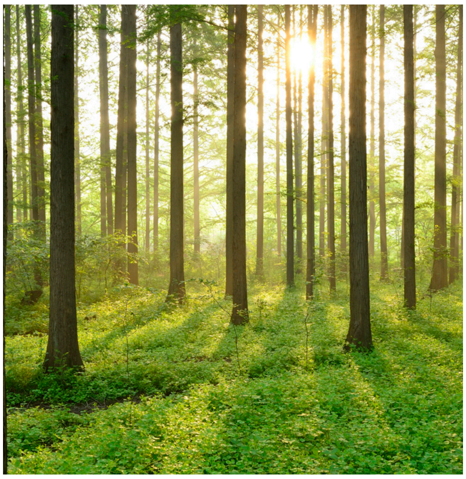
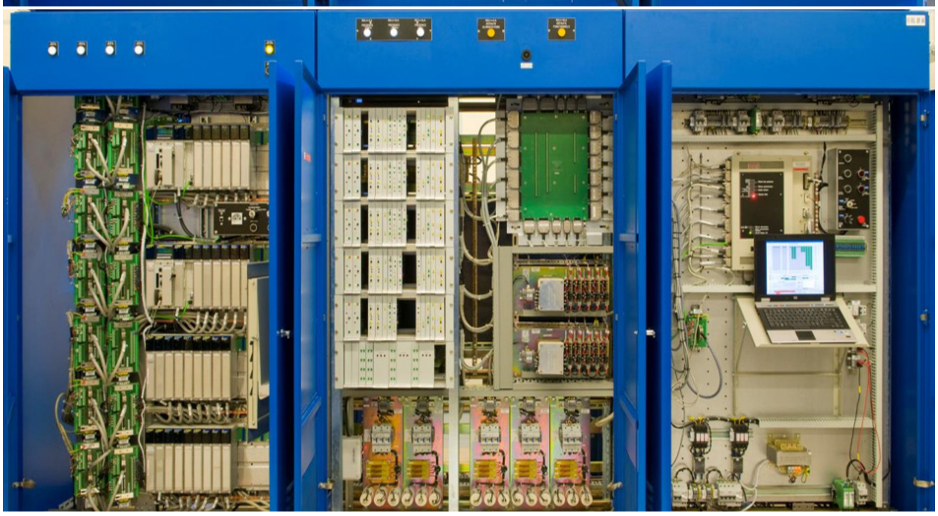
REENGINEERING AND REVERSE ENGINEERING

REPORT 2016:338



ENERGIFORSK NUCLEAR SAFETY RELATED I&C, ENSRIC



Energiforsk

Reengineering and reverse engineering

Experiences from France and UK

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Foreword

When finishing this report it is the end of a sequel of projects that started 2014. From the beginning the intent was to see how original manufacturers, OEMs, handled obsolete equipment. During the project we found that there were options to talking to the OEM, there was a whole market for so called third party suppliers that provided what the OEMs no longer wanted to do. This was the start of the upcoming projects and a very interesting new world to us. It proved to be more or less everyone but the Nordic countries who had discovered this and some countries have proved to have rather extensive experience.

During these years the discussions with the ENSRIC reference group have been many and fruitful. We have searched deep in our networks and found many contacts to use and got to know many new ones. The trips have been most interesting and we have had talks of reflection on what could and what should be done.

I would like to thank the ENRISC reference and steering groups for answering all our questions, a specially Monika Adsten at Energiforsk who have helped us with everything from valuable contacts to report templates.

The aim has been to do something to ease the pain of obsolescence issues and we hope the results and experiences we have gotten will be used within the ENSRIC member organizations!

Anna-Karin Sundquist

Sammanfattning

Denna rapport beskriver erfarenheterna från Frankrike och Storbritannien vad gäller föråldrade, så kallade obsoleta, I&C system. De närmaste åren kommer den nordiska kärnkraftflottan inträda i det som brukar kallas *Long Term Operation*, dvs perioden efter den ursprungligt beräknade livslängden. Obsolet I&C-utrustning är redan idag ett problem och kommer så fortsätta vara. Den nordiska lösningen på detta problem har i mångt och mycket gått ut på att byta ut befintlig utrustning till nya, ofta digitala, alternativ. I ett tidigare projekt har det undersökts hur man hanterar åldrande I&C-utrustning i USA och då drogs slutsatsen att det inte alls var nödvändigt att byta ut I&C-systemen, men att det fanns möjligheter och metoder att bevara befintliga system, ref [1].

Detta projekt är en efterföljare till ovan nämnda undersökning av den amerikanska marknaden samt motsvarande undersökning av europeiska sätt att hantera obsoleta I&C-system, ref [1] and [2]. Syftet har varit att undersöka franska och viss mån brittiska erfarenheter.

I korthet kan sägas att lösningarna i både USA och Europa liknar varandra i stora drag; återkonstruktion (re-engineering) och omvänd konstruktion (reverse engineering) används återkommande. I en jämförelse mellan Tyskland och Frankrike kan man till exempel se en skillnad i hur man värderar vikten av att ha originaldokumentationen tillgänglig, men den återkommande slutsatsen är ändå att det alltid är en individuell lösning som görs och som måste bedömas.

Varken franska eller brittiska myndigheter verkar motsätta sig utnyttjandet av återkonstruktion eller omvänd konstruktion på konceptnivå, utan att det handlar om att kunna uppfylla krav på kvalificering, verifiering och validering på samma sätt som för annan utrustning. Leverantörsaudits görs i enlighet med vad som görs på andra leverantörer.

Normalt sett uppstår inga problem med originalleverantören (OEM) då deras beslut att inte längre sälja en produkt redan är fattat när frågan om omvänd- och/eller återkonstruktion uppstår. Ibland kan de immateriella rättigheterna köpas eller överföras till en tredjepartsleverantör, ibland är det inte ens nödvändigt då originalleverantören inte längre finns. Som redan visats i tidigare rapport, ref [2], kan det finnas legala restriktioner kring återkonstruktion, men troligtvis inte kring omvänd konstruktion. Detta måste dock avgöras från fall till fall. De flesta tredjepartsleverantörer överlåter all kontakt med originalleverantören till kunden, men kan samtidigt åta sig att hjälpa till att tolka originalkontrakt för att säkerställa att de inte bryter mot några lagar eller avtal.

<u>Slutsatser och rekommendationer</u>

- Utredningen visar att användandet av omvänd konstruktion och återkonstruktion är något som bör utredas tillsammans med andra alternativ när föråldrad utrustning är ett problem. Det finns flertalet leverantörer med lång erfarenhet av detta.
- En faktor att noga utvärdera vid valet av lösning är hur svår och kostsam kvalificering och verifiering av det valda alternativet kommer bli.

- Ju bättre dokumentation man har, desto bättre, men dokumentationen måste också vara korrekt och relevant. Det är likaledes viktigt att projekt efterlämnar korrekt och relevant information efter avslutat införande.
- Be om hjälp att utvärdera vad som ska göras. Flera av de leverantörer som projektet varit kontakt med kan erbjuda undersökningar i vilka alternativ som är möjliga för en specifik utrusning.
- Utvärdera konsekvenserna av att inte göra någonting. Man kan naturligtvis hävda att varje ny utrustning som förs in i anläggningen också medför nya möjligheter till fel, men man ska då också betänka att åldrande utrustning också innebär en risk för fel.

Summary

This report describes the experiences from France and the UK regarding obsolete I&C equipment. The years to come the Nordic nuclear fleet to large extent will enter Long Term Operation (i.e. longer than expected from the beginning). Obsolete I&C equipment has been, and will continue to be, a problem and so far the Nordic solution has been to replace that equipment with new, often digital, one. In a previous project the US experiences of Long Term Operations was investigated and it was concluded that it was not necessary to change to digital equipment, but that there were ways of keeping existing analogue equipment in good condition, ref [1].

