2. SUMMARY OF THE WORKSHOP ROBUSTNESS OF ELECTRICAL SYSTEMS

The workshop included an opening session, seven sessions with participant presentations followed by short discussions, and a facilitated discussion session. The contributions presented were devoted to discussions of national post-Fukushima regulatory programme developments, methods to determine allowable coping time for electric power recovery, electric power system simulation methods development and benchmarking efforts, analysis of component capability, and approaches to facilitate electric power system recovery from extended loss of AC power.

2.1 Opening Session

The workshop was opened by the ROBELSYS Workshop Chair, Pascal REGNIER (IRSN). A keynote presentation was then held by Jacques REPUSSARD, IRSN Director General reminding the participants of the importance of improved understanding of the role of electric power and defence against external events in assuring nuclear safety in the world's operating NPPs. John BICKEL, the DIDELSYS Working Group Chair, briefly discussed the history of the CSNI sponsored DIDELSYS Project which originated as a follow-up investigation to the 2006 switchyard fault at Forsmark plant in Sweden. The scope of the DIDELSYS project did not include consideration of external events such as earthquakes, tsunamis, or floods – and this required expansion in light of the experience at Fukushima Daiichi.

2.2 Session 1 - National Programmes on Evolution of Onsite and Offsite Electric Power Systems

This session was devoted to the programmes that many countries have engaged at the national level to strengthen the robustness of either onsite or offsite electrical power systems in NPPs.

The following papers were presented:

- TEMPORARY AND LONG TERM DESIGN PROVISIONS TAKEN ON THE FRENCH NPP FLEET TO COPE WITH EXTENDED STATION BLACK OUT IN CASE OF RARE AND SEVERE EXTERNAL EVENTS, *Patricia DUPUY, Carine DELAFOND, Alexandre DUBOIS (IRSN, France)*

- ELECTRICAL SYSTEM DESIGN APPLICATIONS ON JAPANESE BWR PLANTS IN THE LIGHT OF THE FUKUSHIMA ACCIDENT AND HITACHI EXPERIENCE OF THE SOLID STATE POWER EQUIPMENT IN JAPANESE BWR, *Masashi SUGIYAMA* (HITACHI, Japan)

- ELECTRIC POWER SUPPLY OF GERMAN NPPS: DEFENCE IN DEPTH, PROTECTION AGAINST EXTERNAL HAZARDS AND RETROFITTING AS A CONSEQUENCE OF THE FUKUSHIMA ACCIDENT, *Sebastian A. MEISS* (BfS, Germany), Robert ARIANS (GRS, Germany)

- ELECTRICAL SYSTEMS AT LAGUNA VERDE NUCLEAR POWER PLANT (LVNPP) AFTER THE FUKUSHIMA EVENT, *José Francisco LÓPEZ JIMÉNEZ* (CNSNS, Mexico)

- STATUS OF THE REVIEW OF ELECTRIC ITEMS IN SPAIN RELATED TO THE POST-FUKUSHIMA STRESS TEST PROGRAMME, *Manuel R. MARTINEZ MORENO and Alfonso PEREZ RODRIGUEZ* (CSN, Spain)

- EVOLUTION OF ONSITE AND OFFSITE POWER SYSTEMS IN US NUCLEAR POWER PLANTS, *Gurcharan MATHARU* (NRC, USA)

Many presenters described the electrical arrangements on their sites before the events and how they have been enhanced. They described the use of hardened structures to provide resilience for equipment against specific hazards. Others discussed the revision of national safety guidelines for essential systems to increase redundancy and segregation.

Amongst the various presentations the following common themes have emerged:

- European presenters talked about their activities in the EU Council Stress Test process, while those from outside Europe also described how they had taken the format and applied it to understand the 'Robustness' of their plants to extreme events.
- There is an increased acceptance that plants should have mechanisms to cope with extreme hazards that are well beyond the design basis.
- The general approach is that this should be achieved through supplemental mobile equipment
- Many speakers talked about enhancing battery autonomy through either upgrading battery systems and/or through load shedding.
- Key regulations applied by the U.S. Nuclear Regulatory Commission, i.e., United States Code of Federal Regulation 10 CFR Part 50 and its associated Regulatory Guides, are used by many countries. . It is not clear how the respective countries have considered their suitability in their country or for their own regulatory regime.
- There was a general consensus that installed backup equipment to mitigate a specific design basis, such as flooding or seismic, should be resilient against the design basis event plus a suitable margin. Furthermore, that margin needs to be based on individual plant knowledge and judgment. This could be considered as Design Extension improvements.

