UNRESTRICTED REPORT

ENARD Annex III: Infrastructure Asset Management Phase 1 Final Report

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Phase I Final Report

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Executive Summary

In July 2006 the International Energy Association established a new Implementing Agreement on Electricity Networks Analysis, Research and Development (ENARD). In late 2007 the Executive Committee (ExCo) of ENARD endorsed the formation of a new project group, to be known as Annex III. The ExCo also endorsed the appointment of EA Technology Limited (EATL) to be the Operating Agent for Annex III. The task of Annex III was to investigate and report on the current asset management practices of electricity distribution companies in the participating countries, with the intention of identifying the potential for improvement and any areas that could be regarded as best practice. The Annex III project was carried out over the period April 2008 to December 2009. This report provides a high level overview of the work carried out under the Annex III project. A detailed description of the work carried out under Annex III is contained in a report that is confidential to the Annex III participants.

Initially there were five countries participating in Annex III: Finland, Italy, Norway, Sweden and the UK. A sixth country, France, joined Annex III in March 2009.

The first meeting of Annex III was held in the UK in April 2008, there were three additional meetings held over the course of the project, in Italy, Sweden and Finland. During the first meeting the participants agreed two key points for the scope of work:

1) Annex III should focus on MV assets in the range 6kV to 45kV, the rationale behind this decision was that there is already a wealth of information on higher voltage assets; and for lower voltage assets, while these might be more numerous, they are not as important as MV assets; and

2) Annex III should report on five of MV asset groups:
   - Transformers
   - Cables
   - Overhead lines
   - Switchgear
   - Protection and Control

Also at the first meeting the participants agreed the contents of a questionnaire that would form the basis of a ‘free-text’ reporting template that would be used by each participant for reporting the asset management practices in their country for each of the five asset groups. The reports from each country were collected and collated by the Operating Agent, who then produced a separate summary report for each asset group. These summary reports drew out the key points of each national report, identifying areas of similarity and explaining any differences. The national reports have been collated and presented in five Annexes (A to E) that accompany the Annex III confidential report. The contents of the summary reports, produced by the Operating Agent, provide the basis for the majority of the chapters withint he confidential report.

The Annex III project was also tasked with taking a brief look at the asset management practices of other countries that were not participating in Annex III. To address this requirement the Operating Agent conducted an extensive literature search. The Operating Agent also sought input from all ENARD countries not participating in Annex III, unfortunately no information was forthcoming from these countries. The literature search yielded a small number of relevant papers that have been examined and the key points extracted.

The key conclusions from the Annex III project can be summarised as follows:

- This project has confirmed the fact that all six participating countries have a significant number of MV assets that are near to their forecast end of life and some assets which are still operating beyond their forecast end of life. It is assessed that a similar situation will exist in most developed countries around the world.

- It has been concluded that a risk based approach is the most cost effective method for managing ageing assets. The effectiveness of a risk based approach is related to the quality of three input factors, namely: historic failure information; current asset condition; and an assessment of the consequences of failure.

- The devastating affect of major storms on the performance of overhead lines has prompted some countries to introduce radical policies to reduce the risk of future widespread interruptions.

- It is unclear what impact, if any, *climate change* will have on the ratings and performance of electrical infrastructure.

- The UK has identified a substantial risk for network operators that rely upon a third party to provide communication circuits to support protection systems, namely that the communications service provider might choose to employ a system that extends the delay (latency) of the system in such a way that makes it is no longer acceptable for protection purposes.

- The short review of asset management case studies from around the world has identified a general desire for companies to consider risk when developing their asset management policies.

- This project has focussed on existing network configurations and existing assets, there has been no attempt to look at more active distribution networks, the so called “SmartGrids”.

- The effects of manufacturer consolidation and internationalisation is apparent across all five asset groups. Whilst internationalisation can bring greater cost benefits it is vitally important that equipment is being manufactured and tested to a recognised level of quality, in accordance with well drafted international standards.

- The shortage of skilled resource to work with older assets has been identified as a potential risk for electricity network operators.

- Management of switchgear is a multi-faceted problem for electricity network operators; all countries reported that they have some very old oil filled circuit breakers (some are well over 40 years old), a situation that has recently been compounded by the environmentally based restrictions on the use of SF_6.

