedback the incoming information from international databases and the partners involved in the project is evaluated and sent back to the partners containing an evaluation of the events. In the operational experience feedback framework findings from examinations of the experience feedback of running plants is considered, too.
Figure 5: Operational experience feedback in new build projects

The OEF procedure for new plants considers the different phases of a new build project from the Basic Design and Detailed Design phase up to the construction and installation phase. All the involved people and contractual partners from the licensing procedure are integrated, no matter whether design, manufacturing, construction, erection or the operation of the new plant is concerned. The events to be examined (INES Level 1 and higher) are examined regarding these relevant questions:

- What happened
- How did it happen
- Why did it happen and why couldn’t it be prevented
- What could have happened
- Which countermeasures can be derived

Presently, in the AREVA NP Plants Sector a variety of Lessons Learned processes and tools are implemented. To improve the Lessons Learned process world-wide, unified principles were implemented for all activities: bids, project management, engineering issues, construction and commissioning, for large projects as well as recurrent business.
Therefore specific tools are established to record and to process the implementation of the feedback. Various evaluation systems have been combined to form an information feedback system (RIS – “Rück-Informationssystem”) more than 20 years ago back when the German Konvoi-plants were built. RIS is an integral part of the quality management system and makes a major contribution toward fulfilling Element 14 of DIN ISO 9001. This element requires the establishment of procedures for corrective action.

Figure 6: RIS Information Feedback System Overview

RIS evaluates events affecting the entire power plant, as well as those limited to individual plant components. The main RIS modules are:

- BASEM (site experience reports)
- BEM (operating experience reports)

The BASEM and BEM modules record and process events covering various engineering fields. These events are defined in the documentation and are usually of particular importance to the operation of the whole plant.

In RIS, all of the main event characteristics are stored centrally in edited form, amongst the results of the evaluations, thus enabling further in-depth analyses. Detailed component-specific information is kept up-to-date by the departments locally responsible for each technical field. These departments also compile detailed information on other power plant components (e.g. steam generators, fuel assemblies, electronics).

Site Experience Reports (BASEM)

The BASEM module handles product-specific work processes and organizational structures at construction sites, and encompasses the civil, mechanical, electrical, and I&C
engineering aspects of the power plant. The site experience reports are documented centrally in RIS, and then routed to the process owners at the manufacturing plants, engineering departments, and sales & marketing departments. A BASEM data record is prepared for each report. An important step is the dialogue between the construction and commissioning personnel and the departments responsible for the civil, mechanical, electrical, and I&C engineering. During these regularly scheduled meetings, site experiences are evaluated from a technical and engineering viewpoint. Based on these meetings, the engineering departments independently implement the necessary measures at plants under construction including OL3 unit and in future EPR projects.

The BASEM data base today contains more than 9000 records from nuclear power plants.

Operational Experience Reports (BEM)

The safety philosophy and the licensing procedures of nuclear power plants are mainly based on the prior mathematical analysis of possible incidents and accidents, and hence are very preventive by nature. Since this way an extremely high safety standard is achieved, experience gained in such plants around the world is extremely valuable. The evaluation of these experiences is therefore a significant source of information for systematically improving the safety and availability of nuclear power plants. The dedicated so-called BEM module is described under topic 1. In spite of the large variety of information sources utilized by the BEM data base, RIS can identify different reports on the same event, indicating this by means of cross-references. This feature permits in-depth research and analysis of the entire data base.

Central Reliability and Events Database ZEDB

The systematic analysis of the probability of failure is an essential basis of nuclear safety. It is important to know the fault cause and the rate of failure of the technical equipment (for example pumps, fittings, switches and motors) for precise analyses in order to gather this data in a statistically analyzable form.

To accurately collect and analyze such information from the feedback of operational experience, the VGB PowerTech has set up a Centralized Reliability and Events Database (ZEDB - Zentrale Zuverlässigkeits- und Ereignisdatenbank). Areva NP is operating this database and performs periodic data evaluations. This database contains the histories of safety-related components in nuclear power plants, which comprise records on events and operational experiences, the design data, the results of in-service inspections and the operating conditions important to the components.