Regarding the differences between national approaches, various speakers discussed the use of onsite hardened facilities to store supplemental emergency equipment. Other speakers described the use of offsite locations, using distance as a mitigation to the hazard and to minimize the occurrence of common cause failures.

It was also observed that the various speakers used the phrases: Loss of offsite power (LOOP), Station Blackout (SBO) and "extended SBO" with different meanings which would deserve some reflections and possibly harmonization in order to prevent confusions and misunderstandings.

It was noted that France, UK and USA are implementing rapid response teams with cached supplies (portable generators, quick connect cables, fuel and compressed nitrogen supplies) that can be deployed to bring offsite support in the case of an emergency.

At the end of the discussion, it was noted that while speakers talked about providing additional permanent or temporary generators there was little information on any enhancements being made to "switchboards" or the rest of the electrical infrastructure that could be the weak points in case of beyond design events.

It was also unclear how DC system load shedding would be achieved in practice especially where personnel switching was required.

Recommendations:

- Plants should have mechanisms to cope with extreme hazards that are well beyond the design basis.
- Enhancing battery autonomy through either upgrading battery systems and/or through load shedding should be considered.
- The meaning of the phrases "LOOP", "SBO" and "extended SBO" should be harmonised.
- Enhancement of the robustness of electrical systems in NPPs should not solely focus on additional generators but also consider enhancement on switchboards and on the rest of the electrical infrastructure.

2.3 Session 2 - Role of Electric Power in Severe Accident Management

This session was devoted to the role which electric power plays in the prevention of severe accidents for different reactor types, and the time available to recover electric power to prevent different levels of severe accidents.

The following papers were presented:

- IMPLICATIONS OF EXTENSION OF STATION BLACKOUT COPING CAPABILITY ON NUCLEAR POWER PLANT SAFETY, *Andrija VOLKANOVSKI* (JSI, Slovenia)

- DC LEAD ACID BATTERIES IN NPP, PRESENT AND FUTURE SOLUTIONS, *Gery BONDUELLE* (ENERSYS, Sweden)

- CH-SOLUTIONS FOR PROVIDING ELECTRICAL POWER IN CASES OF LONG TERM BLACK OUT OF THE GRID, Franz ALTKIND, *Daniel SCHMID* (ENSI, Switzerland)

- STRENGTHENING THE FIRST LINE OF DEFENCE: KEEP TURBINE RUNNING AT SCRAM, *Marcel VAN BERLO* (KFD, The Netherlands)

Based on a US assessment during the last three years, six of the seven most important accident sequence precursors in US NPPs were caused by multiple electrical related failures. Improving existing electrical systems to prevent severe accidents may be even more important to improve the overall robustness of electrical systems than to install additional systems to mitigate severe accidents

The vulnerability of the grid was illustrated by pictures of the damage done to the 400kV grid by an ice storm last winter in Slovenia. An extra 400kV line that was recently installed prevented the LOOP for the Krsko plant.

The use of probabilistic safety analysis (PSA) was presented to evaluate a solution for improving safety by adding diesel generators and/or batteries under some consideration of diversity.

Electrical batteries are important for addressing the coping time in SBO condition. An overview of different types of batteries with their pros and cons was given. Today, lead acid type still seems to be the most reliable technology. More information on common cause failures of batteries can be found on the NEA website: ICDE PROJECT REPORT: COLLECTION AND ANALYSIS OF COMMON-CAUSE FAILURES OF BATTERIES, September 2003, NEA/CSNI/R(2003)19.

Although not presented during the workshop, the Swiss paper described their 7 layers of defence in depth of electrical power supply. The last layer consists of mobile generators available at a central storage. Procedures are in place allowing shift operators to operate the ultimate emergency equipment.

