Investigation of the procurement and supply of the emergency diesel generators (EDG) and related auxiliary systems and equipment for the Olkiluoto 3 nuclear power plant unit

27 May 2011

Investigation Team

This investigation report presents the view of the Investigation Team and provides its recommendations of the Team for assuring the quality of the equipment and for enhancing the safety of nuclear power plants when implementing new similar projects. Use of the investigation report for other purposes than for learning from experience and for enhancing safety shall be avoided. The Investigation Team expects that the adequate quality of emergency diesel generators units that were the subject of this investigation will be assured before the commissioning of the Olkiluoto 3 nuclear power plant.

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Summary

Attention has repeatedly been drawn to the poor quality of the design documents for the emergency diesel generators (EDG) and related auxiliary systems and equipment in connection with the reviews carried out by the Radiation and Nuclear Safety Authority of Finland (STUK). Subsequently, it has transpired that control over EDG procurement from subcontractors has been lax and that sufficient steps have not been taken to ascertain the required standard of quality of the components supplied by subcontractors. Similar problems have not been encountered in the manufacture of the engines for the diesel generators or related design documentation.

In response to these problems, STUK initiated an investigation to evaluate the performance of the various parties in the procurement process involving several subcontractors, and to issue recommendations in view of equivalent future deliveries.

Most of the EDG orders were made and implemented during 2005–2006 after a short stage of basic design. Subsequently, measures had to be taken several times in the course of the procurement process to correct the shortcomings of the basic design. Management of the EDG supply has been hampered by complex contractual arrangements. The EDG supply contract was signed on 24 February 2005 between the plant vendor (Areva) and SEMT Pielstick, currently MAN Diesel. Areva's actual contracting party is MAN Diesel. For the purpose of the delivery, a special consortium, MAN Diesel–Alstom TPEG (Thermal Products - Emergency Diesel Generators Product Line*)*, was formed. Alstom leads the communication of consortium directly with Areva and manages its own contracts with further sub-suppliers. MAN Diesel supplies the diesel engines and Alstom TPGE is the supplier of the generators, diesel generator auxiliary equipment, auxiliary system components as well as electrical and instrumentation components.

Due to the long supply chains there have been communication problems in the manufacture of the components for the auxiliary systems and equipment of the diesel generators. Additionally, inaccurate definition of requirements has led to shortcomings in quality assurance. The subcontractor audits carried out by the licensee responsible for the safety of the nuclear facility (TVO) and the review of design documents by the licensee and the regulatory body (STUK) have indicated non-conformances that may affect the manufacture and quality of the end product. One of the reasons for the problems is that design documentation has proceeded been prepared and evaluated in parallel with the manufacture or even after manufacture. The

needs for changes identified in the design documentation have not been followed up by TVO and STUK by applying a systematic approach that would have ensured that their repetition would have been noticed early enough and their underlying causes could have been traced back to the different interpretations of the requirements for the auxiliary equipment and components.

Because the EDG project was at the beginning managed by the electrical engineering experts at the designers, at the plant vendor, at the licensee and at the regulatory body and because the exchange of information between the different fields of technology did not work as well as hoped for, less attention was paid to definition of requirements and to quality management regarding mechanical equipment.

The investigation raised the fundamental question of conditions for using series-produced parts in the safety-classified systems and assemblies of nuclear facilities. The diesel generator supplier had, on several occasions, informed the plant vendor and this information had been passed on to TVO that it was difficult to find suppliers for auxiliary equipment who would use other than series -produced parts. STUK had requested the licensee to present pre-defined procedures for the use of series-produced parts. However, TVO did not submit the requested proposal. The investigation uncovered that TVO had made the interpretation that STUK would have approved of the use of series-produced parts without supplementary quality assurance. As a result of this interpretation, the construction plans for the equipment and components intended for the diesel generator auxiliary systems remained incomplete, and no project specific quality plans were required from the suppliers.

Appropriate procedures must be put in place for equipment and components intended for use in nuclear facilities because they are subject to special fit-for purpose-related requirements. The manufacturing process of series-produced components does not generally comprise procedures to prove that the quality requirements of a certain individual component have fulfilled. Instead, the basis for the quality management is that the manufacturing process provides a standard quality that meets the requirements. Under these circumstances, in order to verify conformance of the Olkiluoto 3 emergency diesel generators and their auxiliary systems and components to the requirements it is necessary to assess the documentation accumulated in the course of manufacture, to evaluate the tests performed on the equipment, and to audit the manufacturers' production processes. If conformance cannot be verified, the component in question involved must be re-manufactured. No open questions in the procurement and manufacture of diesel generators and their auxiliary equipment must be allowed to compromise the safety of the nuclear facility.

Concerns with respect to the construction of the Olkiluoto 3 Unit and the manufacture of related equipment have also previously been found to be related to project management, as suggested by the previous investigation regarding the non-conformances in the concreting of the base slab for the Nuclear Island in autumn 2005. Occasionally, communication of the requirements concerning quality and quality control from Areva to its subcontractors has been inefficient, as pointed out by TVO in connection with audits at subcontractor sites. Indications of the subcontractors' inexperience in nuclear facility construction have arisen both on the site and in the course of the manufacture of the main components and equipment at the factories.

In the case now having been evaluated by the investigation team, important contributing factors – in addition to the concerns identified previously during the Olkiluoto 3 project – were found to include the following: contractual arrangements; preparation of requirements in the initial stage; managing the fulfilment of the requirements in the course of the supply, and different interpretation of requirements. TVO was not initially aware of the length of the entire supply chains and its supervision did not cover these chains to full extent. Most of the involved organisations had limited experience in nuclear industry or they did not have any skills on procurement within nuclear. Lack of experience seemed to have contributed to the problems encountered.

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0 Abbreviations

[1]NC	Construction
NL	Procurement
NP	Project Management
NQ	Quality Management
NT	Plant Technology
NTM	Mechanical Components Office
NTP	Process Engineering Office
NTQ	Quality Control (Plant Technology)
NTS	Electrical Engineering Office
QA	Quality Assurance
QC	Quality Control
QAP	Quality Assurance Plan / Program
ITP	Inspection and Testing Plan
EOMR	End of Manufacturing Report
CFS	Consortium Framatome-Siemens

[1]N-department refers to OL3 project

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1 Purpose and performance of the investigation

During 2009–2010, the Radiation and Nuclear Safety Authority (STUK) found many of the design documents of the auxiliary systems and equipment for the emergency diesel generators (EDG) of the Olkiluoto 3 Unit to be of such a low quality as to raise suspicions of the quality management procedures applied by the plant vendor (Areva) and the suppliers of auxiliary equipment. Emergency diesel generators perform an extremely important function at a nuclear power plant as they are required to supply electricity to systems and equipment important to safety in the event that the regular power supply fails.

Based on these findings, STUK ordered the licensee to carry out follow-up inspections (audits) at the main supplier of the diesel generators and its principal subcontractors. The supplier is the Consortium SEMT Pielstick (currently MAN Diesel)–Alstom TPEG, of which the former supplies the diesel engines and the latter (Alstom) the generators, diesel generator auxiliary equipment, auxiliary system components as well as electrical and instrumentation components. Alstom has almost 30 subcontractors of which around ten belong to a lower tier of suppliers who, in turn, rely on further subcontractors for component deliveries. Additionally, MAN Diesel has several subcontractors for engines; however, the present report will not address this branch of procurement.

The audits performed by TVO uncovered that Areva had not provided Alstom with up-to-date design criteria that were to be used as the basis for the design and manufacture of diesel generators, nor updated documents describing the quality management policies to be followed in the Olkiluoto 3 project. It was found that the quality assurance requirements imposed by the plant vendor had not been duly communicated to the manufacturers and the manufacturers were not required to present project-specific quality plans. STUK considered the findings of the audits significant because they suggested that it was questionable whether the emergency diesel generators and the management of the supply chain for equipment and components important to safety met the applicable nuclear safety requirements. STUK requested an explanation from TVO regarding the compliance of the emergency diesel generators with the requirements.

STUK initiated the investigation in response to the audit findings with reference to the following criterion expressed in the in-house quality manual: “Lacking safety-oriented thinking: deficiencies in the performance of organisation” because the findings lent support to the view already existing that the measures taken by the plant vendor and licensee to control

and manage the supply chain were incomplete and that the procurement process failed to meet the plant vendor's own requirements.

The investigation targeted the activities of the licensee (TVO), the plant vendor (Areva) and the supplier of OL3's emergency diesel generators and related auxiliary equipment (Alstom) and its purchases from subcontractors. At the same time, the investigation addressed the regulatory oversight by STUK in relation to the procurement process. The investigation evaluated the progress of the procurement project and supply chain management, including the procedures applied by the licensee and the plant vendor in controlling and managing the procurement process. Based on this case study, investigation team considered measures required for management and controlling of a long, multinational procurement chain as compared to the assessment and control of quality management by a single subcontractor.

The investigation team issues recommendations, based on the observations and conclusions made in the course of these efforts, for improving performance and developing procedures in the target organisations. Another objective is to learn from experiences in order to be able to make use of this new information in the oversight of other parts of the OL3 plant project; oversight of the modification projects at operating plants; the planning of regulatory oversight in connection with new plant projects; and in the overhaul of the detailed provisions regarding the safety of the use of nuclear energy, or YVL Guides, issued by STUK.

The composition of the investigation team is presented in Annex 1. The team members interviewed individuals in various positions in the organisations involved in the Olkiluoto 3 project (TVO, Areva, Alstom) as well as individuals at the regulatory body (STUK) concerned with the project. Additionally, the team members toured the Olkiluoto 3 construction site and examined the emergency diesel generators brought to the site.

The investigation evaluated the actions of the various parties in light of their in-house procedural guidelines, relevant legislation and the requirements presented in the YVL Guides. Licensing documents regulating the activities, STUK's decisions and TVO's applications were also scrutinised in the course of the investigation, while the EDG procurement process, the actions of the various parties and the roles of specific individuals were discussed in the interviews.

The number of interviewees and the organisations they represented were as follows: 15 from STUK; 13 from TVO; 7 from Areva; and 3 from Alstom. Each individual was interviewed separately. The people selected for the interviews had played a key role in some stage of the EDG procurement process. At STUK, the interviewees included documentation reviewers, a

coordinator involved in the OL3 project and their supervisors. The interviewees at TVO, Areva and Alstom had served in central positions during the EDG process. The number of interviewees was affected by the fact that each individual had served in a specific narrow role for a specific period of time. It was found to be necessary to interview such a great number of people in order to get an overall picture. Notes were made during the interviews to record the main points. Each interview lasted a couple of hours with most conducted in STUK's premises. Two interviews with TVO personnel were held in Olkiluoto.