This project is a sequel of the above mentioned project regarding US experiences and the subsequent project to examine the European ways of dealing with obsolete equipment, ref [2]. The aim has been to investigate the French conditions and briefly the UK conditions.

In brief the solutions are very much the same as in the rest of Europe and US; reengineering and reverse engineering are used on a regular basis. A comparison between the German and French shows that the Germans demands a higher level of original documentation, but there in both cases always seems to be a possibility for individual solutions depending on the project.

As a concept neither French nor UK authorities seems to mind the use of reengineering or reverse engineering as long as the requirements on qualification and verification are fulfilled. Suppliers are audited in the same way a nuclear supplier is always audited.

Usually there are no problems with the OEMs since the decision to not continue to provide a certain product is already made when a question of reverse or re-engineering is raised. Sometimes the immaterial properties (IP) are taken over by third party vendors and sometimes that is not even needed since the OEM no longer exists. As stated in previous report, ref [2], contractual aspects could restrict reengineering, but probably not reverse engineering. This must be evaluated case by case. Most third party vendors do not contact the OEM, but leaves that to the utility owner. At the same time they help read the original contract in order to be sure that they are not doing anything illegal.

<u>Conclusions and recommendations</u>

- The investigation shows that the use of reengineering and reverse engineering are options that should be evaluated when trying to solve obsolescence problems. There are several vendors with substantial experience to perform the task.
- One of the factors to evaluate is how difficult it will be to qualify whatever replacement the project chooses.
- The better documentation the easier to evaluate the options, but the documentation has to be proven to be correct and relevant. For the same reason it is important that the obsolescence project also leaves correct and relevant documentation when finishing a project.
- Ask for help to evaluate what to do. Several of the vendors the project has been in contact with could provide the service of finding out what options that are available and make recommendations on what is suitable for this particular project.

- Considerer the consequences of doing nothing. It could of course be a risk to introduce new equipment of any kind in the facility, but then you should also consider the consequence that the existing equipment could fail due to age.

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1 Background

1.1 INTRODUCTION

The Nordic nuclear fleet of today consists of a mix of technologies for I&C equipment. A large portion of the equipment is still of conventional type but there are also new digital equipment, systems and platforms installed. In the coming years a considerable amount of systems and equipment must be replaced or upgraded because of different aspects of aging. The Scandinavian plants are in a short while entering Long Term Operation, which is operating longer than the original construction life time. This makes it important to have a clear understanding of the different alternatives of how to handle ageing in a Long Term Operation perspective. Replacing and upgrading is a challenge and the experience from recent years is unfortunately mixed.

A previous project aimed to investigate the US market and how US utilities do to manage long term operation regarding I&C and obsolete equipment, see ref [1]. In that project it was concluded that the use of third party supplier (non OEM) where more common than expected. Therefore this was investigated from a European, excluding France (and UK), perspective in the following project, see ref [2]. By this third project France (and UK) is investigated from the same perspective.

This study has aimed to investigate French conditions, but since the nuclear owner in France, EdF, also owns the nuclear fleet in the UK, the UK have also been briefly included.

A general summary of the experiences from the US trip is that nuclear I&C have similar challenges in the USA as in Europe. In the US, the utility owners to much larger extent than in the Nordic countries have been using reengineering and reverse engineering for obsolete parts or components.

1.2 ABOUT ENERGIFORSK AND THE ENSRIC PROGRAM

Energiforsk AB (Swedish Energy Research Centre) is a research and competence company, see [3]. Energiforsk has four research areas:

- Hydro Power and Nuclear Power
- Power grid, solar power and wind power
- Heating, cooling and cogeneration
- Transports and fuel

Within the Nuclear Power area, there are five research programs:

- Nuclear Safety Related Instrumentation and Control, ENSRIC
- Vibrations within nuclear power plants
- Strategic monitoring
- Civil constructions within nuclear
- Grid Interference on Nuclear Power Plants, GINO

ENSRIC is a research program focused on safety related I&C systems, processes and methods in the nuclear industry. The three focus areas of the program are emerging systems, life time extension and I&C overall. Information from the program will assist the nuclear industry and the radiation safety authorities when analysing how to replace systems and methods - choosing a new technology or finding a way to stay with the present solution - with maintained safety and promoting a low life cycle cost. Participation of a mix of junior and senior participants in the program is encouraged to facilitate knowledge transfer.

The vision of the nuclear I&C research within Energiforsk is that the activities should contribute to safe and robust I&C systems that promotes low Life Cycle Cost. The results will be used in the decision making process when choosing the technology pathway forward and also to make the implementation and maintenance process of safety I&C more efficient. The information obtained can be used in the decision making whether to renovate the existing technology in a component/system or to convert to a new technology. The program should also constitute an arena for discussion on nuclear I&C issues for plant owners, authorities, vendors and researchers.

The main focus of the program is on safety classed I&C systems, both digital and conventional analogue and relay based systems. Activities carried out can be on maintaining present systems and on replacing present systems with new equipment. Competence building activities are also included in the program. Many of those who work with I&C issues in the nuclear industry are to be retired within a few years, so there is a need for skills transfer. Because of this the research program will promote, on all levels, a mix of senior and more junior participants.

The activities are financed by Swedish and Finnish nuclear power plant owners and the Swedish Radiation Safety Authority. A steering group consisting of representatives from the financiers has been appointed, and they are responsible for the individual project decisions and follow up. Additional expert groups, for example reference groups, are appointed when needed.

Activities and projects initiated can result in reports, guides, seminars, knowledge databases, and mapping of ongoing research, depending on the need.

The project of gaining experience of reengineering and reverse engineering from Europe, including this report, are part of the focus area “Life Time Extension of Present Systems”.

1.3 SCOPE

The objective have been to retrieve experience from reengineering and reverse engineering both from a utility perspective and from companies that have commercial services and re- or reverse engineered products on the French market. The information and experience retrieved shall be used to draw conclusions in the following areas:

- Could a potential risk be introduced in the plant if a re- or reverse engineered equipment is installed?
- How could a re- or reverse engineered equipment be verified to have the same functional performance as the original equipment?
- What kinds of qualifications / license activities are necessary?
- What kind of legal or procurement issues need to be considered?

The study shall include the following tasks:

1. Identify companies and utilities that have experience from re- or reverse engineering.
2. Identify what kind of legal issues that has to be considered.

3. Identify how functional requirements are identified.
4. Identify how other requirements are identified.
5. Identify what kind of verification that has been used to show the fulfilment of identified requirements.
6. Identify any qualifications/license activities that have been performed.
7. Compile the information and draw conclusions.
8. Propose measures to be taken when re- or reverse engineered equipment is the alternative for obsolete equipment.
9. Propose actions for the next phase in this area.

2 Abbreviations and acronyms

AGR	Advanced Gas cooled Reactors
ASN	Autorité de sûreté Nucléair
CPLD	Complex Programmable Logic Device
ENSRIC	Energiforsk Nuclear Safety Related Instrumentation and Control
EPRI	Electric Power Research Institute
FKA	Forsmarks Kärnkraftverk (NPP)
FPGA	Field Programmable Gate Array
IAEA	International Atomic Energy Agency
IRSN	Institut de Radioprotection et de sûreté de Nucléaire
IP	Intellectual Properties
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NUOG	Nuclear Utility Obsolescence Group
OEM	Original Equipment Manufacturer
OKG	Oskarshamnsverkets Kärnkraftgrupp (NPP)
ONR	Office for Nuclear Regulations
OS	Operating System
PC	Personal Computer
POMS	Proactive Obsolescence Management System
PWR	Pressurized Water Reactor
RAB	Ringhals AB (NPP)
RAPID	Readily Accessible Pars Information Directory
RoHS	Reaction of Hazardous Substances
SSM	Swedish radiation safety authority
TVO	Teollisuuden Voima (NPP)

3 Alternatives of maintenance for analogue equipment

In this project is has become obvious that there is no universal definition for the terms used. Therefore definitions of the terms used in this report are explained below. Seven R: s have been identified as ways of dealing with obsolete equipment: Replace, Repair, Refurbish, Re-manufacture, Re-engineering, Reverse engineering and Redesign. In the previous report, ref [2], a thorough list of definitions was made; here it is only repeated shortly. For anyone who wants to read more the previous report is suggested.