A proposal was made to use the turbine and main generator after scram (when connected to the grid) with an adapted pressure control system instead of dumping the steam to the condenser and/or the atmosphere. This could possibly lead to a smoothing of the transient and the use of auxiliary feed water and diesel generator power supply could be delayed. This proposal led to a lot of discussion where most of participants disagreed based on fundamental safety considerations.

Recommendations:

- Given the evolution of battery technology it could be worthwhile to explore the reliability and robustness of new battery designs. The ICDE project report is covering the period up to the year 2000 and could be updated.
- Further investigation on the use of PSA to improve insights in the role of different electrical power sources in reduction of core damage frequency (CDF) or mitigation of severe accidents.
- Further investigation to determine the available coping time in case of SBO to know the time in which critical functions are to be restored to prevent a severe accident.

2.4 Session 3 - Requirements for Robustness of Onsite Electric Power Systems

This session was devoted to the postulated environmental conditions due to extreme external events, for example, seismic aftershocks, continuous ice storm, continuous flooding, and so on, which should be considered in the specifications of the countermeasures or robustness.

The following papers were presented:

- ELECTRICAL SYSTEM'S DESIGN APPLICATIONS ON JAPANESE PWR PLANTS IN LIGHT OF THE FUKUSHIMA ACCIDENT, *Tsutomu NOMOTO* (MHI, Japan)
- EFFECTS OF COMMON CAUSE FAILURE ON ELECTRICAL SYSTEMS, *Kevin PEPPER* (ONR, UK)
- A SURVEY OF THE HAZARDS TO ELECTRICAL POWER SYSTEMS, *Gary JOHNSON* (USA)

- MODERNIZATION OF UNIT 2 – MAIN OBJECTIVES, EXPERIENCE FROM DESIGN, SEPARATION OF OPERATIONAL AND NUCLEAR SAFETY EQUIPMENT – LESSONS LEARNED, *Salah KANAAN* (E.ON/OKG, Sweden)

- RCC-E A DESIGN CODE FOR I&C AND ELECTRICAL SYSTEMS, *Jean-Michel HAURE* (EDF, France)

- OVERALL STRATEGY AND ARCHITECTURE FOR POST-FUKUSHIMA-MITIGATION AND MITIGATION ON OTHER EVENTS IN THE ELECTRICAL SYSTEM, *Waldemar GEISSLER* (AREVA, Germany)

- COMPARISON BETWEEN DIFFERENT POWER SOURCES FOR EMERGENCY POWER SUPPLY AT NUCLEAR POWER PLANTS, *Magnus LENASSON* (Solvina/AB/Sweden)

- ADVANCING RUGGEDNESS OF NUCLEAR STATIONS BY EXPANDING DEFENCE IN DEPTH IN CRITICAL AREAS, *Thomas KOSHY* (IAEA)

The purpose of this session was to share the technical information relevant for requirements on equipment, components or systems which are established or planned to be established as countermeasures for an SBO.

In addition, it was intended as an opportunity to share lessons learned from several electrical failures in past.

The most significant discussions in this session were the following:

– How to establish the requirements against beyond design basis external events (e.g. flooding, seismic, ice storm)
– Necessity of diversity for the electrical distribution system
– Safety and qualification requirements to the SBO countermeasure systems
– Continuous discussion and information sharing on the one/two-open-phase issue.

Recommendations

Through the discussion, it was found that there are still undefined areas related to electrical systems. It will be very beneficial for all members to continue sharing the information on following items:

- Requirements for addressing beyond design basis external events
- Scope of diversity in electrical systems
- Qualification requirements to systems used to cope with AC station blackout
- Asymmetric 3-phase faults (one/two-open-phase issue).

2.5 Session 4 - Simulation of Transients within NPP Plant Distribution Systems

This session was devoted to the methods and simulation tools used to predict the performance of components and systems in NPP electrical distribution systems and their ability to withstand internal and external hazards that challenge the ability to maintain safety margins.