- As expected the national reports on the effects of Legislation and Regulation confirmed that both of these will have a significant impact and influence on how electricity network operators manage their assets.

Annex III participants identified five recommendations that came out of this project, these can be summarised as follows:

- Network operators should promote the use of a risk based approach to asset management on the basis that it allows network operators to optimise their investment programmes.

- Considering the growing interest in SmartGrids and the likelihood of them being developed, it would be beneficial to look at the asset management implications for SmartGrids.

- Considering the importance of MV overhead lines (OHLs) to network performance, it would be beneficial to conduct a project that looked in detail at the options for managing MV OHLs.

- The environmental restrictions on the use of SF_6 would suggest that there is a clear need to look at future options for managing assets that contain this gas and to look at the potential alternatives.

- The global significance of climate change means that all sectors of society need to consider the potential impact on their businesses and way of life, therefore it would be beneficial to identify what will be the effects of climate change on asset management.

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1 Background

1.1 ENARD

In July 2006 the International Energy Association (IEA)[1] established a new Implementing Agreement on Electricity Networks Analysis, Research and Development (ENARD). ENARD's aim is to become an authoritative, comprehensive and unbiased international source of information, data and advice, such as to inform Governmental officials, policymakers and key industry stakeholders of the pertinent issues relating to current and anticipated developments in electricity Transmission and Distribution (T&D) networks. The intention is that ENARD will enhance the overall performance of T&D networks by facilitating improvements in the way stakeholders tackle the challenges of network renewal, renewables integration and network resilience, the "3Rs" of electrical power systems. The development of ENARD will also contribute to fulfilment of the objectives of the IEA's G8 Gleneagles Programme.

1.2 Executive Committee (ExCo)

ENARD's activities are managed by the Executive Committee (ExCo) which is made up of delegates from all the participating countries; currently there are 13 participating countries[2]. The ExCo is responsible for the ongoing development of an operational roadmap for ENARD, the identification, prioritisation and selection of particular work areas for analysis and review, the periodic review of the operational Annexes and the associated upward reporting to the End Use Working Party (EUWP) and the Committee on Energy Research and Technology (CERT).

1.3 Annexes

ENARD currently has four Operational Annexes, namely:

- Annex I Information Collation and Dissemination[3]
- Annex II DG System Integration
- Annex III Infrastructure Asset Management
- Annex IV Transmission Systems Issues

[1] The International Energy Agency (IEA) acts as energy policy advisor to 27 member countries in their effort to ensure reliable, affordable and clean energy for their citizens.
[2] ENARD participating countries: Austria, Belgium, Denmark, Finland, France Italy, Netherlands, Norway, South Africa, Spain , Sweden, Switzerland, United Kingdom and USA.
[3] Annex I is responsible for the systematic collation and dissemination of T&D network related information and data and also for the organisation and delivery of a series of topical experts' meetings and workshops.

1.4 Annex III: Infrastructure Asset Management

The work of Annex III took place over the period April 2008 to December 2009. Annex III participants saw this project as an opportunity to share knowledge and compare asset management processes and procedures with like minded experts in other countries, with the overall intention of all participants being able to take their existing asset management practices to new levels of excellence.

EA Technology Limited (UK) were selected by the ExCo to be the Operating Agent for Annex III.

This report has been prepared to provide a 'high-level' overview of the work completed by Annex III participants under Phase 1 of the Annex III project. A detailed Final Report has been prepared by the Operating Agent for the Participating Countries only. That report documents all work undertaken during the Annex III project, conclusions drawn, lessons learnt and recommendations for future actions.

1.4.1 Aim

The aim of the Annex III project was to address the challenges associated with the management of increasingly ageing transmission and distribution (T&D) asset bases within the participating countries and beyond, via the exchange of information and data in relation to the ageing, degradation, failure and end-of-life characteristics of the T&D asset base and the complementary development[4] of new asset management techniques and methodologies.

1.4.2 Specified Tasks

The ExCo specified five Tasks for Annex III to deliver:

Task 1	Definition and Categorization of Principal Asset Groups
Task 2	Collation of Distribution Network Operator Experience
Task 3	Review of Existing and Proposed Methods of Quantifying Asset Related Risk
Task 4	Assessment of Distribution Asset Management Case Study Material
Task 5	Consolidation of Information from Tasks 2, 3 and 4

[4] At the first Annex III meeting the participants agreed that the project would not be developing new asset management techniques and methodologies; however the project would exchange information on what developments are taking place either in participating countries or, where identified, in other countries.