The interviews were based on open-ended questions that followed a pre-determined pattern according to the theme being discussed. The themes were: control of the procurement chain; document control; technical implementation; interfaces; communications; specifications management; quality management; organisation; management; and skills and competencies. The observations were tabulated specifically to each individual interviewee. The observations were then extracted from the table and embedded in a diagram using the Mind Map technique (Annex 2). The observations were prioritised according to significance and the way in which they were presented in the interviews. An effects analysis was made of the main observations to evaluate them in relation to one another in order to determine which was 'cause' and which was 'effect'. This exercise made it possible to distinguish between the underlying causes and direct causes. The cause-and-effect diagram is attached as Annex 3.

2 Background for the investigation

The supply contract for the emergency diesel generators was the second of the subcontracts concluded by Areva for the Olkiluoto 3 project. Signed in February 2005, it was made one week after the issuance of the OL3 Construction Permit by the Government. Basic design and planning of the emergency diesel generators and related auxiliary systems and equipment had begun immediately after the signing of the plant supply contract.

2.1 Beginning of the Olkiluoto 3 project

In January 2002 the Government made a Decision-in-Principle (DiP) granting the application filed by Teollisuuden Voima Oy (TVO) in November 2000 for the construction of a new nuclear power plan unit in Finland. The Government's Decision-in-Principle was confirmed by Parliament in May 2002.

Following competitive bidding, TVO signed a contract in December 2003 on the construction of Olkiluoto 3 (OL3) with a French-German consortium (CFS) formed by Areva NP, formerly Framatome ANP (FANP), and Siemens AG. The General Contract was made between TVO and

CFS foreseeing the construction of an EPR reactor based on the European Pressurized Water Reactor concept on a turn-key basis on the Olkiluoto plant site. Areva was to be responsible for the Nuclear Island and Siemens for the Turbine Island. Under the contract, the plant vendor was to assume responsibility for design; licensiability; manufacture and procurement; construction (excluding rock excavation and site works); installation; testing and commissioning; performance characteristics; timetable; and quality.

In its capacity as the buyer, TVO is responsible for the licensing processes. At the beginning of 2004, it submitted an application for a Construction Permit with the-then Ministry of Trade and Industry (MTI), currently the Ministry of Employment and the Economy, which is the authority tasked to prepare license decisions for presentation to the Government. STUK is required to prepare a statement on the application for the ministry to be accompanied by a safety assessment report. STUK's objective is to ensure that the proposed plant can be constructed to meet Finnish safety requirements.

On 17 February 2005, the Government granted the Construction Permit for the OL3 nuclear power plant unit. Following completion of the civil engineering works for which TVO was responsible, the Olkiluoto 3 site was handed over to the plant vendor and actual construction work was commenced in spring 2005.

2.2 Quality management during the construction of Olkiluoto 3

TVO is committed to a quality and safety culture of the highest standard. This principle is applied in all stages of construction of the OL3 unit. The quality management system for the OL3 project is designed to ensure that the plant unit and related construction work meet the requirements laid down in Finnish legislation, government decrees and official regulations. Additionally, OL3 must fulfil the criteria specified by TVO in the documents submitted for the licensing and construction plan approval process.

Quality management during construction, means systematic and detailed control and inspection processes. They are designed to ensure that systems important to safety and availability, actual construction work, installations and commissioning satisfy the applicable requirements and provide a sound basis for the safe operation of the facility. Additionally, a commitment has been made in the OL3 project to risk prevention and continuous improvement. The state of quality management is evaluated on an on-going basis: aside from internal evaluation, quality performance is regularly inspected and monitored by both STUK and an external certification body contracted by TVO.

2.3 Overall challenges related to the construction of the OL3 unit

The original schedule for the construction of the OL3 unit may be considered ambitious considering that it is long time since the previous nuclear power plant projects were completed in Europe and that the current facility is of a type that has never been built before. Neither the plant vendor nor the licensee has previous experience in managing extensive construction projects.

Launching the project took a long time because the plant vendor was not fully prepared to start it at the time when the construction permit was granted. The time and amount of work required for the detailed design of the OL3 unit was underrated when the overall schedule was fixed. Much time was spent looking for experienced contractors and equipment manufacturers. A further problem was presented by the disappearance of companies from the market capable of providing 'nuclear-grade quality'. Both the execution of the project and compliance with the schedule were complicated by the slow completion of plans. As a result, detailed designs and plans were not available to the plant vendor at the time when contracts with selected subcontractors were signed.

The plant vendor has signed specific supply contracts on all major equipment purchases with selected key suppliers. They have ordered specific pieces of equipment from individual subcontractors who, in turn, have relied on other manufacturers for component deliveries. The long subcontractor supply chains are a new feature compared with earlier nuclear facility construction projects in Europe.

Further problems have been created by the fact that the plant vendor was not sufficiently familiar with the Finnish regulatory approach and safety requirements at the beginning of the project. Another reason for the slow start of construction was that Areva had not previously been in charge of entire nuclear power plant projects; instead Areva's earlier projects had been implemented in collaboration with a French power company (Électricité de France, EdF). EdF had managed the purchase of EDG's in those earlier projects, at least for all of its own plants.

The new design solutions associated with the EPR and the application of new technology have posed major challenges in the construction stage. A number of technical features are being used for the first time and there are manufacturing methods and techniques that have not been proven in tests or in practical application until now during OL3 construction. The problems with the manufacture of the main components and the delay in the design of the

plant's electrical and instrumentation systems have required exceptionally close attention on the part of the plant vendor, licensee and regulatory body and has taken up a great deal of resources.

The problems have hampered progress and built up pressures regarding the schedule. One of the consequences is that timely design and delivery contracts of large assemblies separate from the main process and related monitoring have received too little attention, just like the technical and quality management requirements related to such equipment.

The problems and challenges encountered in the construction of the Olkiluoto 3 unit and the manufacture of equipment may be regarded as valuable lessons for the execution of similar projects both in Finland and in other countries building nuclear power plants.

3 OL3 emergency diesel generators and related auxiliary systems

The electrical systems and components of the nuclear power plant are required for the supply of produced electrical power to the 400 kV off-site grid as well as for the supply of power to on-site systems from external and internal power sources such as diesel generators. The reliable operation of diesel generators is of utmost importance to plant safety in case of malfunctions in the on-site power grid due to external or internal disruptions, and in terms of accident management and mitigation of the consequences.

The emergency diesel generator system is designed to ensure power supply to systems and components important to safety when the power supply to the plant unit from the off-site grid is lost. The diesel generators are started automatically by the protection system, but can, if necessary, be started manually from the plant's main control room and the local emergency control rooms for the diesel generators. Primarily, the design of emergency diesel generators is based on the Guide YVL 5.1 *Nuclear power plant diesel generators and their auxiliary systems* [1] and the German standard KTA 3702 *Emergency Power Generating Facilities with Diesel-Generator Units in Nuclear Power Plants* [2].

OL3's power distribution system is divided into four physically separated and parallel subsystems in order to prevent potential common cause failures. In each subsystem, power supply to components important to safety is ensured by a dedicated diesel generator with an electrical power of 6.2 MW. Reactor plant systems important to nuclear safety are designed to provide the required capacity even if one subsystem were inoperable while another subsystem was out of service because of servicing, etc. In view of a simultaneous failure of all off-site power connections and all the four emergency power generators, OL3 is provided with two

smaller (approx. 2.4 MW) SBO diesel generators (SBO=Station Black Out). Additionally, there is a gas turbine plant that can be placed in service when necessary to supply electricity to OL3.

Each emergency power unit at OL3 incorporates a diesel engine and a generator connected to it. In addition to these main components, the emergency power unit contains a range of auxiliary systems necessary for operating the diesel generators as planned. Such auxiliary systems include fuel, start-up, compressed air, cooling, lubrication, exhaust and generator magnetizing systems as well as control, adjustment and protection systems. The auxiliary systems, in turn, include a wide range of various accessories, components and structures such as motors, pumps, valves, piping, tanks, coolers, and filters.

For the purposes of this report, the term 'diesel unit' will be used to refer to the diesel generator and related auxiliary systems. A diesel generator means a combination of a diesel engine and generator [1]. The cooling system is defined as an auxiliary system in Guide YVL 5.1 and as an external system in KTA 3702 [2].

4 Requirements regarding the OL3 emergency diesel generators and related auxiliary systems

4.1 Requirements regarding design, manufacture and quality management

The underlying requirements concerning the EDG procurement are the Finnish legislation and the YVL Guides issued there under. The licensee bears the overall responsibility for ensuring that due consideration is given to the applicable regulations and the provisions of the YVL Guides in the quality assurance programmes of the various organisations involved.

The documents describing these requirements and their relative hierarchy is presented in the following diagram, lists the most important YVL Guides regarding the EDG procurement process. Additionally, the process is regulated by the in-house management systems of the organisations involved and the quality management and manual specific to the OL3 project, such as the vendor's QR Doc document set and underlying nuclear technology standards. However, the main role in the EDG project is played by the Project Specification for Emergency Diesel Generate Sets and the Classification List that are, to a great extent, based on the KTA 3702 standard, and a number of STUK's key decisions outlining the course of action.

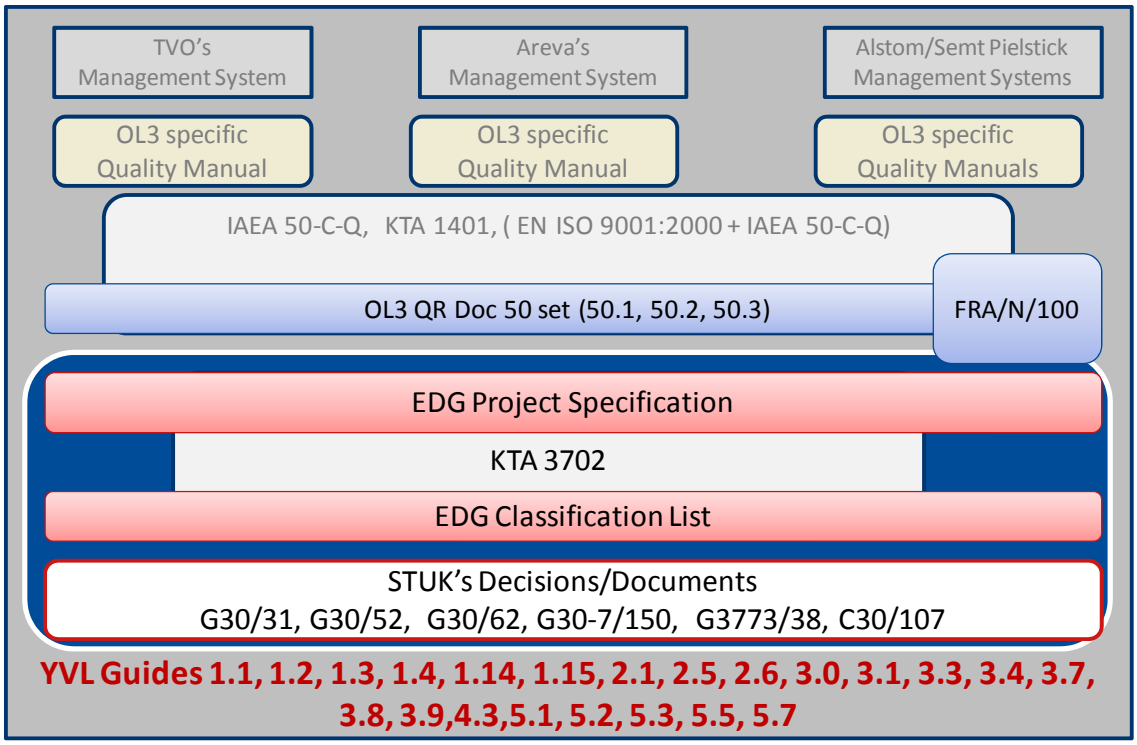

Fig. 1. *Main documents governing the OL3 EDG procurement process.*

YVL Guides

Requirements concerning emergency diesel units are set forth in the following YVL Guides:

YVL Guide 5.1 *Nuclear power plant diesel generators and their auxiliary systems* [1] specifies the requirements regarding the design, manufacture, commissioning and operation of safety-classified diesel units in nuclear power plants, including related regulatory control procedures applied by STUK. Additionally, the Guide defines the licensee's obligations in assuring the safety of the nuclear facility. Guide YVL 5.1 is based on the German KTA Safety Standard *Emergency Power Generating Facilities with Diesel-Generator Units in Nuclear Power Plants* [2] that specifies the detailed design and testing requirements for diesel units. Said standard constitutes the basic level of requirements to be complied with unless otherwise provided in the YVL Guides or otherwise authorised by STUK. The requirements concerning electrical and I&C systems and components are presented in YVL Guide 5.2 and 5.5. [3, 4] that apply to EDGs as appropriate.

Provisions concerning the valves and pumps used in nuclear facilities' safety classified systems and are presented in Guide YVL 5.3 *Nuclear facility valve units* [5] and in Guide YVL 5.7 *Nuclear facility pump units* [6]. The provisions for pressure vessels are laid down in YVL Guide series 3 listed in Fig. 1 [7-13]. These Guides specify the requirements for the design, dimensioning, use,

installation and maintenance of the equipment in question. Additionally, the Guides provide a description of the procedures applied by STUK in monitoring compliance with the specified requirements. The pumps used in the EDG auxiliary equipment are governed by the Guide YVL 5.7 [6] but the Guide YVL 5.3 [5] was not applied in EDG project because all the valves used in the EDGs were serial produced components.

The Guide YVL 2.1 *Nuclear power plant systems, structures and components and their safety classification* [14] provides a description of the principles of safety classification and related procedures.

Guide YVL 2.6 *Seismic events and nuclear power plants* [15] presents the general requirements for the integrity, leaktightness and operability of structures and equipment. All structures, components and systems important to safety must be designed to withstand the seismic loads generated by earthquakes in order to assure the safety of the nuclear power plant.

Guide YVL 1.3 *Mechanical components and structures of nuclear facilities*. *Approval of testing and inspection organizations* [16] specifies the requirements for all organisations performing non-destructive (NDT) or destructive testing (DT) on the mechanical components and structures of nuclear facilities. This Guide also applies to organisations that inspect mechanical components and structures of nuclear facilities in their capacity as an inspection body. The Guide provides a description of the qualification, acceptance procedure, obligations and oversight of the operations of the testing organisations and testers as well as the inspection organisations and inspectors.

Guide YVL 1.14 *Mechanical components and structures of nuclear facilities*. *Control of manufacturing* [17] presents general requirements and procedures for the manufacturing control of mechanical equipment and structures of nuclear power plants. Detailed requirements for the manufacturing and manufacturing control of individual components or structures are determined by safety class according to the YVL Guides specific to each equipment group and the applicable standards referenced in these guides. The construction plan required under Guide YVL 1.14 must provide a description of the control of manufacturing and related requirements. Additionally, the Guide sets forth the requirements for the manufacturing control of the products intended for nuclear facilities to be followed by the manufacturer and licensee, and provides a description of the regulatory oversight exercised by STUK.

Guide YVL 1.15 *Mechanical components and structures of nuclear facilities*. *Construction inspection* [18] presents the principles according to which the construction inspections of the mechanical components and structures of nuclear facilities are carried out. Construction inspections mean inspections and tests performed to ensure that a piece of equipment or structure is manufactured, modified or repaired and quality control carried out in accordance with the approved construction plan and approved procedures.

Areva's project guidelines for OL3

Areva's documents regulating the emergency diesel generators and their procurement are as follows:

- The Project Specification for Emergency Diesel Generator Sets [19] sets forth the technical and quality requirements for the EDG systems and equipment and related design, documentation, manufacture and inspections as defined in the Main contract, KTA 3702 Safety Standard and YVL Guides. The Project Specification is the governing document which is referenced in nearly all the other documents relating to the EDG project. The Project Specification states that KTA 3702 serves as the applicable standard unless otherwise provided in YVL Guides or STUK's decisions.

- The Classification List [20] specifies the standard applied in manufacture (KTA 3702 or Manufacturer Standard), the component's safety class, quality class, seismic class, qualification method and Inspection Group. The Inspection Group defines the level of quality documentation and detail of the quality control measures. Group 1. = series-produced items with requisite proof of a successful operating history; Group 2. = items requiring further documentation for approval and inspections.

- The QR Doc 50 series documents (50, 50.1, 50.3) [21, 22, 23] provide a description of Areva's quality requirements for OL3 suppliers. The documents state, however, that unless otherwise provided, the requirements presented in the Project or Technical Specifications supersede those defined in the QR Doc requirements.

- FRA/N/100/OL3 [24] presents the requirements for the quality management system of the actors participating in the OL3 project and related development needs. According to FRA/N/100, the management systems must conform to the IAEA 50-C-Q Code [25]. Failing that, the systems must be complemented by an OL3-specific quality assurance plan (QAP) or equivalent to be submitted to Areva for review.

Handling of Project Specification and Classification List by STUK

First version of the Project Specification was established in 2004 by Areva's subcontractor Sofinel and first version of the Classification List was drawn-up by Alstom in 2005. There were many modifications of both documents in the course of time. TVO submitted to STUK for approval the Project Specification revisions B (2004), F (2005), G (2005) and J (2007), and revisions F (2007) and K (2009) considering the Classification List.

The latest versions of these documents approved by all parties, i.e. Areva, TVO, and STUK, are revision J of the Project Specification, approved by STUK with some additional requirements in November 2007, and revision K of the Classification List, approved by STUK in May 2009. Revision K of the Project Specification was sent for STUK's information in 2008. In its approval decision considering the Classification list STUK states that the approved document provides the safety, quality and seismic classification of the components of the emergency diesel generator sets. STUK does not mention the Inspection Group in its decision even though it is given for the EDG components in the document together with the aforementioned classifications.

Neither the Project Specification nor the Classification List is a document identified as an official documentation by STUK.

4.2 Key issues relating to monitoring and quality management in the EDG project raised in the correspondence between TVO and STUK

Some STUK's decisions made on the applications by TVO have influenced the management of EDG project. These applications and decisions have been related to the start up of manufacturing and the use of serial produced components in the devices of EDGs. The correspondence between TVO and STUK can be referred briefly as follows:

Start of manufacture in relation to the approval of design documentations

- With reference to Guides YVL 5.1, 5.3 and 5.7 [1, 5, 6], STUK required that the manufacture of Safety Class 2 emergency diesel engines and generators, pumps, pump motors and valves and valve actuators may not be commenced before STUK has approved the essential parts of the related construction plans.

- TVO proposed a procedure under which the manufacture of EDG auxiliary system components could be started after the construction plan had been reviewed by TVO and its notified body and after the documentation had been submitted to STUK for

approval, provided that the review report by the notified body did not contain comments categorized significant. STUK accepted the procedure proposed by TVO. In addition, TVO proposed that the commencement of manufacture of Safety Class 2 serial produced parts should not be tied to the approval of the construction plans.

- While most of the equipment has already been made, the processing of the construction plans for the auxiliary systems and equipment is still in progress because of the poor quality of the plans and the incomplete quality assurance documentation.

Use of series-produced components and required quality documentation

- STUK's starting point was that Safety Class 2 quality management procedures shall be complied with in the manufacture of all components essential to the reliable operation of the diesel generators.

- TVO held that the application of these requirements to series-produced components was not justifiable and that no manufacturers could be found for such components. TVO argued that the limitation imposed by industrial manufacture to be taken into consideration.

- STUK asked TVO to define series-produced components and related quality management procedures.

- TVO responded saying that there was no need for this. According to the information received from TVO in the course of the investigation, this reply only applied to the electrical components of the diesel units. No information regarding responses to the request for additional information on auxiliary components is available, meaning that the situation is still pending.

- Some of the components of the mechanical auxiliary equipment used in the diesel generators have been manufactured in accordance with the standard procedures applied by the respective manufacturers without the device-specific control required under Safety Class 2 provisions.

Approval of manufacturers and testing organisations

- According to TVO's proposals, manufacturers and testing organisations could be approved following a less rigorous procedure since the equipment was conventional in terms of technical design.

- STUK decided that the approval procedure could be relaxed, yet the manufacture of the components and related quality management was to be governed by the level of requirements specified in the YVL Guides.

- As far as the commencement of manufacture was concerned, the resolution of an issue was late because the manufacture of nearly all the components had already started.

4.3 Requirements concerning the management and control of the supply chain

The revised Guide YVL 1.4 *Management systems for nuclear facilities* [26] adopted in 2008 is based on the IAEA Safety Standards No. GS-R-3 *The management system for facilities and activities* [27]. According to the document, systematic procedures must be put in place to ensure conformance of the products to be procured. Adequate quality requirements must be imposed on the products and controls applied to ensure that they are complied with and that an adequate standard of quality is achieved. Qualified personnel must be provided to specify the quality requirements and oversee suppliers. Before any order is placed for a product, the supplier's ability to manufacture products meeting the requirements must be evaluated.

The decision to implement Guide YVL 1.4 (October 2009) states that it shall be applied to the OL3 project without modification. In preparation for this decision, STUK made the evaluation that the procedures put in place for the control of the supply chain were in compliance with the provisions of the Guide. The Guide took effect when the EDG project had reached an advanced stage, but the draft 2 (from 2000) of the Guide under revision was as an appendix of the Main Contract. The draft guide covered also design and construction of nuclear power plants containing revised chapters considering procurement, Quality Management and oversight of subcontractors. The previous Guide YVL 1.4 (from 1991) had not contained equivalent requirements concerning the control of the supply chain; instead, it required clear-cut quality assurance procedures complying with the IAEA 50-C-G code and a commitment to a high standard of performance in terms of quality.