The following papers were presented:

- VERIFICATION OF SIMULATION TOOLS, *Thierry RICHARD* (EDF, France)
- STANDARD PROCEDURE FOR GRID INTERACTION ANALYSIS, *Bertil SVENSSON*, *Sture LINDAHL*, *Daniel KARLSSON* (Gothia Power AB, Sweden), *Jonas JÖNSSON*, *Fredrik HEYMAN* (OKG AB, Sweden)
- ELECTRICAL DYNAMIC SIMULATION ACTIVITIES IN FORSMARK, *Per LAMELL* (Vattenfall, Sweden)
- INTRODUCTION OF ELECTRICAL SYSTEM SIMULATION ANALYSIS USED IN KOREAN NUCLEAR POWER PLANT, *Sang Hak KIM* (KEPCO, Korea)
- COMPUTER SIMULATION OF COMPLEX POWER SYSTEM FAULTS UNDER VARIOUS OPERATING CONDITIONS, *Tanuj KHANDELWAL*, *Cedric BAYLE* (ETAP, France)

The objective of this session was to focus on the methods and simulation tools used to:

- predict the performance of systems and components of the power distribution of NPPs,
- assess their ability to withstand internal and external hazards that could jeopardise the safety margins.

The presentations dealt with simulation tools and their use in slow transient studies of electrical distribution systems in NPPs (including electrical auxiliaries). None of the presentations dealt with fast transient phenomena studies (such as lightning).

A validation and verification process (V & V) of simulation tools used to support the demonstration of nuclear safety studies was also presented.

A focus was made on the importance of the main user of a simulation tool and his scope and missions in:

- the process of functional validation of the software,
- training for inexperienced users,
- maintaining the qualification,
- qualification of new versions.

The required input data and methods and hypothesis used for these studies were also presented. Although the presenting countries have their own specific adaptations, methodologies for slow transients and current calculations of short circuit are close in terms of philosophy.

Based on feedback events observed on the grid and on Swedish NPPs, 13 different profiles (initiating events) were introduced based on the following characteristics:

- Three-phase or single-phase fault, solid or resistant, near or far
- Surge and slow or rapid voltage collapse
- Under-frequency.

A focus on the various events taken place at Forsmark NPP and studies used to validate its basic design were also presented. The results of these studies allowed to plan design changes and improve the robustness of the electrical systems in Swedish NPPs.

Depending on the operating condition of the unit (plant start-up, normal operation, loss of coolant accident, hot standby, cold shutdown, loss of offsite power and station blackout.) and the availability of electrical sources (internal or external), different power balances were presented for Korean plants.

Different case studies included in the design were defined in a summary table through a combination of load cases (power balance) and the availability of the power source.

To confirm the validity of simulation results, comparisons were made with the results of tests carried out on site.

Finally, based on the case study of open phase conditions (Byron 2), a presentation was made:

- on the modifications applied to a simulation tool to take into account the asymmetrical aspects,
- on the validation and verification process, based on an inter-comparison between two simulation tools including one already considered as qualified.

The discussions and exchanges also highlighted the fact that no benchmarking of simulation tools has been made.

However, a format for the input data now exists and is gradually integrated into different simulation tools, which should ultimately facilitate inter-comparisons between tools.

Some simulation tools have important data libraries. However, the use of such libraries requires careful verification that the characteristics of the plant equipment match those of the library components.

To conclude, most participants agree on the following facts:

- Single simulation tool cannot be used to perform all studies (including fast and slow transient studies). Indeed, the models used are different as well as the necessary input data.
- Simulation tools used for the studies supporting the safety case must be qualified and users properly trained and supervised.
- Models representing the components of a single-line diagram must be representative for the studied phenomena and should be adapted to the types of studies.

For example, for the bus transfer studies all buses (HV and LV) and transformers should be represented.

The future studies to perform mainly concern asymmetric faults and:

- their detection,
- the behavior of the NPP auxiliaries,
- the means and logics which have to be implemented in order to identify them and cope with their consequences.

Recommendations:

Based upon the panel discussion at the end of the session a number of participants inquired about the further efforts after the ROBELSYS workshop and particularly the importance of launching an international working group on simulation tools and methods related to this type of studies.

2.6 Session 5 - Requirements for Equipment Used for Emergency Response

This session was devoted to the requirements for equipment used for emergency response in case of loss of electrical power in NPPs. It addresses requirements on new equipment, whether fixed or mobile, as well as requirements to facilitate rapid connection to existing equipment.