It is not always a clear line between the different methods; it is matter of subjective decision. Things to consider are: what are changed? How many parts? How vital are they to the function? Is there a change of technology?

The most important thing, however, is to be clear upon the definition with the one you talk to!

3.1 REPLACE

Parts that are obsolete (not manufactured or supported by the OEM any more) might still be available in other places: warehouses at other vendors, spare part storage at other nuclear plants, plants that have shut down, fossil power plants, or chemical process industries or bought on the open market.

3.2 REPAIR

Circuit boards can be repaired, exchanging the broken component with an identical one (same properties, same manufacturer). This can be done either by the OEM or, if the product is out of support, by another vendor or by the utility itself.

3.3 REFURBISH

If repairing is a reactive way to maintain, refurbishing is a more proactive way. When a circuit board is refurbished, an as-found inspection and testing is performed. Components are evaluated with historical failure rates and broken as well as age sensitive components are identified and exchanged. The circuit board is cleaned up and the container/box/front cover is exchanged if needed. Then the board is tested, calibrated, burned-in and qualified.

3.4 RE-MANUFACTURE

Parts that are not manufactured any more by the OEM can be remanufactured. A small special run can be done either by the OEM or by another vendor.

3.5 RE-ENGINEERING

Re-engineering is when a third party manufacturer or OEM uses original requirements, specifications and documentations to produce new items. Some modifications might be done, typically within physical construction and/or mounting. The logical functions and layout of interconnections between discrete components are usually kept.

In France a generally known term is “cloning”. This means to do an exact copy of what you have with the information available. This means that if your equipment is defect, your clone will be defect. Some vendors only do cloning when there are two samples available, one that could be tested as reference and one that could be picked apart to see every angle. There seem to be almost no limit in what could be cloned, for example could also power electronics for circuit breakers for transformers and generators be cloned.

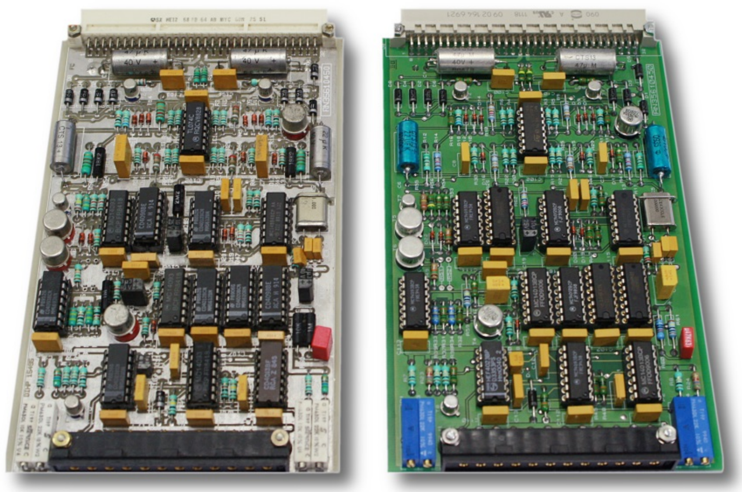

Figure 1. Cloned card (picture from GET Electronic)

3.6 REVERSED ENGINEERING

Reverse engineering is when a third party manufacturer or OEM takes an item apart to understand its functions. None or only some original requirements, specifications and documentations are available. Modifications might be done. If the logical functions and layout of interconnections between discrete components are modified, or larger modifications are made within the physical construction and/or mounting, the activity is called a black-box reverse engineering.

The functionality, size and outer connections are the same as for the old item.

3.7 REDESIGN

With all the focus on maintain the old equipment and keeping the old technology, there are some circumstances that could make a redesign or upgrade interesting:

- If the old equipment doesn’t fulfil the requirements.
- If there are economic benefits with a new technology, like increasing availability for the plant with continuous supervision, or safety benefits like decreasing the risk for radioactive pollution (i.e. fuel damages).
- If it is impossible to maintain the equipment in the ways described above.

A redesign can be carried out either by the OEM or by another vendor who then would need all documentation from the plant and the OEM and perform testing on the old equipment. Crucial to redesign is identifying all new failure modes and any differences in functionality.

3.8 SAFETY/NON-SAFETY

In this report there are numerous mentions of the terms “safety” and “non-safety”. The reasons for not always being more specific - Cat A/B/C, 1E/2E, “safety related system according to IAEA”, etc. - is that the authorities requirements are different in different countries and therefore it is not of much use to be more specific. The knowledge, and the responsibility, of the correct requirements for each system always lie with the owner. Therefore the terms are not relevant here, but the important thing to remember is to communicate what is expected from the vendor regarding this specific part.

4 Vendors, utilities and authorities

The project has talked to several vendors and utilities in order to see what needs and possibilities for reverse engineering and re-engineering there are. In this chapter there is a brief summary of those meetings.

4.1 EDF ENERGY (UK)

EdF Energy, former British Energy, is the owner of all the running nuclear power plants in the UK. They have 15 reactors at 7 locations, 14 are of Advanced Gas cool Reactor types, AGR, and one is a Pressurized Water Reactor, PWR, type, ref [6]. They have a centralized engineering organization with a special department for obsolete equipment. All the British reactors are more or less one-of-a-kind since the reactor concept has kept evolving.

EdF Energy is a member of the POMS[1] database, and their experience is that this is a good tool for large and well defined equipment, but that the data quality is of varying kind. The most important is to have the right processes in place to be able to identify and trend obsolete parts in order to be able to do a prioritization.

They have done re-engineering with the help of Thales, that is also a military supplier, and their conclusion is that it is important to have extensive experience with the supplier especially for safety related products. Another vendor in the UK is Cavendish, also a military supplier, and both Thales and Cavendish can make an obsolescence report before deciding what kind of action that needs to be taken. The EdF experience is that their advice is fair and just.

For a project to be successful it is important to have as much original documentation as possible. But there is also the experience that the documentation is sometimes in such a state that it makes no sense for this specific application. In that case the equipment could still be taken back to a re-design phase and treated as such. The mounting and components could be changed, but the less you need to change the better. The essence is form-fit-function[2] and it is generally a better option to just change the cards, without changing the connectors. If it is just certain components that need to be exchanged, that is even better.

The main regulator in UK, the ONR – Office of Nuclear Regulations, are aware of the obsolescence program and components that have been modified will go back into the system with a "change tag" as well as suitable qualification testing and documentation. If there is a lack of documentation from the beginning the ONR will demand that you don't just take care of the obsolescence issue, but also make sure the future documentation are in good shape.

EdF Energy also has experience from doing a so called *last buy* and keeping the stock themselves. This is of course a risk, since it is not always easy to keep stock, but since the OEM would stop providing the equipment this was the solution considered the best.

[1] POMS database is explained more in chapter 4.7

[2] form-fit-function means that the size, connections and functionality is retained, but the inside of the part is redesigned

No matter what solution is chosen it is a good idea to keep track of failure rates, both for new equipment and old. EdF Energy uses the statistics of the old equipment to calculate how many more spares is needed for the rest of the utility lifetime and also to evaluate if the new equipment is as good as expected.