The information is presently collected for all German NPP, NPP Borssele (Netherlands) and NPP Gösgen-Däniken (Switzerland). This means a total 21 NPP representing a huge amount of operational experience.

The database includes 16 types of various components, which are systematically screened for possible operational experience, e.g. Valves, Pumps, Tanks, Batteries, Transformers, Circuit breakers, Emergency power supplies, Heat exchangers and Fans/Compressors. The total number of components in the database amounts to over 17,600 with currently more than 245,000 operation years.

Thus, ZEDB provides a valuable feedback of operational experience that can be used as an important and reliable basis for probabilistic safety analyses and also for the design of new power plants.

Feedback from Areva NP SAS

Within Areva NP SAS a dedicated organization gathers and analyses all the information regarding feedback of experience concerning technical subjects. The information is collected from the following sources:
• Framatome Owners Group (FROG)
• Network connection between EDF and Areva NP SAS
• The database of the American Institute of Nuclear Power Operations (INPO)
• Utilization of IAEA & OECD publications
• Usage of generic investigations results provided by Areva NP and EDF for special cases.
• Internal information in Areva NP coming, in particular, from the construction sites, and Nuclear Services Operations.

For issues concerning EDF on specific problems, "Working Groups" are organized with the objective of information exchange and definition of actions to be undertaken. The information is periodically issued to the concerned technical departments for further extensive analysis and application on new or already in-service NPPs. The overall process is summarized diagrammatically in Fig. 6.

3 DEVELOPMENT OF THE OPERATIONAL EXPERIENCE FEEDBACK

Nuclear energy is currently experiencing a renaissance beyond comparison. The discussion on reducing greenhouse gas emissions, the low electricity producing costs of NPPs while energy consumption, especially electricity, is growing, and not to forget the safe accident-free operation of the NPPs in the last decades have led to a rethinking throughout the world.

This large nuclear expansion cannot be done by one vendor on its own, i.e. in the future a multitude of different reactor types are going to be in operation. This has the following implications for the area of operational experience feedback:

a) on the one side there will be an increased demand for personnel with deeper knowledge of external installations

b) on the other side a more intensive operational experience feedback of the nuclear industry with itself and with authorities and expertes has to be performed.

To make this work all levels of the society have to rethink. The tense situation between industry and authorities, which exists in Germany because of political reasons, has to be broken up and an open discussion about technologies has to be possible again. Therefore the media has to acknowledge their own responsibility. Matter-of-factly – of course also critical – reporting is necessary, but no ideological fight.

Many cooperations and mutual support between embarking countries and established nuclear countries are a step in this direction. These cooperations allow the directed build-up of authorities, legislative proposals and technical support by boards and specialists on the authorities’ side and the implementation of the structural organization and operational structuring on the utilities’ side.
An essential point hereunto is the creation of the organization for the operational experience feedback on the authorities’ and utilities’ side. The operational experience feedback as part of the practiced safety culture has to be taken into account already in the first phases of a nuclear project to be applied widely and efficiently. Authorities and utilities, analogically to the procedures of the vendors of new plants, have to build up organizational structures, which deal with the topic of operational experience feedback from commercial operation of the NPP onwards.

4 EXAMPLES FOR FEEDBACK FROM OEF

Chapter 2 allows the conclusion, that the systems for operational experience feedback existing at AREVA and its partners work together closely via organizational interfaces and foster each other. In the following this mutual fertilization shall be explained in greater detail with the help of two technical examples. With the help of these examples the future developments described in chapter 3 become visible.

4.1 Example Sump clogging

Findings and events lead to the classification of the sump clogging matter as a generic safety question (GSI-191) already early in the 80’s in the United States. In particular for American plants numerous INPO/WANO reports and reports from the utilities exist up until recently. Thus there are significantly more than 10 IRS reports since the end of the 1980’s, especially mentioning the IRS 7258 from June 9, 2004.

Furthermore several bulletins and generic letters from the NRC and international publications (reports, congress materials, etc.) exist on this topic.