1.4.3 Participating Countries

Country	Organisation
Finland	VTT Energy Systems
France[5]	ERDF
Italy	ERSE S.p.A.
Norway	SINTEF Energy Research
Sweden	Vattenfall AB
United Kingdom	Electricity North West Limited

1.4.4 Approach

The programme of work followed by Annex III is shown in the Project Plan for Annex III, Phase 1, shown under Appendix II to this report.

At the inaugural meeting of Annex III the participants agreed the following approach to delivering the five specified Tasks:

1.4.4.1 Task 1: Definition and Categorization of Principal Asset Groups

Categorisation. For the purpose of Annex III reporting, assets should be categorised on voltage level alone and there should be one voltage band, 6.6kV – 45kV, with equipment being differentiated on use, ie whether the asset is associated with Primary or Secondary Distribution. Where Secondary Distribution means the next voltage level down is low voltage (230/400V)[6]. The rationale behind this decision was twofold, firstly this voltage band contains the greatest volume of assets; and secondly, most surveys and data gathering exercises conducted to date have focussed on the EHV and Transmission assets, meaning that there is little information available on MV assets.

Asset Groups. There shall be five principal asset groups, on which Annex III shall report:

(1) Transformers
(2) Cables
(3) Overhead Lines (including aerial bundled conductor, ABC)
(4) Switchgear
(5) Protection and Control

1.4.4.2 Task 2: Collation of Distribution Network Operator Experience

Each participant agreed to provide information on each asset group using an agreed reporting template that had the twin aims of consistency and coverage. The Operating Agent was tasked with collating the participants responses and producing a single summary report for each asset group, drawing out the areas of common practice and explaining any areas of fundamental difference.

[5] ERDF formally joined Annex III in March 2009.
[6] The Participants of Annex III consider plant operating above 45kV was considered by the participating members to be either Transmission or Sub Transmission and therefore out of scope for Annex III.

1.4.4.3 Task 3: Review of Existing and Proposed Methods of Quantifying Asset Related Risk

Each participant agreed to provide information on the existing and proposed practices for quantifying the asset related risk for each of the five principal asset groups; adding this information to each of the Task 2 reports. It was accepted that the Task 3 details are likely to be broadly generic to all five principal asset groups.

1.4.4.4 Task 4: Assessment of Distribution Asset Management Case Study Material

It was agreed that all Annex III participants, and members of the ExCo would be asked to provide details / leads for the Operating Agent. In addition the Operating Agent also conducted an extensive web-search and literature search.

1.4.4.5 Task 5: Consolidation of Information from Tasks 2, 3 and 4

This report and the associated annexes provides a comprehensive register of all work undertaken, data gathered and information learnt from Phase 1 of the Annex III project.

1.4.5 Existing Practices

At the inaugural meeting, four of the participating countries gave a presentation on the current asset management practices employed in their country. Listed below are some of the key points that came out of the presentations.

- Some network operators have established bespoke departments with responsibility for Asset management.
- The drive to improve network reliability and associated regulatory penalties (financial risk) are key influencing factors behind network investment strategies.
- Some network operators have devised three outputs to their asset management procedures: No Further Action; Maintenance / Replacement due in time; Urgent Replacement / Repair required.
- Across the Annex III participant countries and across the network companies within these countries, there are different approaches to asset management – some use risk based approaches; others use timed inspections and maintenance; and some use a combination of the two. There are different practices for the collection and recording of asset information.
- The use of new technology and asset management prioritisation tools are seen as being crucial to improving existing practices and delivering enhanced value to all stakeholders.
- All countries reported that documentation of asset information is most comprehensive for EHV assets, reducing proportional to the voltage level, ie the low voltage network is the least documented. This factor was key to the decision, by Annex III participants, to select the 6.6kV – 45kV voltage band for Task 2 reporting.
- The condition based risk management (CBRM) methodology, as used by Electricity North West and others, quantifies risk as a function of: probability of failure (PoF), consequence of failure (CoF) and criticality.