The EDG Project Specification [19] states that the manufacturer must submit a *Manufacturer assessment file (MAF)* to Areva. It goes on to say that the manufacturing and testing organisations must be approved of by TVO and STUK, and that the manufacture of Inspection Group 1 components may start once Areva has confirmed that they belong to this group. Additionally, the manufacturers of Inspection Group 1 components are required to provide the documents identified in the Project Specification. The Project Specification does not spell out

the requirement specified in Guide YVL 1.4 for the evaluation of the manufacturer before the order is placed for Inspection Group 1 components manufacturers.

Areva's quality requirements as defined in QR Doc 50.1 [22] state that the following documents must be submitted to TVO and Areva for review before commencement of manufacture: *Manufacturer Approval File* as well as the following documents as appropriate: *Testing Organization Application File or accreditation certificate; Prerequisite for welding operation; and Inspection Organization Application File.* Additionally, it is stated that a testing plan specific to each individual manufacturer and component must be submitted to Areva, TVO and, if required, to STUK for review and approval before the manufacture of any main component is commenced by a subcontractor.

Alstom's project quality assurance program specific to the OL3 EDG project [28], section 7.2.2 *Inspection and test plans,* specifies that the testing and inspection plans must be approved by Alstom TPEG (*Thermal Products- Emergency Diesel Generators Product Line*) and, if necessary, Areva before the commencement of manufacture. Section 7.2.3 *Product quality control* states that Areva will give permission for the shipment of the product after first checking that the contractual obligations have been duly fulfilled and the necessary documents submitted to Alstom.

TVO's OL3 project plan states that TVO is responsible for the licensing of the OL3 project and the plant to be built. The plant vendor is responsible for the licensiability of the plant and will prepare and submit the documentation required for licensing to the licensee for presentation to the authorities. TVO reviews the documentation and also supervises the manufacturing, installation testing and commissioning operations, and forwards the appropriate documentation to STUK for approval. TVO will monitor the quality produced by the plant vendor and its subcontractors through a range of inspections and, if necessary, additional testing [29]. Guide YVL 1.4 (2008) specifies that the licensee is responsible for ensuring that the regulatory requirements and guidelines are complied with in the procurement of products affecting the nuclear and radiation safety of nuclear facilities [26].

According to the OL3 Project Plan [29], responsibility for technical delivery and quality control rests with Plant Technology (NT) and Construction (NC). Quality Management (NQ) participates in supplier evaluations by performing supplier audits. According to TVO's Quality Manual [30], suppliers must be evaluated before any purchases are made. TVO's guidelines for supplier audits states that a supplier audit is carried out when there is no knowledge of the

quality management procedures; or they are known to have been flawed; or the quality of the product cannot otherwise be assured.

It is stated in TVO's project procurement control process that TVO monitors the fulfilment of the Plant Contract (e.g. supplier selection and supervision) in accordance with the contract, agreed modifications and procedures: *"Steps will be taken to ensure that the selection of suppliers by the plant vendor satisfies the criteria specified in the plant contract; the internal approval is carried out by TVO in accordance with a specific guideline; and that information on all manufacturers and contractors are gathered in TVO data systems* [31].

TVO's project instruction "*OL3-Project, Mechanical components and structures, Manufacturing supervision by TVO"* [32] states that the head of the Process Engineering Office (NTP) is responsible for specifying the quality requirements for systems and components, while Quality Control (NTQ) is to ensure that the components meet the specified quality requirements. According to the guide, supervision is subdivided into 4 categories, of which category 1 is the most stringent. In the guide, the EDG unit is assigned to category 2, meaning that inspection tours focus on the early stages of the manufacture of main systems and components. The construction inspection is one of the measures normally required for this category.

4.4 Requirements concerning skills and competence

TVO's OL3 Quality Manual [30] states that when people are recruited to the project organisation, the required qualifications must be specified in advance; further, it must be established that the successful candidates possess sufficient skills and competence for the position involved. Induction of new staff members must also include an introduction to the organisation's quality management system.

According to Guide YVL 5.1, section 2.4, the manufacturers of diesel engines, generators and auxiliary systems important to their operation as well as their subcontractors shall have sufficient qualifications for the design and implementation of the work, appropriate facilities and tools, qualified staff and a well-functioning quality management system in order to ensure reliable operations [1].

5 Supply chain for the OL3 emergency diesel generators

5.1 Period preceding the OL3 Plant Contract

Framatome ANP (FANP, currently Areva NP) carried out the conceptual design of the emergency power system as part of the concept development of the EPR plant. At that point,

the focus was not on the technical details of the EDG diesel unit or in the EDG procurement process; instead, the estimated required power, size and space requirement, layout, and estimated cost of the diesel units were the primary concerns.

TVO published the invitation to tender the construction of a new nuclear power plant unit in Finland in early October 2002. Presumably, FANP requested from EDG manufacturers not only technical data but also preliminary price information for preparing the price of the tender of OL3 Plant.

5.2 OL3 Plant Contract between TVO and CFS

TVO signed the Main Contract on the OL3 plant with a consortium Framatome ANP–Siemens AG on 18 December 2003. The contract foresees an 'EPC delivery' (Engineering, Procurement, Construction). In the way of implementation according to EPC approach, and in the EPC contracts, the equipment specifications provided by the buyer are functional. With regard to EDG, the OL3 Plant Contract merely specifies compliance with the KTA 3702 Safety Standard and YVL Guides. There are no other specific requirements in the Plant Contract regarding the EDG system. Procurement and quality management in respect of EDG diesel units is to be governed by the general provisions of the Plant Contract.

The OL3 Plant Contract between TVO and CFS contains a list of preferred sub-suppliers. For EDG, the contract lists seven suppliers. The stipulation is that CFS can select the supplier from the listed companies at its own discretion. TVO's approval would only be required if the supplier is chosen from outside the list. Conversely, if TVO wants a supplier other than that selected by CFS, TVO would be required to pay compensation. These stipulations for deviations were not used in the course of procuring the EDG.

5.3 EDG supply contract between FANP and SEMT Pielstick

Within the CFS consortium, the EDG system belongs to the scope of supply of FANP (later Areva NP). After the signing of the plant supply contract, Areva commenced basic design and procurement of the EDG system specifically for OL3. To prepare the design and technical specifications, Areva assigned Sofinel, a French company, which is a joint venture of Areva and the French electrical energy company EdF (Électricité de France). Sofinel is specialised in the design of French nuclear power plants intended for export and in the provision of design assistance. Actual procurement was taken care by Areva.

One of the first actions was to invite budgetary tender for identifying and pre-selecting the potential suppliers. For this purpose, only very general input data were provided, such as the required power of the diesel generators and a definition of a 'standard delivery'. The latter is understood to refer to a typical delivery available from the suppliers, and the practice of Areva. Two suppliers were short-listed: SEMT Pielstick (France) and MTU (Germany). MTU owned a one-third share in SEMPT Pielstick at that time while MAN was the principal owner of SEMT Pielstick. Thus, in real terms, a single party consisting of partners already engaged in mutual cooperation was pre-selected.

The first version of the Project Specification for Emergency Diesel Generator Sets for OL3 – PS 7353.1/FIN005 – was prepared by Sofinel and it is dated 7 June 2004. It is within the framework defined in this Specification that Areva has attempted to carry out the EDG procurement and supply from beginning to end. Several revisions have been made to the Specification since the first version, the current revision (early 2011) being revision K.

In June 2004, Areva invited tenders for the diesel generators for OL3 from SEMT Pielstick and MTU. Investigation group did not have details on the invitation to tender, the tenders received or the evaluation of tenders.

On 7 January 2005, Areva signed a letter of intent with SEMT Pielstick. Immediately after signing, Areva had to increase the required power of the diesel generators and requested an option for a higher capacity. Subsequently, the parties agreed on the change of the rating, which required, among other things, the addition of two more cylinders to the engine.

The EDG supply contract was signed on 24 February 2005 by Areva as the purchaser and by SEMT Pielstick as the supplier. The terms of the delivery is "ex works". Operations which are outside the scope of the contract and for which Areva is responsible include packaging, transport, installation and commissioning. Even if the responsible contracting party supplying the equipment is a single company SEMT Pielstick, the actual supplier is the consortium SEMT Pielstick—Alstom TPEG. Areva has been fully aware of said consortium and wanted to steer and organise the procurement.

The EDG supply contract is a fixed price contract, i.e. a contract for the delivery in accordance with the scope, requirements, methods, quality control measures and documentation defined in the contract at the time when the deal was closed. The contract does not contain any clear provisions for processing modifications and additions. There is only the normal contractual principle of change order that based on the purchaser´s request for change the supplier shall

submit a specific offer, including the consequences in terms of price, timetable and other effects. The changes will not be effected until the parties have agreed on these consequences.

On 27 April 2005, the SEMT Pielstick–Alstom consortium issued a proposal and first version of the Classification List for OL3's EDG equipment – PSK O3SUBP---PO001 – which has become a key document, along with the Project Specification, governing quality of the equipment and quality assurance.

5.4 Consortium SEMT Pielstick–Alstom TPEG

On 7 February 2005, just before the signing of the EDG supply contract, SEMT Pielstick and Alstom TPEG entered into a consortium agreement regarding the supply of the EDGs. According to the consortium agreement, SEMT Pielstick is the consortium leader and solely liable for the delivery towards Areva, including any sanctions such as contractual penalties for delay. SEMT Pielstick was to do the invoicing and represent the consortium for legal purposes. The FANP—SEMT Pielstick EDG supply contract is linked to the consortium agreement and obligates Alstom and SEMT Pielstick to comply with it. As far as scopes are concerned, the shares of the consortium partners are as follows: SEMT Pielstick will manufacture the diesel engines and assemble the engines and generators on common base frames; Alstom will supply the other components such as generators, diesel generator auxiliary equipment, auxiliary system components as well as electrical and instrumentation equipment.

At the time when the EDG supply contract was signed in early 2005, SEMT Pielstick was a French company owned by the German companies MAN (2/3) and MTU (1/3) with the respective ownership shares indicated in parentheses.

On 6 October 2005, a deal was announced by which MAN acquired MTU's minority share and SEMT Pielstick became a wholly-owned subsidiary of MAN. The transaction was closed on 1 January 2006. At the same time, SEMT Pielstick was renamed to MAN SA, a name that has been used in reference to the EDGs ever since.

Alstom TPEG focuses on emergency diesel generators of nuclear power plants. It is a product line of Alstom Thermal Products. It does not manufacture assemblies for EDG units; instead, it acquires the products and assemblies from other suppliers or original equipment manufacturers. TEPG's contribution to the supply of EDG consists of design and procurement.