When a qualification of component is done it could be reused in other facilities and it could also be sold to other utility owners. This is of course dependent on what kind of qualification it is, seismic qualification could only be reused if the preconditions are the same etc. EdF and EdF Energy cooperate over qualifications.

EdF Energy has recently begun to use item equivalence. They use the EPRI[3] method, but so far the experience is that for anything with logic inside the EPRI equivalence could not be used, but for simple equipment it is a good way of finding solutions.

Refurbishments are done in the utilities in their own workshops and are generally not managed on a corporate level. For the most critical equipment refurbishment is done, but for other equipment it is on a case by case basis.

For any contracts made with a third party (or OEM) there is also a maintenance clause. The standard solution is to have the maintenance guaranteed for the utility lifetime. If reverse engineering is done EdF Energy wants to own the rights to the new equipment themselves, since that gives them a guarantee to continuous supply of the equipment even if that particular provider will go out of business. All vendors have to be carefully evaluated and audited.

4.2 EDF

EdF owns all the commercial nuclear power plants in France; they also own the subsidiary EdF Energy mentioned above. France has 58 commercial nuclear power plants. They are all made of Framatome/Areva and are limited to three different kinds. 34 are of type CPY and were built during the 1970s and early 1980s. 20 of them are of P4 and P’4 kind and were built during the 1980s. 4 are of N4 kind and were built in early 1990s, ref [6]. This limited set of reactor types means that a lot of experience and strategies could be reused, and EdF have a strategy of keeping the reactor types as a like as possible within its group. Every tenth year they have a longer outage due to additional inspections for 10 new years of authorization to run the utility. During this outage there is a possibility to do maintenance and upgrade projects, but always with the intent to do the same project for the same reactor types. It is emphasized that the outages should be short and that changes could only be made during their ten year inspection outage.

EdF identified already in the 90:s that they would possibly have a problem with obsolete I&C equipment in the future and identified a handful of suppliers that was important for them to keep. They established a 20 year contract with these suppliers and an agreement that the supplier was responsible for the continuance of their agreed equipment (spares, competence, repair etc). These contracts have then been, or shall be, prolonged to last the utility lifetime. By this kind of agreements they have covered the major systems. Apart from this they have made shorter agreements on specific systems on 3-5 years. This strategy seems, so far, to have been very successful and the surprises have been few.

[3] EPRI equivalence is explained in chapter 4.7

EdF don’t use tools like EPRI equivalence, but this is not because they don’t find the service good, but rather that this part is instead upon the suppliers that they have made long term agreements with. Therefore the need for a tool like EPRI equivalence is not there.

EdF works on a long term view for how to run their utilities, and leaves the more practical aspects on how to exchange certain parts to their appointed partners.

They work according to the philosophy that most things could be repaired. Sometimes, in rare occasions, stock is kept in order to make sure the equipment is available, but most of the time this is not necessary because of the agreements mentioned above.

As far as possible the original supplier should be used, but a well-known third party supplier is also acceptable. When it comes to safety/1E equipment is it very important to have experience from the supplier. For French authorities this is very important and they have easier to accept a well-known supplier than to use a new one. They also have easier to accept a clone, with no change in the design, compared to a re-engineered piece of equipment with some changes in design. The access to original documentation is also important, the more documentation the better. If it is a safety/1E piece of equipment it is probably easier to do a new design than to try to do a black box reverse engineering. In general analogue equipment is fairly easy to handle compared to programmable equipment. In their experience a project have two major risks: the qualification and the risk of prolonging the outage due to qualification issues.

EdF does not use POMS/RAPID or any other database services, but they are instead member of group of both vendors and suppliers in oil and energy business that they exchange information with.

EdF have an I&C policy with tree principles:

1. As few changes as possible and limit the changes to strictly needed
2. If a change is necessary, make it small and with the original supplier
3. If this is not possible, investigate a broad perspective of options

They have a centralized purchasing unit for all EdF Generation in France.

EdF have done substantial research in the use of FPGA some if it has also been covered in the FPGA projects at Energiforsk, ref [5]. They have done tests, but so far no large scale exchanges to FPGA and the project has been closed without implementation.

EdF have also done tests with CPLD in a project together with Nexeya mentioned in chapter 4.5.

According to their research FPGA are suitable if the functional requirements remain the same, but if the functional requirements need to be changed another technique is suggested.

4.3 ROLLS ROYCE

Rolls Royce Nuclear consists of 2000 employees mostly based in the UK, but for the parts concerning I&C the business is mainly based in France and employ 500 people. Rolls Royce is both an OEM and provider of re-engineered/reverse engineered products. They have done reengineering/reverse engineering projects in France, Czech Republic and USA, but they don’t do refurbishment.

To be an OEM for nuclear safety systems is their core business, but providing services for obsolete equipment is a way of making sure there is business even in the future. They have for example taken over the production of the ABB biblock sensor that ABB no longer manufactures.

Rolls Royce's modernization strategies range from circuit board scale to full plant modernization with modified architecture and are roughly divided in four types:

- Equipment, Cabinet internals and Functional blocks (no change of documents)
- Specific system
- Full scale – no impact on architecture
- Full scale – impact on architecture (for ex the ongoing Loviisa NPP project)

Rolls Royce works on both safety and non-safety systems. For safety-related equipment, they can help out with (or support) the qualification work. They have experienced problems with hidden requirements, typically old equipment that do not have any requirements regarding EMC for example, but thorough testing and practical experience could make up for this however.

When it comes to component level actions, Rolls Royce does work like:

- Repair boards and supply spare parts
- Reengineering or replica reverse engineering (copy and cloning)
- Reengineer boards based on function (black box reverse engineering)
- Black box reverse engineering, starting to overlap with modernization projects.

The attitude of the OEM is one input when deciding on strategy, if they want to keep on supporting or remanufacturing the piece, or if they are willing to let somebody else work on it (so called orphan products). The utility approach the OEM of a potential piece of equipment to reengineer, but Rolls Royce look into the original contract to make sure no violence of agreement is at risk.

The strategy for a system should cover both long term and short term costs and benefits. Long term aspects could be to look at the system as a whole, and not just a troublesome card. It could be worthwhile to do a cabinet completely instead of doing the cards one by one, so you know the status of the cabinet for example.

Rolls Royce offer long term support, as one of their services. They are the owner of the spare parts database POMS that is a database and search engine that connects to the members maintenance databases and thereby have the knowledge of the members amounts of spare parts. Thru POMS the members could also buy products found in the database. 130 nuclear units are members.

4.4 SPHEREA – GET ELECTRONIC

The Spherea Group have 550 employees in Europe and the US and have a turnover of 110 million Euros. GET Electronic is a subsidiary to Spherea Group that does electronic repairs, obsolescence management, testing, cabling etc. They are 75 employees, all in France, and have a turnover of 6,5 million euros. They started in 1965 in order to provide test equipment for Concorde (ATEC). Since 2013 they are independent from Airbus, but Airbus still owns 1/3 of the company.

Spherea group is covering the entire life cycle of a system; GET Electronics is part of the last part in that cycle. GET Electronic is a spinoff of Schneider Electric and have three locations, all close to Areva. Repair and cloning are their biggest "products". They also do diagnosis of systems and manufacture system that have been repaired by GET. They also provide help to diagnose troublesome equipment and recommend what kind of action a system needs.

4.4.1 Obsolescence management

One part of obsolescence management is dealing with obsolete software.
For example if an old PC needs to be replaced it is quite common that the new PC could not handle the old OS. A solution could then be to run the old OS on a new machine using the virtual machines principle. That means to redirect the flow of communication through a port or Ethernet while preserving the behaviour, such as the cycle time for example, and original interfaces. No modification of software and original applications is done and thereby the original functions and behaviours could be said to be maintained at least for non-1E equipment. For 1E equipment the requirements are higher.