With the VGB order to Siemens KWU in 2000 based on the experience evaluations and particularly under consideration of the status report (NEA/CSNI (95)11), which the NRC created for the OECD, a testing program was developed with the following characteristics:

- Alignment of the examinations to the specific boundary conditions of Siemens PWRs (to avoid too big complexity of the examinations)
- Examination of effects in integral tests, which are as akin to the actual plants themselves as possible, to model the interaction of physical effects (due to the finding, that
single effect tests in some cases do not consider significant interactions between physical and chemical effects)

![Diagram of test procedures and measures](image)

**Figure 8: Concept of the tests for the secured sump suction**

The findings gathered until today and the iteratively further deepened tests have created a essentially different level of knowledge compared to the level of knowledge during the construction of the running plants.

The experience feedback/knowledge gain from the tests led to a series of measures in German plants:

- Optimization Insulation material concept, i.e. Elimination of problematic combinations of fibrously and/or particulate fragmenting insulation material types (all PWRs and BWRs)
- Reduction of the aperture size of the sump sieves from 9 mm to 2 mm (PWR), partly finer perforated plates (BWR)
- Increasing of the aperture area in some cases (5 PWR, in part BWRs)
- Introduction of procedures and measures to follow the differential pressure development over the sump sieves and to the eventually required removal of an allocation diminishing the flow rate, e.g. by back-flushing

It was possible with the measures, which where developed based on the inspection program ordered by the VGB, to provide a new and secured basis for the functioning of the sump circulation after loss of coolant accidents.

The knowledge gained from the worldwide examinations was simultaneously introduced into the planning of the current new plants. Thus the aperture size in Olkiluoto 3 was 2 mm in combination with a construction-conditioned very large aperture area. The current findings lead to changes in Flamanville 3, too, where the sump sieves are adapted as well.

### 4.2 Example: Voltage transients following the transition to house load operation for German NPPs (Forsmark 1 and Olkiluoto 1 events)

The event in Forsmark 1 led to a general examination of the whole electrical and I&C installations of the German nuclear power plants performed by a work group led by VGB
PowerTech, in which AREVA NP was represented, too, regarding the robustness of the plants against recurrent stress transients. Goal of the work group was to check the robustness of the plants against occurring load transients and identify optimization potential. Due to the complexity of the undertaking the work group chose an approach which was rather unusual to date, at least if seen from the German point of view. Resulting from this interconnection is the 4-column-model explained further below.

Following the incidents at Forsmark–I (in Sweden) in July 2006 and Olkiluoto–I (in Finland) in May 2008 the important question arouses regarding the robustness of electrical components/systems against overvoltage transients. According to national safety rules and standards the boundary conditions (e.g. voltage amplitude) for sufficient robustness may be slightly different. In any case the requirements are supposed to be in reasonable balance with the probability of the postulated transient. In order to determine such requirements a probabilistic assessment was carried out for German NPPs.

In preparation for the probabilistic assessment some aspects have been considered. Considering voltage transients challenging the robustness of plant power supply systems/components had to be answered.

A fully excited generator which is switched off from the grid and reconnected to the internal plant power supply in one single moment has the most challenging potential for voltage transients. This statement can be derived from generator diagrams. With simulations the corresponding voltage dynamics can be found. Four barriers can be identified for voltage limitation:

- Voltage Control (1st Barrier)
- Voltage Protection (in German NPPs part of the Unit Protection, 2nd Barrier)
- Turbine Control (3rd Barrier)
- Turbine Protection (4th Barrier)

The four–barrier–defence–in–depth–system can be suitably presented in a “4–column–model”.

![Figure 9: Defence–in–Depth of Electrical Systems: 4 Successive Barriers and Acting Facilities](image)

The only single failure resulting in a voltage transient is the voltage control failure. The failure of all but one barrier has no consequence. If Voltage Control fails the Voltage Protec-
tion limits the transient with Generator Breaker opening and Generator De–Excitation (divers Voltage Protection actions!). Whereas when both fail the turbine will accelerate and the voltage will increase respectively. Following up is the Turbine Control acting on the Turbine Control Valves. For a generic analysis the only option to assume conservative values close to the Turbine Protection threshold. The fourth and last Barrier is the Turbine Protection, limiting the rpm. Uncertainties result in a theoretical voltage amplitude including sufficient tolerance margins.