5.5 Sub-supplies ordered by Alstom

It has been mentioned by the interviewees that the EDG supply contract (and/or consortium agreement) allowed Alstom to select its sub-suppliers but Areva had a right to reject selection. Alstom has carried out the necessary basic design, prepared specifications, invited competitive bids and made the purchasing decisions independently. Procurement has been carried out in a form of purchase orders that contain references to the general commercial terms of purchase as applied by the companies. The technical documents used in this connection consist of Alstom's standard specifications and in-house materials standards. Most of the orders to the sub-suppliers were made by Alstom and even implemented by sub-suppliers during 2005–2006.

The subcontractors have not been routinely provided with the Project Specification or with the specifications for the quality documents required of the suppliers and of the product to be supplied.

Alstom has made around 27 orders, of which at least nine go further to the next level of suppliers who, in turn, need to rely on other manufacturers or other sites of a global company (e.g. ABB) for component deliveries. The orders received by the suppliers at the end of the chain have not indicated that the ordered item is intended for a nuclear power plant, not to say anything about the quality requirements specified at the front end of the supply chain.

The control of sub-suppliers was based on the Inspection and Testing Plan (ITP) drawn up for the piece of equipment (or assembly) and involvement in specific witness and hold points in course of its implementation. In this, Alstom relied on service providers such as Lloyds and Bureau Veritas. The final documentation including the quality documents are meant to be compiled and delivered in the folder of an End of Manufacturing Report (EOMR). According to Alstom, the EOMRs have been duly submitted to Areva and the pending issues related to them are being finalised between Areva and Alstom.

The progress of the procurement of the emergency diesel generators for OL3, related contracts and interfaces between the individual actors are presented in Annex 4 (Restricted).

6 Findings

6.1 EDG supply chain

Findings regarding management of the supply chain

TVO and Areva did not use efficiently the existing tools for managing the flow of information in the supply chain and for ensuring uniform interpretation. Although Areva held kick-off meetings with MAN, Alstom and their sub-suppliers at the beginning of the projects, communications were not followed up after that. Communications were also hampered by the commercial disputes between Areva and Alstom, which were at least partly due to the large number of changes made to the specifications included in the first contract. Evaluating the effects of the changes required much extra work on Alstom's part and resulted in additional costs. Alstom serves as the consortium's ´Communication Lead' handling directly communications with Areva. Communications were signed "*On behalf of MAN*". MAN and Alstom are equipment suppliers while Areva itself is responsible for the entire EDG.

The sub-assemblies procured from various sources meet with each other only at site during the installation. Areva has purchased the installation work as a separate sub-project.

EDG supply contract between FANP and SEMT Pielstick

The EDG supply contract gave to the supplier side a strong position.

The Project Specification was amended four times even before the EDG letter of intent was signed. This indicates that basic design had to be completed before making the contract.

The supply contract was based on not enough specified information and requirements that were not adequately specified as concerns technology, quality management, verification of conformance with requirements, quality control and quality documentation. Insufficient specifications caused problems in EDG project implementation.

Consortium SEMT Pielstick–Alstom TPEG

MAN's share in the EDG supply was clear and focuses on what MAN itself manufactured. In contrast, Alstom's share in the EDG project was far more extensive than MAN's regarding design, procurement, exchange of information and logistics. Primarily, Alstom focused on sub

supplies. Although the decision maker in the consortium is MAN, Alstom enjoys a strong position due to the circumstances discussed above. Alstom could afford to be inflexible and influence MAN's decision making.

Sub supplies ordered by Alstom

According to Alstom suppliers offering special nuclear quality, as implied in the YVL Guides, do not exist in the markets. Therefore Alstom was compelled to use series-produced components in the auxiliary systems. This issue was addressed among others at a meeting between Areva, TVO and STUK on 1 September 2006. At the meeting, Areva proposed that proven series-produced parts manufactured in accordance with relevant industrial standards could be used in certain Safety Class 2 equipment and components in the EDG systems. For the documentary proof Areva would provide a certificate of suitability for intended use and the manufacturer´s documentation to the extent required by STUK. STUK's work practice is not make any decisions on proposals made at meetings; instead, the decisions are taken in response to applications filed in writing. However, after the meeting Areva and TVO did not submit any written proposal to STUK regarding the use and qualification of series-produced parts.

6.2 Quality management

The most important observation relating to quality management is that the various actors made different interpretations of the quality management requirements based on their different experience. The YVL requirements concerning the EDGs depart e.g. from French and German practices. The biggest differences relate to the requirements for the mechanical components of the auxiliary equipment: the YVL Guides provide component specific quality control for auxiliary equipment but the practice of manufacturers is not to follow specific components throughout the manufacturing process.

Areva and Sofinel have regarded the KTA 3702 standard [2] as the governing document for EDG requirements. According to this standard, series-produced parts can be used in the EDG's auxiliary systems. Section 2.2.6 *Suitability of the Diesel Engine and its auxiliary systems* of the Project Specification [19] makes reference to section 3.6.4 of KTA 3702 [2] stating that the suitability of auxiliary systems can be evaluated by means of operating experience records and the results of type tests. If fulfilment of the nuclear safety standards cannot be demonstrated through records or type test results, specific suitability tests are required. Right from the beginning, Areva and Sofinel communicated in the Project Specification that series-produced parts will be used in certain EDG auxiliary systems and equipment, in which case quality

management actions will be determined by the inspection group to which the part is assigned to (Inspection Group 1 and 2). Areva's OL3-specific document FRA/N/100 allows the suppliers in the supply chain to propose their solutions for individual products using a graded approach to quality assurance based on safety significance.

TVO

TVO has focused its supplier control efforts on monitoring Areva's activities. Initially, TVO was not aware of the extent of the supplier chain and the large number of suppliers. The interviews conducted by the investigation team uncovered that TVO had not carried out the supplier audits prior to procurements as provided in its Quality Manual. Since 2005, audits have been carried out on a few select main suppliers during the course of the project. The audits have also been attended by STUK's inspectors. Evidently, the early audits did not produce findings that would have predicted quality management problems at later stages because the project proceeded up to 2010 without any larger indications of problems.

TVO's instruction for the OL3-Project [32] states that TVO assumes responsibility for the inspections to be carried out by the licensee in accordance with the applicable legislation. Quality Control Office (NTQ) is responsible for TVO's in-house inspections. On NTQ's recommendation, OL3 Quality Management Department (NQ) carries out supplier audits if inspection tours uncover any circumstances suggesting sub-standard management system performance. Most likely, relatively few such problems have been reported to NQ. According to the information received by the investigation team in the interviews, the NQ staff members were not always in full agreement as to when audits were required.

Responsibility for the review of the documents relating to EDG quality management rests with Plant Technology Department (NT), where quality management expertise is fairly narrow and the policies different from those applied by Quality Management (NQ), for example with regard to the processing of a sub-supplier's quality assurance plans. The main focus of NT has been on technical inspections. For the review of the documents relating to the mechanical components of auxiliary systems, TVO has retained the services of TÜV-SÜD, an inspection and certification organisation. In response to an application filed by TVO, STUK accepted that the manufacture of auxiliary equipment could be started, despite a number of pending comments, provided that no such comments had been made which prevent the commencement of manufacture according to what had been defined in STUK's decision. The large number of pending comments complicated and slowed down the processing of documentation between STUK, TVO and Areva.

In the project correspondence and at the meetings, TVO approved Areva's proposals for the quality assurance of series-produced parts. TVO had interpreted that STUK would have approved the use of series-produced parts in the auxiliary systems of the diesel generators, even without any supplementary quality assurance.

AREVA

Areva has made its own interpretations of the quality management requirements specified in the YVL Guides. Areva did not notice the importance attached to the pre-inspection procedure applied in Finland.

In its Project Specification, Areva presents the relative hierarchy of quality management requirements saying that the level of quality management is determined by the Project Specification unless otherwise provided in the YVL Guides or otherwise approved by STUK. Consequently, the activities have been in compliance with STUK-approved documents, such as the Project Specification, Classification List and specific decisions. According to Areva's interpretation, STUK has, by its decisions, accepted deviation from the requirements presented in the YVL Guides. The Project Specification relies quite heavily on the KTA 3702 requirements for qualification, particularly with regard to auxiliary system components. The investigation uncovered that the list of YVL references in the Project Specification omits reference to Guide YVL 5.3 *Nuclear facility valve units* [5]. According to Areva it was not needed because its experience is that all valves in the auxiliary systems of EDGs have been manufactured and approved as series produced.

Areva explained its interpretation of the quality control of series-produced components to TVO and STUK at several meetings (e.g. 1 September 2006). Areva did not get the impression from the meetings that the approaches proposed by them would not be acceptable because neither of the Finnish organisations (TVO, STUK) present at the meetings took a clearly negative standpoint on the proposals.

No OL3-specific quality management plans for auxiliary components were submitted to STUK as required under QR Doc 50.1. Project-specific quality management plans were replaced by the FRA/N/100 inquiry.

Areva failed to file a timely application for the approval of manufacturing and testing organisations by TVO and STUK as is required in the EDG Project Specification.

Alstom

Alstom has controlled the quality management in the supply chain in accordance with the requirements specified for the inspection groups in the Classification List. According to the classification used by Alstom, Inspection Group 1 items are sound, reliable products subjected to less extensive controls because sufficient documentation on the products are available, such as good operating experiences. Inspection Group 2 classification means that the product cannot be assigned to group 1 and that qualification requires further tests and documentation, and the control of manufacture is more strict. The use of the inspection groups is an important reason underlying the conflict between the quality management requirements for Safety Class 2 components specified in the YVL Guides and what really happened.

Areva and Alstom agreed already in the early days of the EDG project that project-specific quality plans will not be required from Alstom's sub-suppliers. The reason for this could not be determined in the interviews. However, section 4.2.3 of Guide YVL 5.2 stipulates that a quality plan specifying the quality management measures to be used shall be drawn up for the design and implementation of Safety Class 2 and 3 electrical power systems [3].

Alstom's quality plan presupposes that Areva inspects that all the contract requirements are duly fulfilled by Alstom's sub supplier and the necessary documents have been delivered to Alstom before Areva releases the shipment. The investigation team has concluded that such procedure has not been followed; instead, documents are only now being collected even though some of the components have already arrived to the plant site.

STUK

At the beginning of the project, STUK did not fully realise the importance and governing nature of the Project Specification and Classification List. The YVL Guides do not require the Project Specification and Classification List. The document reviewers at STUK held it self-evident that control and monitoring is always based on YVL Guides in every step of the way. The division of components into inspection groups 1 and 2 used in the Classification List was ignored; instead, the reviewers relied heavily on Safety Classification (SC2) and on the examination of the construction plans of individual components were required under safety classification.