The following papers were presented:

- DESIGN PROVISIONS FOR STATION BLACKOUT AT NUCLEAR POWER PLANTS, THE IAEA TECDOC, Alexander DUCHAC (IAEA)
- TIMING CRITERIA FOR SUPPLEMENTAL EMERGENCY RESPONSE EQUIPMENT, John H. BICKEL (ESRT, USA)
- RESILIENCE IMPROVEMENTS TO UK NUCLEAR POWER PLANTS, Kevin PEPPER (ONR, UK)
- EMERGENCY MITIGATING EQUIPMENTS – POST FUKUSHIMA ACTIONS AT CANADIAN NUCLEAR POWER PLANTS PORTABLE AC POWER SOURCES, Jasmina VUCETIC, Ram KAMESWARAN and Krishnan RAMASWAMY (CNSC, Canada)
- FUNDAMENTAL DESIGN BASES FOR INDEPENDENT CORE COOLING SYSTEM, Jan HANBERG (SSM, Sweden)
- ULTIMATE ELECTRICAL MEANS FOR SEVERE ACCIDENT AND MULTI UNIT EVENT MANAGEMENT, Xavier Hubert Rene GUISEZ (Electrabel, Belgium)

The first paper dealt with the already observed need to harmonise some basic definitions regarding electrical systems, starting with the definition of SBO (station blackout). It presented the motivation and current status of an IAEA technical document (Tecdoc) dedicated to SBO topic which should be published in June 2015.

The following papers gave some feedback on studies and solutions implemented for emergency response equipment for specific NPPs. The presentations and the associated discussions lead to the general following remarks:

- The decision if supplement response equipment should be stored on site or in remote response centres requires specific studies to establish the coping time. An example of such a study involving computations on 80 scenarios and sensitivity studies was presented confirming that the envisioned on site supplemental equipment (with adequate fuel and compressed Nitrogen gas storages) would be sufficient to prevent fuel damage even beyond the 24 h delay to have remote equipment brought to the site.

- Improving the resilience of NPPs to SBO can be achieved through a significant enhancement of the battery capacity (i.e. 40 min to 8 hours). This can be done by augmenting the battery capacity and sometimes using load shedding. Additional mobile diesel generators are also currently installed on many sites worldwide.

- Implementation of an independent core cooling system is also sometimes considered.

- Improving the resilience of NPPs to SBO is, however, not only having more diesel generators but rather the ability to supply power through the distribution and down to the safety actuators. This leads to the need to explore solutions such as suitable event qualified connection points and making prime-mover-driver generators and pumps self-sufficient (i.e., not requiring shared support systems). Additional specific requirements for emergency response systems may also include qualification to extreme seismic events, proper initial and periodic testing as well as dedicated procedures.

- Limiting the size (and hence the power) of emergency response equipment should be considered as it leads to equipment which is more likely to be self-sufficient and capable of being moved, installed, and started up by hand.

- Emergency equipment is meant to operate when no other equipment may be operable. Hence, it may be better to relax the types and/or thresholds of the electrical protections in order to favour operation of the loads versus electrical protection (in particular not implementing overvoltage protections). The extent to which the electrical protection could be relaxed was debated.

Recommendations:

- Further investigations are needed to develop more internationally consistent requirements for emergency response equipment.

- Further investigations are needed to explore which types of electrical protection feature requirements could be relaxed for emergency equipment.

2.7 Session 6 – Margin Assessments for Modern Power Electronics

This session was devoted to the safety implications and design margins associated with modern solid state power electronics used in applications such as battery charger/inverter units and main generator excitation systems. It is motivated by the increasing number of applications of modern electrical systems important to safety making use of power electronics, e.g. thyristors and IGBTs. More precisely, recent operating experience in NPP's, e.g. IAEA IRS #7788 and #8294, has revealed that the design margins that should have been applied to deal with uncertainties in the real stress values and the equipment capability were inadequate.