2 Conclusions

2.1 Strategic Conclusions

C1. This project has confirmed the fact that all six participating countries have a significant number of MV assets that are near to their forecast end of life and some assets which are still operating beyond their forecast end of life. It is assessed that a similar situation will exist in most developed countries around the world.

C2. It has been concluded that a risk based approach is the most cost effective method for managing ageing assets. The effectiveness of a risk based approach is related to the quality of three input factors, namely: historic failure information; current asset condition; and an assessment of the consequences of failure. A risk based approach allows network operators to optimise their asset management programmes by focussing on corrective action for those assets where the probability and consequences of failure are considered to be unacceptable.

C2.1 Gathering sufficient data to determine the current condition of the asset base is not a trivial task, however the money spent on gathering and collating asset condition data will be rewarded by a more accurate assessment of asset risk and therefore a more accurate set of decisions on how best to manage the risk. The whole process can be greatly enhanced by the use of numerical health indices and other approaches that facilitate simple and consistent gathering and use of the raw data.

C2.2 It is important that network operators maintain an up to date data-base that contains a comprehensive suite of information on all assets within their networks. The data-base should also include information on historic failures, in particular the cause of the failure should be recorded.

C2.3 The consequence of failure is a multi-dimensional assessment that will be particular to the situation under consideration, for example some of the factors that might be taken into consideration are: number and type of customers at risk; safety implications; cost implications, environmental implications; network performance etc.

C3. The devastating affect of major storms on the performance of overhead lines has prompted some countries to introduce radical policies to reduce the risk of future widespread interruptions. For example, France has committed to underground all high risk bare overhead lines and Sweden has committed to undergrounding a number of their MV overhead lines.

C4. It is unclear what impact, if any, *climate change* will have on the ratings of electrical infrastructure, particularly transformers and overhead lines. If, as suggested ambient temperatures are set to increase and summer loadings are also predicted to increase due to more use of air-conditioning. Assets bought for a particular environment might have to be replaced before their expected end-of-life as a result of climate change. There is also the

additional consideration of a predicted acceleration in the growth of vegetation, which might be particularly troublesome for overhead lines.

C5. The UK has identified a substantial risk for network operators that rely upon a third party to provide communication circuits to support protection systems, namely that the communications service provider might choose to employ a system that extends the delay (latency) of the system in such a way that makes it is no longer acceptable for protection purposes. The financial consequences of this problem are enormous, with network operators having to seek alternative service providers / communication systems at many £10M's per company. None of the other countries in this project have reported this problem, which might mean that it is still to happen or the DNOs in these countries employ alternative communication systems or they own the communication system.

C6. The short review of asset management case studies from around the world has identified a general desire for companies to consider risk when developing their asset management policies. The use of risk as a key influencing factor is encouraging companies to take a proactive and targeted approach to investment decisions, rather than rely on time driven cycles for asset maintenance / refurbishment / replacement.

C7. This project has focussed on existing network configurations and existing assets, there has been no attempt to look at more active distribution networks, the so called "SmartGrids".

2.2 General Conclusions

C8. The effects of manufacturer consolidation and internationalisation is apparent across all five asset groups. Whilst this can bring greater cost benefits it is vitally important that the network operators are supported by well drafted international standards to ensure that equipment is being manufactured and tested to a recognised level of quality. Internationalisation has also led to less bespoke designs, which again can deliver cost benefits if the customer can accept a "standard" item of equipment.

C9. The shortage of skilled resource to work with older assets has been identified as a potential risk for DNOs. One example is the case of modern cable jointers not being familiar with PILC jointing techniques; this could expose DNOs to excessive costs if they were to experience an increased level of PILC cable faults. Another example is the lack of skilled fitting staff who are familiar with air-blast switchgear.

C10. All countries have reported that they have some very old oil filled circuit breakers, some are well over 40 years old. Previous moves to replace oil filled switchgear with SF_6 equipment has now delivered the DNOs with a potential problem with the environmental issues associated with this gas. However, while vacuum can be used at the lower end of the MV range, above 40kV there is no obvious alternative to SF_6. The laws concerning the management of equipment containing SF_6 are a subject in their own right. The consequence for network operators is that they have an ongoing requirement to monitor, address and report SF_6 leaks. These requirements are loading DNOs with costs that could not have been envisaged when the

equipment was first installed. At the same time the DNOs still have to manage the replacement of their ageing oil filled switchgear.