While STUK had listened to TVO's and Areva's presentations on the quality management principles applied to series-produced parts, it did not take any position on the use of such parts. Series-produced items have been discussed in the pressure equipment working group,

executive meetings, etc. The interviews gave the impression that there was no consistent perception of STUK's internal position on the use of series-produced parts in the EDG system.

In its correspondence with STUK, TVO did not clearly indicate that it was appealing for Safety Class 2 components such procedure which departed from the YVL Guides. One of the consequences was that STUK approved documents that were applied more extensively than was intended by STUK. EDG-related documents have mostly been reviewed by experts in mechanical and/or electrical engineering with the result that the review of quality management was limited.

6.3 Management of the requirements

Defining the requirements has proved to be a big problem between the various parties. At the time when the Project Specification was reviewed, the input data had not been defined to the required level of accuracy because the Project Specification and system description were addressed in the wrong order. The system description had not been approved in its entirety: only the sections essential to the review of construction plans had been dealt with. The interpretations of the level of the requirements diverged because the discussions on the requirements between the parties were not exhaustive enough. In particular, the requirements concerning auxiliary components were insufficiently defined.

Another issue that emerged in the interviews was that the requirements presented in the YVL Guides are not unambiguous in all respects and can thus be interpreted differently. Requirements have been issued in several YVL Guides, which makes it harder to manage the overall wholeness. Additionally, the YVL Guides provide different approaches for different type of structures and components, for example concerning submittal and approval of construction plans with respect to commencement of manufacture [7, 33]. Official English translations are not available for all YVL Guides. In particular, a translation was not available for the Guide YVL 5.1 that deals with the EDG's.

6.4 Review of design documents

The document control did not proceed according to the normal stages because the system description was provided after the Project Specification and manufacture began before the final approval of the construction plans. The number of construction plans related to the EDG units is very high. The documents have been of poor quality and a large number of shortcomings have emerged; for example, strength analyses, drawings, welding documentation and even basic dimensioning data have been missing. In STUK's view, the

entire review process has been characterised by the large volume and poor quality of the documents right from the beginning.

The poor quality of the documentation has also created problems in TVO's in-house reviews. However, TVO should have identified the deviations from the YVL requirements in its own reviews instead of just passing on the documentation for approval by STUK. As it was, TVO's reviews appeared superficial as if the aim was just to carry out them as quickly as possible. As a result, the review process has not met TVO's own quality standards.

For the review of the construction plans of the auxiliary components, TVO obtained support from TÜV-SÜD because of its expertise in the German KTA standards. The assignment to TÜV specifies the reviews to be carried out against the EDG Project Specification and the KTA 3702 criteria (not the YVL requirements). Judging from the large number of STUK's comments and observations, it may be concluded that TÜV did not give sufficient consideration to the component-specific requirements presented in the YVL Guides [e.g. 5, 6], nor did TVO take due account of the YVL requirements. The documents submitted to STUK subsequent to the review by TÜV contained a large number of comments. STUK found further points to comment, and TVO failed to give timely responses to the comments. Manufacture was started prematurely although the documentation was defective and not approved by STUK. Possibly, the review of the design documents was relaxed as a result of the Inspection Group classification introduced by Alstom/Areva.

STUK did not return to TVO any of the documents submitted for approval with a request to correct them before starting review, even though many of them failed to satisfy the requirements specified in the YVL Guides. In the course of the review process, the documents were approved subject to numerous additional requirements and comments because a large amount of work had already been done and returning documents was not the customary procedure. The reviews were carried out by several inspectors, and many of them with little regulatory experience. The review of low-quality documentation taxed STUK's resources considerably, and actually STUK conducted review work that should have been done by TVO and Areva.

6.5 Technical implementation

As far as technical implementation is concerned, manufacturing problems were encountered, among other things, in the machining of connecting rods and in the design and manufacture of fuel tanks. Non-conformance reports addressing errors in manufacture were filed in

connection with audits performed by TVO in 2010 at Alstom and its sub-supplier Jeumont Electric.

In the 100-hour type test of the emergency diesel generator, two fuel injection nozzles failed due to unsuccessful heat treatment [34]. STUK's view of the success of the type tests differs from that of TVO, Areva and the diesel engine manufacturer. STUK finds the type test unacceptable and has therefore required supplementary tests to be carried out on the plant site.

According to the interviews, the construction inspections of the actual diesel engines have gone smoothly. The problems relate mostly to the quality of the documentation and manufacturing of the components for the auxiliary systems and equipment.

TVO's, Areva's and Alstom's experts are confident of the technical and functional compliance of the diesel units with requirements. It is assumed that sufficient testing of the diesel units can be carried out on the plant site. At this point, problems are mainly perceived in the incomplete documentation, a concern that Areva and TVO are currently resolving. TVO has requested from Areva an account on the diesel units' conformance with the requirements. Verification of the required level of quality in the absence of adequate quality assurance procedures is felt to be a problem that will be aggravated in the course of the project.

The supply of the EDG instrumentation and control system is about to begin, and many of the interviewees consider that it will pose a significant risk to keeping the schedule.

6.6 Skills and competence

EDG was one of the first OL3 subsystems to be procured and implemented by Areva. With no nuclear power plants built in Europe for a long time, the parties involved lacked sufficient experience in procurement and project management. The lack of experience applies to all the main parties of the project, i.e., Areva, TVO and STUK.

Areva was unfamiliar with Finnish legislation and the requirements of the YVL Guides, and was very much left on its own to get familiar and interpret the regulations. The interviews suggest that TVO did not take a very active role in the interpretation of the YVL Guides. Moreover, Sofinel – the design organisation retained by Areva to prepare the governing documents for the EDG project, such as the Project Specifications – was probably not familiar with the Finnish YVL Guides to the required degree, either. Based on the interviews, the documentation produced by Sofinel was of poor quality and implied some inexperience.

Since the EDG project has been going on for years now, many people in all the organisations have been replaced and these changes have contributed to gaps and lack of continuity in the skills.

Both in the Plant Technology and (NT) and Quality Management (NQ) Departments, there are several consultants hired by TVO who, according to the interviews, are not familiar enough with the quality management requirements presented in the YVL Guides, nor with the duties and responsibilities of TVO's various organisational units. The body of administrative and operating guidelines created by TVO is very extensive and to manage it is a true challenge to any individual.

At STUK, the review of the documents relating to the EDG auxiliary components is found to serve as efficient induction for new inspectors since the technical features of the assemblies are fairly conventional.

6.7 Organisation and project management

Organisation and project management at TVO

At TVO, the emergency diesel generators and their auxiliary systems have been the responsibility of the Electrical Engineering Office (NTS). At the beginning of the project, the reviews of the documentation related to the EDG project were carried out as routine expert assignments within TVO's line organisation. In the spring of 2007, TVO's Electrical Engineering Office hired a consultant to serve as an expert and review the documentation on diesel generators and their auxiliary systems with regard to electrical systems as well as to coordinate the exchange of EDG project documents on a full-time basis. In the autumn of 2009, another full-time consultant was hired for the EDG project in the Electrical Engineering Office.

With regard to mechanical systems and components, the EDG construction plans have been reviewed by TVO's Mechanical Components Office (NTM) where one technical expert working as TVO's consultant has been involved with the EDG project since late 2007. As a result of the reorganisation carried out towards the end of the summer of 2008, the responsibility for all systems issues was assigned differently within the TVO organisation, leaving mechanical components and piping remaining as the main duties of the office. Additionally, since 2009, reviews of the documentation on mechanical systems have been carried out by TVO's subcontractor TÜV-SÜD, who has been reviewing the auxiliary system documentation against the KTA 3702 standard and EDG Project Specification.

Responsibility for quality assurance has rested with Quality Management (NQ) that is in charge of TVO's audit activities. Over the years, several quality assurance engineers, mostly TVO's consultants, have participated in the sub-supplier audits in the course of the EDG project. Responsibility for supplier approval has rested with Project Management (NP) and responsibility for quality control with Quality Control (NTQ) which is subordinated to Plant Technology. Previously, responsibility for the approval of suppliers in the OL3 project rested with Procurement (NL).

No specific individual responsible for the EDG project has been designated by TVO. While the Electrical Engineering Office has been nominally in charge of the project, each technology sector has, in reality, managed its own area more or less independently without anybody being assigned firm responsibility for the entity. As far as mechanical systems are concerned, overall management is even more fragmented because TÜV has also been performing its own reviews independently. TVO's mechanics experts, as a rule, have not examined the comments received from TÜV; instead, the comments have been forwarded to the plant vendor without review. Except for audits, NQ's role has remained relatively vague because TVO's main focus in the project has been on the review of technical documents.

Another factor complicating overall management and blurring responsibilities is that correspondence from TVO may have been sent either through the Electrical Engineering Office or Mechanical Components Office depending on which is primarily responsible for the reviewed document. Additionally, the document review process put in place by TVO contributes to the dispersal of responsibility: documentation review is carried out using an electronic document management system (Kronodoc), in which each reviewer enters their comments according to their respective area of expertise. After this, an assistant prepares a summary of the comments and encloses it in a letter sent to the plant vendor. Each expert has only answered for his or her own area without the overall responsibility for the technical systems being assigned to anybody.

In the absence of a project organisation and clear-cut meeting and reporting procedures, internal communications in the EDG project between the individual areas of technology within TVO have entirely depended on the activeness of the individual experts participating in the project. Although a degree of cooperation was exercised, it should have been much closer in the opinion of all the parties.

In order to ensure comprehensive management of the EDG procurement, TVO initially considered the possibility of establishing a sub-project for this purpose; however, no decision

to this effect was made. Managing an extensive project embracing several fields of technology without a clear-cut project organisation, responsibilities and reporting procedures has thus proved to be extremely complicated.

TVO's guidelines [30] obligate each individual working on the OL3 project to immediately report all failures to meet the safety and quality requirements or non-conformances in the organisation's activities to the immediate superior. According to the information gathered during the investigation, the OL3 Project Management did not react to the problems encountered in the course of the EDG project.

Organisation and project management at Areva

In Areva's organisation, responsibility for the EDG project is divided between three departments: Engineering, Procurement and Inspection subordinated to Quality Management. At Areva, the EDG project as a whole has been coordinated by a project engineer who is a liaison between the in-house departments on the one hand and TVO on the other. The project engineer used to work in Erlangen, Germany, up to the summer of 2010 when the position was relocated to Olkiluoto, Finland.

Areva's Engineering Department has been responsible for coordination and monitoring related to technical design documentation in the EDG project. One to three technical experts from the Engineering Department, mainly representing electrical engineering, have been involved in the EDG project depending on the period of time involved. Up to the end of 2009, the design work for which Areva is responsible, such as the preparation of project specifications and system descriptions, was handled by Sofinel in its capacity as Areva's consultant. Areva's own technical experts have been working in Erlangen, Germany, whereas Sofinel is based in Paris, France.