Another part of obsolescence management is cloning. A clone is done without knowledge of what functional requirements that are copied. It is not necessary to have drawings of the PCB board/card; the functional features are not dealt with. Functional requirements are only important when some components can't be identified and needs to be replaced. If the system does not behave like the original one, it is not a clone. It is possible to do a clone on a malfunction PCB board, but then the malfunction will also be cloned. Therefore you either need a functional PCB board (but not necessarily functional requirements) or a malfunction PCB board together with the functional requirements. For a board with more than 2 layers, you need one board that could be torn apart in order to get a good result. You then need a functional card in order to clone the functions right. If there is only one card left that could not be allowed to be torn apart it is possible to x-ray in order to see the different layers. To date GET Electronic could do cloning for as many as 8 layers, but the more advanced the board is, the more difficult it is to do a clone. There are in general no problems to extract and transfer data from an old EPROM/EEPROM to a new one.

Cloning of a PCB board could be done in two different ways:

- Optical – with the help of scanning the different layers
- Electrical – when the electrical result is verified. This is very powerful when you have a lot of layers.

If possible it is always best to use the same manufacturer for the components as before, but for simple surface mounted components it could be impossible to find out who is the manufacturer. For more complicated components it is generally easier to find out who is the manufacturer and then find the same.

Sometimes it seems easy to "just fix" some minor problem while cloning a card, but it could be difficult to see the consequences and therefore it is not considered a clone anymore and should hence be used carefully.

At last it is also possible to do a clone from just a picture or a visual inspection of a card/PCB board, but then there could be no functional testing or guarantee of the function.

4.4.2 Working process for obsolescence issues

0: Feasibility – main part (needs and feasibility study, risks and solutions, ROM Cost: cost analysis and quotation). After this phase there will be a recommendation on how to proceed.

1. Study and production (PCB cloning, electronic component study, replacement solution study, reverse engineering)
2. Prototype and verification and validation (procurement, prototype, non-functional test)
3. Manufacturing (Industrialization, pre-series, manufacturing, component, obsolescence management for manufacturing durability)

The cloning process involves structural tests and board not powered on, in order to guarantee only the physical identity of the cloned board toward its model. A reference test is also done on the model.

The next step is functional testing and that is normally not included in the process at Spherea GET Electronic, but could be an option if the customer wishes for that. Most of the time the customers themselves are involved in the functional testing due to their knowledge of the all the related means and wanted functions. What kind of testing that is performed is decided on a case by case basis depending on the complexity of the function and on the pre-requisites for the cloning (ie what information that is available).

4.4.3 Others

Spherea GET Electronic also do the housing and the contacts of the equipment if needed. Simple contacts and its housings could be done in-house with a 3D-printer for ex, when the contacts could not be found any more. In the future it might be possible to print entire PCB boards.

Spherea GET Electronic have a signature analyser that can do simple behaviour analysis as well as a fly probe test system that can do CAD reverse engineering drawings. They also have a functional board tester that do a screening test to identify defective components. It’s a non-regression tester with a unitary test on functions that can do limit tests and control of electrical characterization.

Figure 2. Component stock in paternoster at Spherea

4.5 NEXEYA

Nexeya Group has 1000 employees and a turnover of 130 million euros. They are represented in Europe, North America and Asia and have started a small business in Northern Africa. They have their customer base in aerospace and defence industry and in recent years an increasing part in transport and energy sectors. The Toulouse factory is dedicated to maintenance, support and testing.
The Energy solutions department is divided in four groups; *Nuclear for defence industry*, *civil nuclear and research reactor*, *conventional energy* and *Big physics*. Nexeya holds several quality certifications and have been audited by EdF and Electrabel for reverse engineering and manufacturing of boards. For civil nuclear they have done work for CEA, Areva, Electrabel and EdF for ex. EdF and Tractebel do audits every other year in order to see if they are still compliant with their quality system.

4.5.1 Obsolescence surveillance process and tools

They have their own software for obsolescence surveillance, based on Thales database PEREN[4] and their own data and customer input. With this they can make a status report for a specific component on whether or not it is obsolete. They could also provide help with “last buy order” and then keeping the equipment in stock for their customers when a certain equipment is about to be obsolete.

[4] See further information on RAPID/POMS/PEREN in chapter 4.7

4.5.2 Reverse engineering

There are three ways of working with reverse engineering at Nexeya

- Manual reverse engineering – measuring by hand the function of the board
- Automatic reverse engineering method based on 3D x-ray machine. The equipment is located in Paris and could handle as much as 14 layers on a PCB board.
- Semi-automatic reverse engineering method based on fly probe machine.

Nexeya have done reengineering and reverse engineering on both 1E and non-1E equipment and this has been approved by IRSN (for EdF). They have also done reengineering/cloning of PCB boards for Electrabel. They have extensive experience with military industry, both naval, nuclear and aerospace. They have also experience from the space industry (IRIDIUM for ex). They can do training for customers and they have test benches and could also develop specific test equipment if necessary.

Normally the IP discussions are for the customer to have; in some exceptions they have made agreements themselves. They have a legal department that normally proposes a black box approach since this avoids being accused of copying according to them.

For EdF they have also done a primary pump management and measurement unit, class 1E, as a reverse engineering project. They have used a black box approach, but with some old interconnection drawings. In this project they used CPLD technology (one time programmable) to exchange the obsolete microprocessor 6809. They did refurbishing on one old piece of equipment in order to ensure functional requirements and after that qualified the new equipment for 1E use. This piece of equipment will now go into serial production for 120 units.

4.6 CEGELEC

Cegelec Control System is a part of Vinci groupe. Vinci groupe have a total amount of 190 000 employees and a revenue of 40 300 million euros. The subsidiary Cegelec Control Systems are 1550 employees with a turnover of 10 million euros at 27 offices. Their main customers are EdF (56%), CEA (10%), and Areva (17%). They have also worked with Electrabel/Tractebel.

Cegelec Control Systems do business within 1E and non 1E systems as well as technical support on refurbishing and testing. They could also do cloning of PCB boards, but they generally don’t do single PCB boards; they rather do partial replacements instead of exchanging parts.

If the equipment lacks documentation they make a footprint of existing parts in order to have something to test against when finished. They have done projects on integrating commercial of the shelf products (COTS) into nuclear applications. For example they have done this for EdF with Schneider equipment inside an existing cabinet (reverse engineering of existing equipment).

One of their nuclear customers has a strategy of not changing a whole system, but rather critical parts of a system. Sometimes the exchange is for new digital equipment, sometimes for analogue equipment. That means that the result could be a mixed system, but they rely of an analysis about what is strictly needed and not necessarily the best. The most important factor is the cost of the qualification, since their nuclear fleet has very short payback time.

It is a common problem that there is a lack of documentation and to add on to that the wiring is not always correct compared to the drawings. The documentation could also be of general kind and not specific to that installation. Therefor it is important that in an early stage in the project evaluate the information for relevance and correctness. The status of the documentation is crucial when trying to decide how difficult or costly a project will be.

For cloning a 1E card the automated test bench is used to analyse the card. Simple components are preferred or military components, since they often have long life and durability.

The contacts with authorities are always handled by the customer. Their experience is that there is no problem exchanging equipment from the same family as long as you can prove that the behaviour is the exact same and then no requalification is needed. The easiest approach is to "stay on the same norm", that is keep to the same standards as before, because if you change norm/standard you need to do a comparison between them and adapt your solution. The adaption could lead to new requirements and then it is not the same equipment any more. For the same reason it is also often a good idea not to change the cabling, but depending on the needs that could still be done.

Whether or not new requirements could be added depends on the regulations in that country. If you change the soldering technique (due to new environmental regulations) or RoHS driven changes you need to do requalification for example.