The following papers were presented:

- RECENT OPERATING EXPERIENCE INVOLVING POWER ELECTRONICS FAILURE IN KOREAN NUCLEAR POWER PLANTS, *Jaedo LEE* (KINS, Korea)

- HOW TO SECURE UPS OPERATION AND SUPPLY OF SAFETY CRITICAL LOAD DURING ABNORMAL CONDITIONS IN UPSTREAM SUPPLY, *Joerg LAASER* (GUTOR, Switzerland)

- MODIFICATION TO BATTERY CHARGERS INVERTERS UNITS, *Florent RAISON* (AEG, France)

The technology of power electronic systems and components is still evolving. Functionality gets more complex and ratings of devices are increased. Design and knowledge of the design basis should be transparent for both manufacturers and customers so that systems can be designed and maintained with sufficient margins for electric transients and ageing.

Power electronics are susceptible to transients, both to power-frequency over voltages and switching and lightning impulse voltages. A knowledge gap between what the equipment is subjected to in the real word and what it is designed to endure still exists. This gap continues to represent a risk factor in reactor safety as many safety features are dependent on power electronics.

In order to combat this risk further work has to be done in several fields. The session identified the following items:

- strengthened design basis,
- improved standards for testing,
- diagnostics for transients,
- knowledge on ageing effects on silicon-controlled rectifiers (SCR) and
- improved knowledge through fault reports and statistics.

The session also identified that there is some customer reluctance to implement software based power electronics in safety grade systems. However, this seems not to be driven by failure statistics but rather on the issues of qualification, design knowledge, maintenance knowledge and obsolescence.

Hence, a life time perspective has to be included in the design (e.g. software lifecycle).

The presentations and associated discussions lead to the following findings:

- There are aging effects on SCRs (including device types of Thyristors, gate turn-off thyristors, and insulated-gate bipolar transistor) used in power electronics such as rectifiers, inverters and variable speed drives. Some manufacturers' claim long life time for such devices. However, further knowledge has to be gathered to support these claims.
- The measuring of the status and possible degradation on devices is not easily done. Simple measurement of impedance and insulation status is not sufficient. The devices have to be measured under load conditions (with current) based on the supplier's recommendation, in order to provide information for a correct assessment.
- Power electronics are susceptible to transients, both to power-frequency over voltages and switching and lightning impulse voltages. The problems of power-frequency over voltages have been discussed extensively in the DIDELSYS workshop. Impulse voltage is normally attenuated by surge arresters close to the source but harmful residues of the impulse may travel down as a travelling wave into the medium and low voltage systems hitting power electronics. Further modelling of voltage transient phenomena has to be developed. Over voltage protection (e.g. arresters) are recommended also at medium and low voltage systems and at sensitive components (e.g. power electronics).There is a need

for developing improved standards for testing power electronics against power-frequency over voltages and switching and lightning impulse voltages.

- Power distribution systems often lack instrumentation capable of verifying fast electrical transients. The real over voltages to which these power electronics are subjected to can therefore not be recorded. Hence, neither errors in design assumptions nor possible degradation can be discovered. Suitable diagnostics have to be developed.
- The need for gathering more knowledge on power electronics from the failure reports collated by international bodies such as the Institute of Nuclear Power Operations (INPO) or IAEA International Reporting System (IRS) was identified.
- The technology of power electronic systems and components is still evolving. Functionality gets more complex and ratings are increasing. There is a great interest and need for improving power electronic systems and the knowledge of these systems, so that the systems can be designed and maintained with sufficient margins for electric transients and ageing. A life time perspective has to be included in the design. The design and knowledge of the design basis should be transparent for both manufacturers and customers.
- Several customers have requested *software free* power electronics (e.g. containing no embedded microcontrollers and software). The drivers for this request focus on the issues (from the customer's perspective) on design knowledge, qualification, maintenance knowledge and obsolescence. However, there seems to be no failure statistics that indicate that software based power electronics have more problems than non-software based equipment.

Recommendations:

- A periodic replacement programme for SCRs should be considered, based on the manufacturers' recommendations.
- A proposal for new standardised transient voltage wave forms was suggested. These wave forms could replace or supplement the present lightning and switching impulse test wave forms used.
- The need for gathering more knowledge from failure reports on power electronics.

2.8 Session 7- Digital Components in Power Systems

This session was devoted to the current and foreseen use of digital components in electrical systems of NPPs, including operating experience, considerations for equipment selection, methods of qualification, and qualification issues.