Responsibility for manufacturing control in the EDG project rests with Areva's inspection team. Additionally, the inspection team was tasked to ensure that the suppliers had at their disposal all the documents and requirements necessary for manufacturing. The inspection team is based in Paris.

Responsibility for the preparation and monitoring of subcontracts rests with Areva's Procurement Department. For each sub-supplier, Areva has designated a specific responsible individual (expeditor) in the Procurement Department who handles contacts with the sub-supplier in all matters affecting the contract. For example, all changes to the documents or requirements made after the signing of the contract have been forwarded from Areva to the

equipment supplier via the Procurement Department. The Procurement Department operates in Paris. Other parties involved in supplier evaluations and monitoring include the team responsible for manufacturer evaluation under Areva's Quality Department which, among other things, maintains and updates the list of approved suppliers, and the team responsible for non-conformance monitoring.

As far as design is concerned, Areva's role has mostly been limited to overall coordination. Up until late 2009, Areva's in-house organisation did not carry out any design work related to the EDG project; instead, all the system design for which Areva is responsible was subcontracted to Sofinel. With regard to construction plans, design has been carried out by Alstom and its sub-suppliers as part of the EDG supply.

The individuals responsible for the EDG project at Areva have changed several times. Over the past six years, five different people have served in the position of the project engineer. Similarly, four different individuals have been responsible for contract monitoring in the Procurement Department. All the replacements have not been due to retirement or change of employer. Many of the former expeditors are still in Areva's employ, but they have been transferred to new duties in the middle of the project. Recurring changes of responsible individuals complicates management and blurs overall project responsibility as the individuals assume it for a short time only.

Despite the fact that Areva had an EDG project organisation in place, the investigation suggests that the overall entity has not been managed effectively.

Organisation and project management at STUK

STUK never established a specific diesel sub-project. As a result, the review of mechanical and electrical auxiliary components and parts has been highly fragmented without anybody having a clear responsibility or idea of EDG as an entity.

At STUK, a large number of inspectors and consultants have been involved in the review of construction plans for mechanical systems in particular. Many of them have only reviewed small portions of the whole while being unaware of other or earlier decisions related to the same subject. Additionally, most of the EDG documents were exceptionally incomplete and disorganised and responses to requests for additional information were slow in coming, which increased the time required for processing and led to situations in which individuals responsible for the review of a specific set of documents changed in the middle of the process.

STUK too focused on technical issues. Quality management resources were fairly limited and the individuals responsible for it changed in the course of the project.

6.8 Organisational interfaces and exchange of information

The exchange of information along the supply chain has primarily been handled through official correspondence. TVO submitted its own review comments and forwarded those of TÜV to Areva in letters. After processing the comments, Areva forwarded them in a written format to its own equipment supplier or design organisation for dispatch to their own sub-suppliers. The revised documents updated in response to the comments and any responses were subsequently returned backwards in the supply chain stepwise from organisation to organisation. Similarly, TVO sent STUK's decisions, complete with introduction memos translated into English, to Areva who forwarded them to its sub-suppliers when necessary.

The documentation passed along the supply chain was not clarified through meetings or discussions to the extent that would have been advisable. While Areva and Alstom held monthly meetings on EDG issues, TVO and Areva addressed them only as part of general meetings on electrical engineering systems. There were numerous other issues to deal with at these meetings, and as the technical experts responsible for the EDG project attended them only occasionally, EDG issues only received a highly general treatment. As far as the mechanical components of EDGs was concerned, there was no established meeting procedure between TVO and Areva.

To some extent, EDG issues were also addressed at the joint meetings of Areva, TVO and STUK at which Areva, among other things, presented its position on the use of series-produced parts. At these meetings, STUK did not take any standpoint on Areva's proposals because STUK does not make decisions at meetings; instead, it expresses its position in the form of official decisions. Based on past experience of similar projects, Areva, for its part, was accustomed to discuss potential differences specifically at meetings. Thus the lack of any clear-cut statement by STUK might have been interpreted as tacit consent in cases where no official written proposal was submitted and consequently STUK did not express its position at a later date.

Informal communications by e-mail, phone, etc., was limited to 'next level' in the supply chain. While informal contacts between STUK and TVO on one hand and TVO and Areva on the other are fairly good on the expert level, TVO was unable to communicate directly with Areva's sub-suppliers for contractual reasons. Similarly, Areva had a working dialogue with its own equipment supplier but not with its sub-suppliers. TVO did not invite Areva to the hearings related to STUK's decisions, which would have given the opportunity to clarify the regulatory

decisions. In the interviews, Areva expressed the opinion that a direct dialogue between STUK's and Areva's experts would have contributed to a better understanding of the issues.

In the absence of a direct channel of communication extending through the entire supply chain, it was hard to detect and correct diverging interpretations related to the preparation of requirements and to key documents. The different interpretations were reflected in that the updates to the design documentation forwarded by TVO from Areva to STUK failed to meet STUK's expectations; conversely, the comments forwarded by TVO from STUK to Areva failed to meet Areva's expectations. Instead of the issue being tackled head-on, this led however to a new round of correspondence through the same channels of communication up and down the supply chain, which did nothing to clear up the situation.

At the same time, the flow of information between Areva and Alstom was hampered by contractual ambiguities; as a result, Areva was unable to provide Alstom with the latest versions of the requirements. Consequently, Alstom's sub-suppliers did not receive them, either.

Areva is currently in process to assess the performance of its sub-suppliers and also evaluates the situation in view of the latest requirements in force between Areva and TVO.

Because of pressures in schedule, the various parties have been in a hurry to proceed with the project. The large number of pending issues or the differences in the views of the parties have not been an adequate reason for TVO and Areva to halt the project for the time required for clearing up the matters; instead, clarification of the pending issues has been pushed forward by resorting to various temporary procedures. The language and style used in the correspondence has not always been unambiguous in every respect, and the findings of investigation team and the interviews suggest that the headings of TVO's letters have sometimes been even misleading.

7 Conclusions and recommendations

7.1 Procurement of technical equipment for nuclear power plants

Basic design and engineering before signing of the supply contract

The basic design phase was of short duration and in the course of design technical details were not adequately addressed. TVO did not follow actively the implementation of basic design but was passive in is role as the buyer.

The contract and the main points of the YVL Guides and the KTA standard were not 'deciphered' in plain language in order to make it clear what was actually expected for providing adequate proof of suitability and fulfilment of quality requirements. The quality assurance measures were not planned to be implemented throughout the manufacturing life cycle (including pre-inspection procedures) but most of the verification of quality was to be conducted after completion of manufacture.

Recommendations:

1. Basic design and engineering stages should be carried out with care and enough time should be reserved for it. Basic design should generate comprehensive technical specifications, quality control specifications, specifications for the documents required for regulatory oversight, and specifications to demonstrate conformance.

2. The licensee should review the results of basic design provided by other parties. The licensee should, already in the basic design stage, prepare a framework document specifying the quality control and regulatory oversight measures to be carried out in accordance with the YVL guides and other national regulations.

Supply contract

The supply contract was based on too limited, incomplete or entirely unspecified information and requirements (regarding technology; quality management; demonstration of conformance; quality control and its documentation during manufacture; timely communications; final documentation; elucidation and clarification of YVL Guides, etc.). While the contract does not provide clear stipulations (formal frame), the parties were nevertheless able to agree on the first change order flexibly enough. From Areva's point of view, the contract is disadvantageous. Later on in the course of the project, the supplier gained the advantage since it was entitled to additional compensation for even the smallest changes. Another thing affecting the management and progress of the project was that Alstom was not Areva's contracting party. Instead of the completed operating entity, the EDG contract concerned just sub-assemblies for it. Overall responsibility for the EDG entity rested with Areva.

The EDG supplier chain proved to be extremely long and complex. The licensee was not aware of the companies included in the supply chain, nor did it have procedures in place for supervising suppliers that provided a wide range of different products.

Recommendations:

3. When assemblies comprising parts from several fields of technology are procured, preference should be given to a supplier who himself is capable of managing the entire supply and all the sub-suppliers necessary for its completion.

4. The contract with the supplier responsible for the complete assembly of equipment (such as an EDG) should specify among other things:

    - technical requirements for the complete assembly;
    - a preliminary component-level technical breakdown of parts to serve as a basis for classifications (safety, quality, seismic, ...) and quality specifications;
    - the quality management requirements generated in the basic design stage and quality management requirements for the manufacturing stage, including scheduled control measures to be carried out by the licensee;
    - the requirements concerning the documentation of quality control results;
    - methods and timetable for the exchange of information;
    - the itemisation of licensing documents in accordance with the YVL Guide requirements.

    The licensee should review the preceding parts of the contract if it is not party to the contract.

5. When assemblies representing several fields of technology are procured, the contractual relationships throughout the entire supply chain should be clearly defined. There should be no shared responsibility at the supply contract interfaces.

6. All the key suppliers and manufacturers involved in the supply chain should be known to the licensee and their ability to deliver should be evaluated according to the safety significance of the part to be supplied. All the companies in the supply chain and the range of their mutual relationships should be categorised taking into account their importance for safety. The starting point is that all the individual suppliers and manufacturers are governed by specific criteria based on the safety significance of the component to be delivered and/or manufactured regarding acceptance and manufacturing control.

Organisation and project management

No specific EDG project with clearly defined duties, responsible individuals, and reporting and communications procedures was established either by TVO or STUK. As a result, overall responsibility was dispersed with no one responsible for the entity. Although Areva had a

project organisation in place, the recurring changes of people during the project had a disadvantageous effect on its performance. In all the organisations, the project was led by experts in electrical engineering with the result that the necessary mechanical engineering expertise was initially insufficient. The role of experts in Quality management and control has been small throughout the project.

Recommendations:

7. The licensee should be required to allocate adequate resources and a sufficient number of in-house personnel to key duties in order to be able to manage the procurement of the assembly of equipment.

8. For the planning and implementation of projects involving several fields of technology, a special working group or sub-project should be established where the exchange of information, responsibilities and division of duties are clearly defined, and where all the needed fields of technology and quality management expertise are duly represented.

9. Strong project management skills are required in a project involving several fields of technology. The adequacy and suitability of the expertise required for the project should be reviewed on an on-going basis during the project. New resources should be provided when necessary.

10. At the beginning of the project all the key parties to the project should be introduced to the national legislation and regulations and steps taken to ensure consistent interpretation.

    a. The licensee should introducte suppliers and subcontractors to Finnish safety requirements and regulatory procedures. During the course of such induction, due consideration should be given to the previous experience of the various actors and provision of information on the background for the requirements, etc., in order to avoid diverging interpretations.

    b. The plant vendor should ensure that all the national requirements it has defined are understood and fulfilled regardless the country where equipment and their components are manufactured.