Cegelec have their own non 1E and 1E product solution to obsolete equipment based on the former AC-132. They have invented a compact module that can be used instead of the obsolete equipment. The module exists in two versions:

- ACN – D, with digital I/O
- ACN – A, with analogue I/O

It fits in a common base 19" rack 6U.

This solution is suitable for small perimeter automation I/O functions. The equipment is classified as a module using a programmable memory, PROM, and standardized wiring that will not change and therefore the verification and validation is kept easy. It is based on software, but software that is one time writable. Only the application could be changed. If you follow the working procedure you may not need to requalify the application, depending on what level of changes that are done. The simple software relies on variable tables, modules of personalization tables and enchainment tables of modules. The application only calls on the lists inside the basic software and connects the different functions. Of course the function needs to be tested and verified and validated, but not qualified. The basic software is build one time and always identical and then qualified (in all controllers). The software is visualized graphic in an engineering station (not 1E) and you can watch it in real time working. They call this a module software. To this there is an automated test bench that does the testing. They follow both the European standard IEC and the American equivalence, IEEE. CEA have bought this kind of system for the Jules Horowitz Reactor and for the moment there are negotiations with EdF.

Maintenance and support could be bought from Cegelec, but also training in order to manage the maintenance in-house after installation.

4.7 OTHERS

4.7.1 E-NUOG

European Nuclear Utility Owners Group. We have been in contact with a Swedish representative in this group that has just recently started. The aim of the group is to share experiences and findings in order to deal with equipment obsolescence. For the moment there is little information on their further whereabouts.

4.7.2 EPRI and EPRI equivalence

The Electric Power Research Institute has made a list of substitute components that could be considered valid spare parts without requalification. This list is approved by US Authority NRC, but is also used elsewhere even though without official status, see also ref [4].

4.7.3 POMS/RAPID/PEREN

There are several different spare part databases where the members provide their inventory information in order to share this with other utility owners. The databases work a bit different, but the essence is always to share information. RAPID is owned by Curtiss-Wright and was described in the previous report, ref [2]. POMS (Proactive Obsolescence Management System) is owned by Rolls Royce and is described in the chapter 4.3. PEREN is owned by Thales and there are others as well.

5 Requirements

As been said in previous report, ref [2], it is very good to have the requirement for the equipment that you would like to do reverse engineering or reengineering on, but not necessary. The more documentation and requirement there is, the easier the process. It is also important to remember that even if there are original requirements, there is always a possibility that this is not enough. There could be "hidden requirements" or the existing requirements could be badly specified. Therefore the existing requirements must be scrutinized, but also questioned for "Is this it?" and "Could there be more?"

For 1E systems it is of course even more important to have accurate requirements. Compared to Germany there is not an absolute demand for what you could do and what you could not do, but it seems always to be a matter of the specific conditions at the time. The vendors of reengineering and reverse engineering products admits that sometimes they are questioned by the authorities, but they also state that it all comes down to doing a good job and being able to prove it.

5.1 NEW REQUIREMENTS

Several of the companies we have talked to stated that adding new requirements makes the process harder. The new requirements must then not affect the original requirements. The French way seems to be a bit more like the US strategy not to change any requirements as long as you could.

6 Qualification

In general qualification is handled as for any other equipment, this being said it is still of utter most importance that the qualification does not become the major issue during a project. For some projects the qualification has been the single reason for choosing a special solution since the qualification could easily be the most costly of a project.

It seems to be in France as in the other countries investigated in this project; both vendor and equipment needs to be qualified for 1E. The original qualification is not always known and this is of course why it is important to know the requirements as mentioned previous. In general it seems to be no problem to do the testing needed as long as the requirements are known.

The more complex an equipment is the more difficult is the qualification. Software application could be very difficult to qualify and it could very well be more difficult to qualify new digital equipment than reverse or reengineered analogue equipment.

It is the utility who is responsible for the qualification, the authorities' demands qualification, but it is up the utility to see to it. There is no responsibility on the vendor from the authorities' part, but the utility is responsible for whoever performs the tasks (in house or someone else).

The qualification of reengineered or reverse engineered equipment is the same as for new equipment. The working process, audits and controls are the same.

7 After-market

7.1 MAINTENANCE AND SUPPORT

All the companies investigated states that they offer maintenance and support according to the customer demands.

EdF Energy says that they demand support until end of life for systems that they do reverse or re-engineering on. If it is not possible for the vendor to guarantee this, a "last buy" could be done instead.

7.2 TRAINING

All vendors provide training in some form. It all depends on the equipment in case and on the sort of training that is needed. It does not seem to be a major problem to gain the training necessary.

7.3 TESTING

All vendors visited provided testing equipment for the equipment sold. Sometimes the testing equipment had been bought from the OEM when the OEM no longer provided the service; sometimes they made the testing equipment themselves.

Figure 3. General Electric PMC testing equipment.

8 Field trip and meetings

During a week in September 2016 a group from Energiforsk met with four companies in France.

Patrik Larsson	Vattenfall (Ringhals NPP)
Mika Sinkkonen	TVO (Olkiluoto NPP)
Matti Tiitto	Fortum (Loviisa NPP)
Anna-Karin Sundquist	Vattenfall
Annika Leonard	Vattenfall
Torbjörn Ek	Vattenfall (Forsmark NPP)

8.1 COMPANIES VISITED

Visits were paid to Cegelec, Spherea, EdF and Nexeya. Participants at the meetings were:

Cegelec

Bernard Moreau	Sales Manager
Vincenzo Mistretta	Business Development Manager
Jean-Marie Tarin	Directeur

EdF

Nguyen Thuy	Senior research engineer

Spherea

Philippe Lasman	President Delegue
Naim Souissi	Responsable industrielle

Nexeya

Olivier Bontaz	Regional sales manager
Matthieu Doudement	Bid manager critical system
Joelle Cebron	Business line director

8.2 OTHER MEETINGS

8.2.1 Rolls Royce

During a visit in Stockholm the Energiforsk project and invited guests met Rolls Royce.

Peng Lin	Customer Business Manager – Nuclear I&C
Nicolas Hardy	

8.2.2 EdF

A phone meeting was held with EdF purchasing department.

Michel Esbrat	Responsable Stratégie Achats – Electricité et Contrôle Commande

8.2.3 EdF Energy

A phone meeting was held as well as email communication with

Daniel Gray	Lead C&I Engineer, C&I Aging and Obsolescence
Noel Evans	Equipment Reliability Program Manager

8.3 FRENCH PREREQUISITES

It has been decided by the French government to not allow any new nuclear reactors in France. The newly built, but not yet commissioned, plant in Flamanville will be allowed to start. This means that all investments now need to have a payoff until the end of lifetime. For some reactors that will be very short period of time.

8.3.1 Nuclear regulatory authority

Institut de Radioprotection et de sûreté de Nucléaire, IRSN, and Autorité de sûreté Nucléaire, ASN, both have responsibilities within the nuclear field in France. This project has not been able to talk to any of them.

IRSN: http://www.irsn.fr/

ASN: http://www.french-nuclear-safety.fr/

Office for Nuclear Regulations, ONR, is the responsible authority in the UK. This project has not been in contact with them.

http://www.onr.org.uk/

8.4 RESULTS

8.4.1 Nuclear power plants

There was no possibility to talk a specific plant, but the EdF strategy was explained by the EdF personnel we met. EdF owns all the nuclear power plants in France (conventional). Every tenth year, every reactor needs to do a more thorough outage with detailed inspections. During this extra-long outage there is a chance to do larger projects for power upgrades or life time extension for example. Big efforts are made to make sure that the three reactor types are kept the same in order to not have any "one-of-a-kind". That means that once a project for one kind of reactor has been approved it will be implemented in all units of the same kind during a ten year period.