The following papers were presented:

- DIGITAL COMPONENTS IN SWEDISH NPP POWER SYSTEMS, *Tage ERIKSSON et al.* (SSM, Sweden)

- OPERATING EXPERIENCE OF DIGITAL, SOFTWARE-BASED COMPONENTS USED IN I&C AND ELECTRICAL SYSTEMS IN GERMAN NPPS, *Stefanie BLUM, André LOCHTHOFEN, Claudia QUESTER, Robert ARIANS* (GRS, Germany)

- SMART DEVICES IN THE UK NUCLEAR SECTOR: A REGULATOR'S PERSPECTIVE, *Steve FROST* (ONR, UK)

- MASS ALARMS IN MAIN CONTROL ROOM CAUSED BY CONDENSATE ON THE INSTRUMENTATION AND CONTROL CARDS IN TURBINE BUILDING, *Cheol Soo GOO* (KINS, Korea)

This session had a consensus that digital components are increasingly replacing analogue devices for control and protection in electrical systems as it becomes more and more difficult to obtain components based upon analogue technology.

Digital components can provide increasing functionalities but show a higher level of complexity. Due to the more complex structure, digital components show the potential for new failure mechanisms and an increasing number of failure possibilities, including the potential for common cause failures. Failures in the electrical systems have been challenging to analyse, often due to a lack of detailed information about the systems, which has led to non-detectable, or non-identifiable, failure modes.

Operating experience has shown that the failures of digital components were mainly caused by parts which are not related to the software. Nevertheless, new failure mechanisms in digital components were identified (e.g. programming errors can have a major effect on the system). Due to the increased complexity of digital components they will require a more thorough assessment than simple analogue technology.

Therefore, digital components need to be rigorously qualified for their application depending on their safety significance. The qualification should also include the evaluation of the manufacturer's production of excellence and independent confidence building measures.

Recommendations:

- Digital components should be assessed in depth to gain further insight in failure mechanisms and failure possibilities.
- Digital components need to be rigorously qualified for their application depending on their safety significance.
- The qualification of digital components can be time consuming which should be taken into account when considering digital components for use in NPPs.
- When installing digital components, an appropriate design basis should be established. This should take into account possible new failure mechanisms as well as an understanding of component behaviour and sensitivities.
- In some circumstances the increased functionality and sensitivity or reduced response time of digital components can give the best overall solution for protection arrangements. For example phase unbalance may be difficult to measure accurately with analog devices.

3. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made based on workshop presentations, discussions during particular sessions, and facilitated discussions:

- Based upon the panel discussions at the end of the workshop, a majority of the participants suggested the need for continuing efforts after the ROBELSYS workshop and particularly the importance of launching a more permanent international working group on modeling tools and methods related to nuclear power plant electrical power system studies. The working group would be modelled on WGRISK. (It is recognized that creating such a permanent working group would require a multi-year commitment of CSNI and the participants.)

- It will be very beneficial to continue international information sharing of the following items, eventually leading to development of suitable international electrical standards:
  - System and component requirements for addressing beyond design basis external events
  - Recommended practice for incorporating diversity in the onsite electrical power system
  - Recommended practice for relaxing electric power protection features used in emergency situations (assuring margin against spurious electrical shutdowns)
  - Recommended practice for qualification requirements for existing systems and portable components used to cope with AC station blackout.

- There is a need for further development and improvements in the analysis and simulation of the following:
  - Simulation of asymmetric 3-phase electrical faults (one/two-open-phase issue)
  - Development of standardised transient voltage wave forms for use in qualifying onsite electric system components. (These wave forms could replace or supplement the present lightning and switching impulse test wave forms used.)
  - Reliability and robustness of new battery designs relied upon in SBO scenarios

- In coordination with WGRISK the following developments in PSA modeling should be given priority for improvement:
  - Investigation on the use of PSA tools to improve insights in the role of different electrical power sources in reduction of CDF or mitigation of severe accidents
  - Improved and consistent methods to determine the available coping time in case of SBO to know the time in which critical functions are to be restored to prevent a severe accident (to be done also in coordination with the CSNI Working Group on Analysis and Management of Accidents (WGAMA)).