The 4–Column–model was used for a probabilistic assessment to determine the frequency of successive Barrier failures. The method used was the event tree analysis using a database accepted in Germany for determining the branching probabilities. The database consists of a collection of reported component failures in nuclear energy.

Table 1: results of the 4-column-model

<table>
<thead>
<tr>
<th>Results failure postulates</th>
<th>Peak voltage [% rel. to U₀]</th>
<th>Duration [s]</th>
<th>Event Frequency [1/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td>no single failure</td>
<td>~ 131</td>
<td>&lt; 2</td>
<td>10⁻²</td>
</tr>
<tr>
<td>voltage control</td>
<td>&lt; 140</td>
<td>&lt; 2</td>
<td>2*10⁻⁶</td>
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<tr>
<td>voltage protection</td>
<td>&lt; 159</td>
<td>&gt; 8</td>
<td>3,11*10⁻⁷</td>
</tr>
<tr>
<td>turbine control</td>
<td>~ 160</td>
<td>&gt; 8</td>
<td>2,05*10⁻⁹</td>
</tr>
</tbody>
</table>

Table 2: Component failure and initiating event

<table>
<thead>
<tr>
<th>Initiating event</th>
<th>Initiating event component failure</th>
<th>a) No single failure</th>
<th>b) High vol. power breaker</th>
<th>c) Generator breaker</th>
<th>d) Plant Supply Connection Breaker</th>
<th>e) Main transformer on load tap changer</th>
<th>f) Plant load tap changer</th>
<th>g) Emergency breaker</th>
<th>h) Over voltage protection</th>
<th>i) Buchholz protection</th>
<th>j) Low frequency protection</th>
<th>k) Low excitation protection</th>
<th>l) Power system stabilizer</th>
<th>m) Loss of synchronous protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Low line voltage circuit</td>
<td>1a</td>
<td>1b</td>
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<td>2) High line voltage</td>
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<td>3) Low line frequency</td>
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<td>4) High line frequency</td>
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<td>5) Oscillation in the power grid</td>
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<tr>
<td>6) Generator rotor short-to-ground circuit</td>
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<tr>
<td>7) Oscillation attenuation device acts towards high voltage</td>
<td>7a</td>
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<tr>
<td>8) Oscillation attenuation device acts towards low voltage</td>
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<td>9) Short circuit in main transformer coil</td>
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<td>10) Short circuit in plant supply transformer coil</td>
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<td>11) Short circuit in plant supply transformer coil</td>
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The probabilistic assessment stated that the generic approach often demanded the assumption of very conservative failure rates. Consequently the failure of 2 or more barriers is very unlikely. Barrier 1 and 2 are sufficiently divers and have different acting mechanisms. So the found voltage amplitude can be seen as a reasonable boundary condition for the verification of sufficient robustness. Maybe some conservatism should be included into the device testing procedures. With respect to the result of the voltage amplitude (Barrier 3/4 successful), the demonstration of robustness at this voltage amplitude will be on the safe side.

Parallel to the generic investigations of the VGB-workgroup the consequences of the events of F 1 and OL 1 were checked for the new plant OL 3. A covering load transient was identified and especially the selectivity of the electrical installations among each other was examined. Therefore the findings of the workgroup could be integrated directly into the ongoing new build project.

5 CONCLUSION

The operation experience feedback procedure performed by AREVA NP has proved itself during the last 20 years and has led to a series of improvements and thus an increase of the safety standards of the German nuclear power plants.

During planning and building of new plants like e.g. OL3 the results of this operation experience feedback are directly applied to all project phases. In addition new build projects partly take into account information sources and cooperative activities with other organizations and our partners for the specific needs of the respective project phase. Thereby a steady information exchange and operation experience feedback on all levels is ensured. In particular the countries with low experience in the nuclear business benefit from the experience of the rest of the nuclear society. Insofar an active participation of embarking countries in the operation experience feedback leads to competency gain on the embarking side and the implementation of a strong safety culture.

6 REFERENCES