It has been decided to not build any new nuclear power plants in France. The not yet commissioned utility in Flamanville will be finished, but no new projects will be allowed. Therefore great efforts are being made in order to make the existing nuclear fleet survive as long as possible.

In the UK it is to large extent the opposite. Almost all reactors are unique and it is difficult to find a solution that fits all. Several new reactors are being planned for by both EdF and for example Horizon Nuclear Power.

8.4.2 Brands, systems, platforms

All the companies we have talked to are open to work with any kind of system. It all depends on what information that is available.

8.4.3 Documentation needed for reengineering

There is no absolute need for original documentation in France or UK in order to be able to do re-engineering or reverse engineering. The more material that could be obtained the better, but no specific rules. If it is a safety system the requirements are of course higher, but it all comes down to how complicated the equipment is and how well the functionality could be proven and qualified.

8.4.4 Technical aspects on reengineering and reverse engineering

The French vendors had a much more automated process compared to the ones we met in Germany. For example in France they did functional testing of a cloned card with a fly probe that automatically checked the functionality instead of testing by hand. For cloning of cards they use a scanner that could scan several layers etc.

One crucial part is the connectors; usually they need to be bought from the OEM in order to fit properly. Recently a new technology has proved to be suitable for this – 3D-printing. With the help of a 3D-printer it should be possible to recreate simple contacts and its housings instead of keeping them in stock. This is rather new, but believed to be of great importance for the industry since the problems with casings and connectors are far-reaching.

8.4.5 Testing

All of the vendors we have talked to can do testing of their products. Some of them have bought testing equipment from the OEM when they have stopped providing certain equipment; in other cases they have made testing equipment of their own.

In France it is common for the utility to be responsible for the functional testing of a cloned PCB board, instead of the manufacturer. This is due to the fact that the user of the equipment has better knowledge of the functional requirements and the environment that the cloned PCB board normally operates in. This is however subject to negotiations and other agreements could be made. The manufacturer makes a structural test in order to guarantee the physical identity of a PCB board for example.

8.4.6 Qualification

The qualification procedure differs between different countries, but in general it seems that the French companies we have talked to helps out with the qualification. Some vendors could do some qualifications in-house; it all depends on the regulations and on the vendors. It is easier to qualify simple analogue equipment than software based equipment.

8.4.7 Reuse of qualifications

It is not uncommon to re-use qualifications, whether or not a qualification could be re-used depends on the agreements with the original buyer and of course that the conditions are the same. Another way of dealing with the problem of expensive qualifications is to do joint qualifications from the beginning. That means that several companies with the same needs do a joint procurement and share the expenses.

8.4.8 Support and maintenance of produced items

All vendors provide support and maintenance according to agreements.

8.4.9 Procurement of reengineering or reverse engineering

Reengineered or reverse engineered equipment could be procured in many different ways. Sometimes the vendor could keep stock for a specific customer; sometimes there could be a promise to keep the product in line for a specific time of years. Some companies only buys products that could be guaranteed to live throughout the utility lifetime for example.

The fewer the samples the higher the price, but it could still be worth doing a single example of an obsolete equipment if it is easy enough to not render to complicated qualifications etc. It is more expensive to do 1E equipment than non-1E equipment.

8.4.10 Relation with OEM

Generally it is the utility have the contacts with the OEMs, but sometimes the third party vendor have bought the equipment and the IP rights from the OEM and then keep the products available.

If the there is doubt on IP rights it could possibly be solved by a black box approach, that demands nothing more than a functional sample in order to make copies. In some cases some of the utilities have preferred this approach instead of having lengthy discussions with the OEM.

8.4.11 Competence

None of the vendors we have talked to have indicated that competence would be a problem the same way it was in Germany. There was no real explanation for this, but only that they didn't see this as a problem.

8.5 CONCLUSIONS

In both France and the UK re-engineering and reverse engineering are used as a practice. There is an acceptance from the authorities however it is difficult to exactly say to what extinct since we have not had the opportunity to talk directly neither French nor UK authorities.

At least in France the use of an exact copy, a clone, seems to be a quite common measure for non-1E equipment and sometimes also used for 1E equipment. In some cases it wouldn't even need to be requalified as long as it could be proven to have the same functions.

Reverse- and reengineering is used mainly by the aviation industry, the military and the nuclear industry. The amount of customers seems to be much larger in France compared to Germany and therefore the workshops and level of industrialization seems to be more developed in France compared to Germany.

9 Pilot case

In order to get a brief idea on what kind of information that a supplier needs in order to make a copy of an obsolete I&C card, an actual case was borrowed from an NPP and information sent out to several of the vendors we have met during all of the three projects. The information given was a photo of a PCB board, a drawing, a list of components and some layouts. In addition to this there was also a functional description, but since this is in Swedish it was not included in the information package only mentioned as a possible resource.

9.1 ANSWERS

The answers from the suppliers have differed a bit in how detailed they have been, but in general they have identified the same components as "difficult to find" and given the same evaluation of the material as "rather good". All of the suppliers have said that this copy is possible to do. Some have said that they rather not do a single copy, but it is still possible however the price will be high.

What differs is how they look upon functional testing. Everyone can do a functional testing, but in some cases it is obvious that functional testing is something they normally leave to the utility itself. This is an important difference in working procedures that should be taken into account when evaluating different options.

10 Summary and conclusions

10.1 SUMMARY

Reengineering and reverse engineering is used on a rather common base in both France and UK. From the US experience, described in ref [1], it is known that the use of reverse and reengineering comes from the military industry. This seems to be the same in France and in UK. The providers we have talked to are generally providing equipment also for the military. Rather often there are also connections to aviation and railway.

In general there is no problem with the OEM. Reengineered or reverse engineered products come in question once the OEM no longer wants to provide the equipment. Whether it is possible to use reengineering or reverse engineering have to be decided case by case.

Usually there is no problem regarding the authorities either. They have accepted the method as long as the requirements for qualification, verification, validation and supplier audits are fulfilled. That said, that does not mean that it is always easy to qualify, verify and validate a re-engineered or reversed engineered item only that from what we could conclude there is no special treatment upon these projects.

Both reengineering and reverse engineering could be used for both 1E and non-1E equipment. The requirements for 1E equipment are higher and the qualification, verification and validation are more extensive. However there don't seem to be any formal obstacle for using both of these techniques. We have not discussed the possibilities for doing far end equipment such as sensors or transmitters or opto isolators for example with everyone we have met, but for those we have asked about this none have said that they deliver this.

Regarding cyber security it has so far not been a major issue since the equipment that is dealt with is in general not digital and if it is digital it does not have any connectors. Cyber security is dealt with according to relevant standards if applicable.

Counterfeit is a known problem, but most of the ones we have talked to says that their quality system could take care of this problem and that this normally does not provide any problems.

In general the overall experience from their long term usage of re-engineering and reversed engineering techniques are positive and with low failure rates.

10.2 CONCLUSIONS AND RECOMMENDATIONS

The conclusions from this project are the same as for the previous projects – reversed- and reengineering should be evaluated together with other alternatives when obsolescence is a problem, both for 1E and non-1E systems. There are also other alternatives, such as using conventional products (COTS) and qualify them for nuclear use for example, the vendors investigated in this project had many different stories on solutions and adaptions they had made. The standard solutions seem to be few.

The question of what could be done regarding IP rights etc. is always a question for the utility owner, who needs to examine its original contracts very carefully.

The process is easier the more documentation there is. Drawings, requirements, functional descriptions etc. Everything that could add to the knowledge of the equipment and its functions are of value for the decision of what could be done. All vendors included in this project, in one way or another could provide some sort of help to choose what solution is best fitted for that specific problem.

There should be a general obsolescence strategy in order to see if there is any other equipment or utility that could use the same solution, several utilities could make a joint venture and share the costs for qualification and development for example.