11. In case of personnel changes, steps should be taken in all prolonged projects to ensure proper induction of new people to the project and related operating procedures.

7.2 Design documents

Defining the applicable requirements created problems between the various parties already in the initial phase. As a result, the interpretation of the requirement level was inconsistent - and that was specifically highlighted in the case of auxiliary components. No discussions to clarify the level of requirements were conducted between the parties. As a result of the inadequate determination of the requirements, the design documentation was incomplete and of poor quality. The review of the documentation has taxed STUK's resources considerably as it has conducted review work that should have been done by TVO and Areva.

The Project Specification prepared by Areva was not detailed enough to steer the EDG project. The YVL requirements specific to individual pieces of equipment such as valves, pumps and electric motors, were not taken into account. The Project Specification and system descriptions were reviewed in the wrong sequence. The final system description has not yet been approved in all respects even today. Approval from STUK is a prerequisite for granting the Operating License for the plant.

At STUK, the governing nature of the Project Specification and Classification List of components was not fully understood; instead, STUK expected the construction plans to provide the detailed design data. STUK's starting point was that the project would be governed by Guide YVL 5.1 [1] and component-specific YVL Guides such as 5.2, 5.3, 5.5 and 5.7 [3-6]. According to the interviews, however, room for interpretation is left regarding the YVL Guides and their application. It is obvious that YVL guides meant for individual big valves and pumps are not well applicable for small pumps and valves used as auxiliary equipment in the EDG.

The division of components into inspection groups 1 and 2 as defined in the Classification List was overlooked at STUK, which expected the manufactures to comply with the requirements based on the Safety Classification presented in the YVL Guide. However, the safety classification did not have any tangible impact on quality management.

Recommendations:

12. The design documents should be clear and expressions leaving room for interpretations should be avoided. Interpretations should be confirmed by direct talks and meetings.

13. The shortcomings detected in reviews should be systematically followed-up and underlying causes identified.

14. The licensee or the regulatory body in the end should return design documentation containing significant shortcomings and should demand improvement in its quality before starting the detailed inspection.

15. If the licensee submits to STUK design documents not specified in the YVL Guides, the purpose of such documents should be clearly stated and clarified. STUK should only acknowledge receipt of the plant vendor's and licensee's in-house guidelines as informal documents because their approval may lead to problems with interpretation later on.

16. When new YVL Guides are drafted, special attention should be paid to the clarity of the requirements and the potential for misinterpretation should be minimised. Due notice should be taken of the fact that the regulatory practices may vary considerably from one country to another, which only makes it harder to understand the requirements.

7.3 Manufacturing and its oversight

The documents used for controlling the EDG project have not been unambiguous for the oversight of component manufacture. In particular, confusion was created by Inspection Groups 1 and 2 in relation to Safety Class 2. The concept of the Inspection Group has only been applied to OL3 EDG and nowhere else within the OL3 project, or in any other deliveries by Alstom or Areva. The Inspection Groups have been derived from KTA 3702 section 3.6.4 *Suitability of the Auxiliary Systems and the Instrumentation and Control Systems* even though the concept of the Inspection Group is not, as such, used in that section[2].

The requirements in guides YVL 5.3 and YVL 5.7 for the EDG auxiliary systems are more stringent than the requirements set in other countries (STUK's survey of 7 February 2011 for OECD/NEA/CNRA/WGOE member countries and interviews). According to the interviewees, there are no suppliers offering auxiliary system parts for EDGs that meet the requirements as written in those YVL guides. It is conceivable that Areva applied the graded approach as defined in section 4.1 of FRA/N/100 [24] by the introduction of Inspection Groups 1 and 2, which were then used for defining the quality requirements for the components. The division into these two classes was made by Areva's supplier Alstom. The application of the inspection groups is a procedure that deviates from the YVL Guides, something that would have required an application for specific approval from STUK. No such application was ever filed.

Recommendations:

17. When a component is assembled from a number of separately manufactured parts, its technical itemization must define the functional importance of each part: important if the

part, upon failure, impairs the reliable operation of the entire component / less important if it does not influence the operability. Even if an important component were series-produced, it must meet the same rigorous quality requirements as the assembly as a whole. If the quality of a separately identified part is not documented in all relevant manufacturing stages, the manufacturer must have a quality management system that proves in a credible manner that all products of the same manufacturing series meet the same quality requirements. The implementation of the quality management system has to be verified by auditing the manufacturing process at the level of shop floor. For manufacturing of less important parts, a solid industrial practice can be applied.

18. If series-produced components or parts of components are intended for use in the safety classified systems, the Licensee has to define a methodology for assuring their adequate quality. Similarly, STUK should take a stand on the issue and lay down its clear requirements in the YVL Guides. In the same connection, the prerequisites for starting manufacture should be defined.

19. When necessary, STUK should use its right to revoke decisions that have been found to cause misinterpretation. Prompt action should be taken in response to any observed confusion to ensure that the decision is adjusted.

7.4 Quality management

The EDG supplier chain proved to be long and complex. Alstom had almost 30 subcontractors, of which around ten extended to a lower tier of suppliers and further to part-level suppliers. The supplier control exercised by each organisation focused mostly on the subsequent step of the supply chain. Not enough resources were assigned in the supply chain to quality management during manufacture. The supply chain had limited understanding of the OL3 project and Finland's national regulations.

TVO has not had a specific supply control plan of its own for monitoring the EDG delivery. According to the interviews, TVO has been passive in supervising the supply chain. Although a few audits were carried out, they were not timely and were not effective. The role of Quality Management department (NQ) in overseeing the supply chain remained small. The exchange of information and cooperation between Plant Technology department (NT) and NQ was less than efficient. The large number of pending issues indicates that supervision was insufficient and it was not conducted at the right time.

Recommendations:

20. The licensee should assume an active role in overall control of the delivery. The licensee should, already in the planning stage of the project, prepare an oversight plan for the delivery addressing project management issues (control of schedule, cost, progress, documentation and exchange of information) as well as QA/QC measures. The plan should also take into account the required regulatory oversight.

21. In order to ensure due compliance with the requirements, the licensee and main supplier should prepare project specific quality management plans for each sub-supply and ensure –through on-going supplier oversight based on safety significance – that all parties to the supply chain act in accordance with the requirements.

22. Adequate quality management and implementation skills should be ensured throughout the supply chain.

7.5 Communications between the parties

The exchange of information up and down the long supply chain has primarily been handled through official correspondence and the written documentation was interpreted differently in different organisations. Misunderstandings were not detected on time - some were completely undetected - and the correction of even those misunderstandings that were detected was inefficient because the corrective message were sent up and down the same chain. In many issues, communications between STUK and Areva only took place through correspondence via TVO. The channel for the exchange of information has not been adequate for a full understanding of STUK's requirements and the YVL Guides.

The documentation submitted was not equivalent to the purposes intended in the YVL Guides either by content or scope. In its correspondence, TVO did not clearly identify the issues for which they were seeking STUK's approval, while STUK, in turn, did not clearly indicate the issues it approved and the issues in respect of which it took no position. Processing by STUK took often a long time, sometimes even a year. As a result of poorly managed correspondence, decisions were interpreted and applied differently from what STUK intended. It seems that manufacturing went ahead according to its own schedule, while approvals were received concurrently or afterward. The reviews by TÜV were carried out in reference to KTA requirements with little consideration for the YVL requirements.

A large number of inspectors, reviewers and consultants were involved in the process, many of whom focused on small slices of the whole without being aware of other or earlier decisions related to the same subject. Additionally, a number of people with little professional experience were involved in the reviews.

Recommendations:

23. More attention should be paid to the clarity of applications and decisions. Additionally, the licensee should ensure their correct interpretation along the entire supply chain through meetings and discussions.

24. The requirements presented should be justified by unambiguous criteria and follow the jointly-adopted guidelines. The policy guidelines and decisions should be brought to the attention of all the persons involved in the project implementation and inspections.

25. The licensee should ensure that the technical standards applied in the project, YVL Guides and regulatory decisions are available to all the parties taking part in the project and applied in a consistent way.

26. New people joining the project *en route*, including consultants, should be thoroughly familiarised with the earlier policy guidelines and documents including regulatory procedures.

7.6 Safety culture

In the interviews, TVO's, Areva's and Alstom's experts were confident of the ultimate conformance of the technical and functional compliance of the diesel units with requirements. The main problem as perceived by them was the incomplete documentation - a concern that Areva and TVO are currently investigating. Verification of the required standard of quality in the absence of adequate quality assurance procedures was felt to be a problem that will be aggravated in the course of the project. The EDG instrumentation and control system supply is just beginning, and many of the interviewees consider that it will pose a significant risk to keeping the planned schedule.

The division into inspection groups applied in the quality control of the equipment is not based on the safety significance of the components; instead, the division is product-based. This approach is not in compliance with safety thinking or what is deemed as a sound safety culture.

The parties were in haste to proceed with the project. The resolution of pending issues and the problems detected was routinely postponed. For example, the problems found in the type tests of the diesel generators were not reported to STUK, nor were the tests repeated at the factory. Instead, a decision was made to perform supplementary tests on the plant site. Problems started to accumulate with the progress of the project; however, the large number of pending issues or the differences in the views of the parties was not reason enough for TVO and Areva to call a temporary halt to the project to resolve the matters. The licensee's actions do not convey the impression that safety would have been the first priority and timely resolution of issues would have been taken care of.

TVO's correspondence to STUK includes ambiguous applications that failed to clearly identify the issues for which approval was sought. In applications it was not clearly indicated whether it was a deviation from procedures defined in the YVL Guides. .

TVO's role in processing the documentation related to the project was passive and documents were sent to STUK for approval without TVO ensuring by its own inspections that they conformed to the requirements.

Based on the investigation, it appears that TVO has to put further efforts to improve the safety culture.

Recommendations:

27. When problems with equipment deliveries are detected and solved, the first priority should be given to safety irrespective of any time pressures and potential additional costs.

28. Quality control in the manufacture of the equipment should be organised using a classification which takes due account of the safety significance of each device in ensuring reliable implementation of the safety functions.

29. The licensee's management and key individuals should serve as an example in the commitment to safety.

30. The licensee should demonstrate that it is retaining the primary responsibility assigned to it under all circumstances. The licensee should ensure that it is able to address any sub-standard performance in the documentation or compliance with technical execution, and that any problems encountered are promptly resolved before they start to accumulate.

8 References

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9 Annexes

1. OL3 EDG Investigation. Composition of the investigation team. 26.11.2010.
2. OL3 EDG Investigation. Key findings concerning the activities of TVO, Areva and STUK. Mind Map diagram. 30.3.2011
3. OL3 EDG Investigation. Cause-effect diagram.
4. The progress of the procurement of the emergency diesel generators for OL3, related contracts and interfaces between the individual actors (Restricted).

STUK

27 May 2011