C11. As expected the national reports on the effects of Legislation and Regulation confirmed that both of these will have a significant impact and influence on how DNOs manage their assets. A good example is the case of overhead lines, where the effect of various legal constraints on building new overhead lines coupled with regulatory network performance targets has meant that DNOs have seen increased pressure to either refurbish existing lines or replace them with underground cables.

3 Recommendations

R1. Network operators should promote the use of a risk based approach to asset management on the basis that it allows network operators to optimise their investment programme; addressing risk by managing those assets where the probability and consequences of failure are considered to be unacceptable. This will entail network operators having an up to date data-base of asset condition and historic failure rates.

R2. It would be useful to look at the asset management implications for SmartGrids, in order to confirm that the conclusions of this report still remain valid where the consequences of failure might be more pronounced than for existing distribution networks.

R3. Options for managing MV OHLs – a detailed review of current practices in order to identify the conditions / situations where each of the following approaches might be considered to be optimal:

- Minimal intervention – fix on failure
- Refurbishment – major replacement of ageing components
- Renewal – rebuild on existing route
- Replace with underground cable

R4. Environmental pressure and restrictions on the use of SF_6 present a number of questions that DNOs need to have answered:

- What is the future for SF_6?
- Should DNOs continue to install SF_6 at MV?
- What are the options / prospects for an alternative insulating / arc quenching medium at HV?
- How should DNOs manage their ageing assets that contain SF_6?

R5. What will be the effects of climate change on asset management? In particular what will this mean for the ratings of transformers and OHLs as ambient temperatures are predicted to increase; also what will be the effect of change environmental conditions on all asset groups; and what will be the effect of increasing environmental pressure on electricity network operators?

Appendix I Glossary of Terms

GLOSSARY OF TERMS

AAAC	All Aluminium Alloy Conductor
ACSR	Aluminium Conductor Steel Reinforced
AIS	Air Insulated Switchgear
BLX	PE insulated overhead line
Capex	Capital Expenditure
CB	Circuit Breaker
CBRM	Condition Based Risk Management[7]
CENS	Cost of Energy Not Supplied
COF	Cause of Failure
CT	Current Transformer
csa	Cross Sectional Area (of a conductor)
DF	Dissipation Factor
DF	Dissipation Factor
DGA	Dissolved Gas Analysis
DNO	Distribution Network Owner / Operator
DP	Degree of Polymerisation
EHV	Extra High Voltage
EMF	Electro-magnetic Field
EOL	End of Life
FDS	Frequency dielectric spectroscopy
FFC	Fluid Filled Cable
FMEA	Failure Modes and Effect Analysis
FRA	Frequency Response Analysis
GIS	Gas Insulated Switchgear
HV	High Voltage
LV	Low Voltage
MV	Medium Voltage
NPV	Net Present Value
OHL	Overhead Line
OLTC	On-load Tap Changer
Opex	Operational Expenditure
OPGW	Optical Fibre Ground Wire
PD	Partial Discharges
PDC	Polarization and Depolarization Current
PE	Polyethylene
PEX	Cross-linked Polyethylene
PILC	Paper Insulated Lead Covered
PM	Preventive Maintenance
PMCB	Pole Mounted Circuit Breaker
PMT	Pole Mounted Transformer
POF	Probability of Failure
QA	Quality Assurance
R&D	Research & Development
RCM	Reliability Centred Maintenance
RMU	Ring-main unit (ie two isolators and one fused switch or circuit breaker)
RTU	Remote Terminal Unit
RVM	Recovery Voltage Measurement
SCADA	System Control and Data Acquisition

[7] CBRM is a risk based asset management process developed by EA Technology Limited (UK).

SF_6	Sulphur Hexafluoride Gas
SRPB	Synthetic Resin Bonded Paper
S/S	Substation
VT	Voltage Transformer
XLPE	Cross-linked Polyethylene

Appendix II Project Plan

IEA Implementing Agreement on Electricity Networks Analysis, Research & Development (ENARD)

Annex III Infrastructure Asset Management

Project Plan ver4