Everyone the project has talked to have stated the importance of having as much documentation as possible, but some have also warned about this being a false friend. Sometime what seems to be sufficient amount of documentation is for a fact instead information of general kind that is not particularly helpful for that specific application, drawings could be faulty or not updated. Therefore it is not only important to have documentation, but to have correct and reliable documentation and this should be an important part of the pre-study to decide what kind of information that is available.

There is no general advice for when to choose any special solution, but a number of parameters have to be weighed together on a case by case basis. This project could however strongly recommend to evaluate the options of re-and reverse engineering in order to find the best solution when obsolescence is a problem. All different alternatives should also be weighed against doing nothing. You could of course always argue that new equipment, of any kind, is introducing potential fault, but then you should also consider the consequence that the existing equipment could fail due to age.

There is a difference between Germany and France in how far the industrialization of the working process has come. There is an obvious difference between the German regulations and the French. Unfortunately this project have not been able to contact the authorities directly and therefore it is difficult to state what could be accepted and not. Clearly, however, the German authority regards the importance of original documentation higher than the French. Therefore the German archive of original documentation was far more extensive than the French equivalence from what we could tell. This project recommends ENSRIC to look into this matter from an authority point of view in the future.

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Appendix A: Question list used in the project

RE-ENGINEERING SURVEY

Introduction

Energiforsk is a Swedish joint research organization aimed at research and development in the energetic area which represents different Nordic organizations like Vattenfall (Ringhals NPP, Forsmark NPP), Fortum (Forsmark NPP, Oskarshamn NPP, TVO NPP), Uniper (Oskarshamn), Swedenergy as well as SSM (Swedish Radiation Safety Authority).

Energiforsk ENSRIC is a research program focused on safety related I&C systems, processes and methods in the nuclear industry. Information from the program will assist the nuclear industry and the Radiation Safety Authority when analysing how to replace existing obsolete systems while maintaining safety and promoting a low cost during the whole life cycle.

Within ENSRIC program, we at the Vattenfall are currently performing a survey with objective to retrieve experience from reverse engineering / redesigning of the obsolete I&C equipment, both from utility perspective and from companies that have commercial services and reverse engineered or redesigned products already on the market.

We would very much appreciate if you can provide us with answers to the questions below. You can either write your answers and send them back to us by email or we can arrange a meeting and discuss those areas of interest personally or via teleconference.

Market survey questions

1. Which kind of equipment production did you utilize?

Please select one or more of the following:

a) Reverse engineering.

New equipment has been created and manufactured completely from the scratch based on the sample of the original one, with no access neither to original requirements / specifications nor to the original documentation.

b) Re-engineering.

New equipment has been manufactured by a third-party manufacturer using available original requirements, specifications and documentation.

c) Re-design.

New equipment has been newly designed and manufactured by third-party manufacturer according to available requirements and specifications. New equipment utilizes completely new design or even technology but matches the original functionality, external shape, size and connectors / interfaces.

d) Re-manufacturing.

New equipment has been manufactured again the same way as the original one by the original manufacturer according to his own old documentation, requirements and specifications.

e) Refurbishment.

Instead of manufacturing a new equipment, the original one has been revitalized by the means of cleaning, replacing non-working parts and readjusting / testing.

f) Other – please specify.

2. Could you provide us with a list of manufacturers or vendors of such equipment you utilized or you were in contact with?

Legal issues questions

3. Could you send us the agreements you have regarding purchase of equipment that could be of interest to redesign, please?

We understand that this may be a sensitive matter to send us a copy of your agreements or their parts, so we are ready to sign a NDA first (Non-Disclosure Agreement) if demanded by you or your legal department.

4. Are there any other agreements that you know of that could be of interest to our research?

5. What legal issues have you found or do you interpret to be the hardest to fulfil for reengineering to work?

6. Do you cooperate with other plants to make deals with the vendors for obsolete equipment, like remanufacture cards or letting go of the rights of the obsolete equipment?

Qualification

7. How do you see on reengineered equipment, a change in the plant or a 1:1-exchange?

8. Does reengineered equipment affect the permits or licenses for the NPP?

Requirements questions

Whenever within our questions below we say “new equipment”, we mean a new equipment delivered as a result of redesigning, reengineering or reverse engineering.

9. How do you handle the requirements at all?

This is a general question: we would like to see any ideas about requirements you have for redesigned or re-engineered equipment in general, e.g. your general approach.

10. Was a new equipment implementation affected by new rules/standards?

It is possible that there are new rules nowadays imposed by authority or new standards exist today, which did not exist or which were different at the time when the original equipment was delivered and installed. Did you experience such problems?

11. Is there any difference between your requirements for Safety System (Cat A / 1E)

and Non-Safety System redesign / reverse engineering?

12. Any experience with refurbishment?

We are interested to know what problems may occur if individual spoilt parts of the original equipment will be just replaced by nowadays parts manufactured with a different (more recent) technology. This is a special question for the case when we just replace broken parts in the original equipment – e.g. refurbishment instead of a full reverse engineering / redesigning.

Functional and other requirements

13. How do you define functional requirements?

For example demanded functionality, power supply restrictions, I/O limitations, requested operational environment, etc.

14. How do you handle “hidden requirements”?

We mean possible impact to existing plant systems caused by implementation of a new equipment, which can have particularly different behaviour in comparison to the original one. For example different heat dissipation, power supply requirements and limitations, EMC durability, EM transmission (noise), different environmental limits, different accuracy, different time-response, etc.

15. How do you cope with rules and standards?

This question includes requirements automatically applicable due to official standards or imposed by a law. For example radiation durability, seismic durability, EMC, environmental safety, etc.

Verification

16. Which verifications are necessary to be performed?

We would like to see who issues or defines those demands for verifications as well.

17. Describe please your verification process in general.

Do you perform verifications yourselves (in-house) or was it done by equipment’s manufacturer or by another external service provider? Who defines verification procedures and acceptance criteria? If independent review required, how do you ensure the independency of reviewers?

18. Do you have any special requirements for verification personnel?

For example education, special training, experience, license, etc.

19. Which tools are required for performing verification?

For example special laboratory, special equipment or software, simulators, etc.

20. How to ensure that performed verifications were relevant and sufficient and that results are acceptable to proceed with the verified equipment?

21. What about those verifications where it was not possible to test all theoretically existing statuses of the verified equipment?

We mean a situation when there is so many possibilities and statuses that only part of them can be tested / verified at the reasonable time, so only special selection of statuses or values may be verified (operational range, critical points, limits, etc…).

22. What was difficult to verify?

Please describe if you experienced any difficulties during the verification process.

23. Is there any difference between verifications for Safety System (Cat A / 1E) and Non-Safety System?

Maintenance and support

24. What are the conditions for support?

We would like to see how long and which way the manufacturer provides a warranty support and also post-warranty support, how long do you expect that spare parts would be available, also if there are some training and documentation provided.

25. What about long-time support including the decommissioning phase of the plant?

This question includes a new equipment and its spare parts availability from the long-term point of view.

26. Is a new equipment repairable in-house, do you have your own spare parts in stock?

We are interested if, in the case of malfunction, a new equipment can be repaired by a local maintenance team (by opening a box and fixing just a broken spoilt element) or if it would be necessary to replace the whole equipment at once.

27. Did a new equipment implementation cause any special demands for maintenance?

For example special training for a maintenance team, necessity to replace existing maintenance tools or to purchase new ones, updating existing procedures or creating new procedures, etc.

REENGINEERING AND REVERSE ENGINEERING

Is it possible to maintain old analogue instrumentation and control equipment? Yes, there are several ways! This report reveals how maintenance is done in Europe. and what the Scandinavian nuclear power industry can learn from that.

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