Asset Management Decision Support for Service Aged SCFF Power Cables

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March, 24th, 2010

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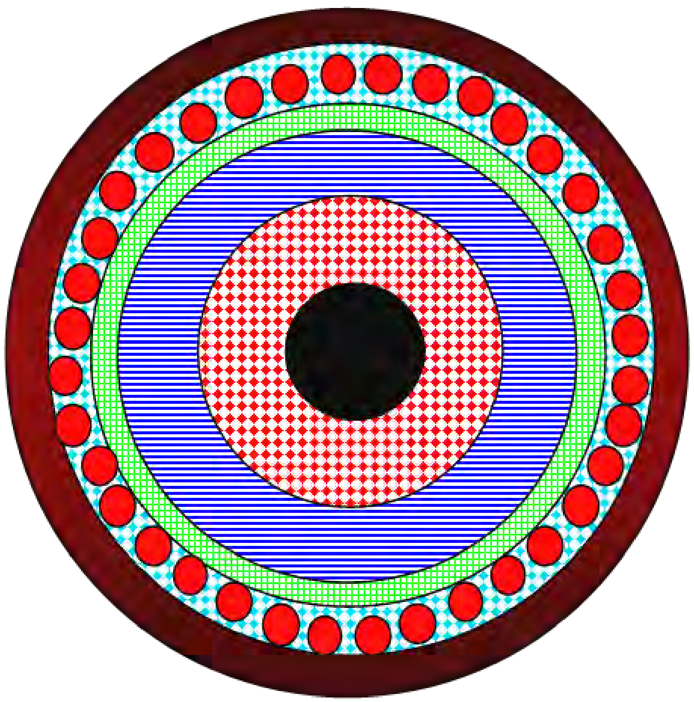
Introduction

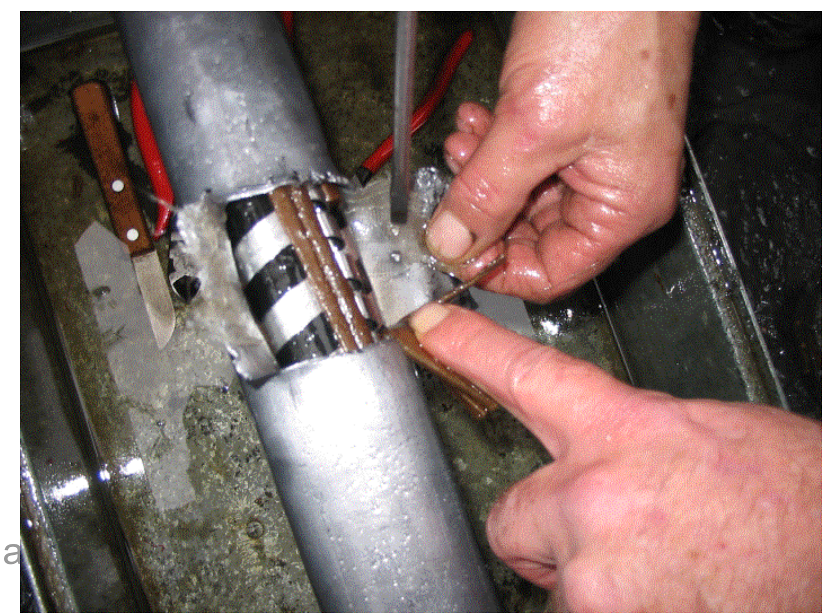
Alliander is considering preventive replacement of our SCFF cable systems as a solution to avoid the risk that might arise with corrective replacement

Is the benefit of reaching your destination worth the risk?

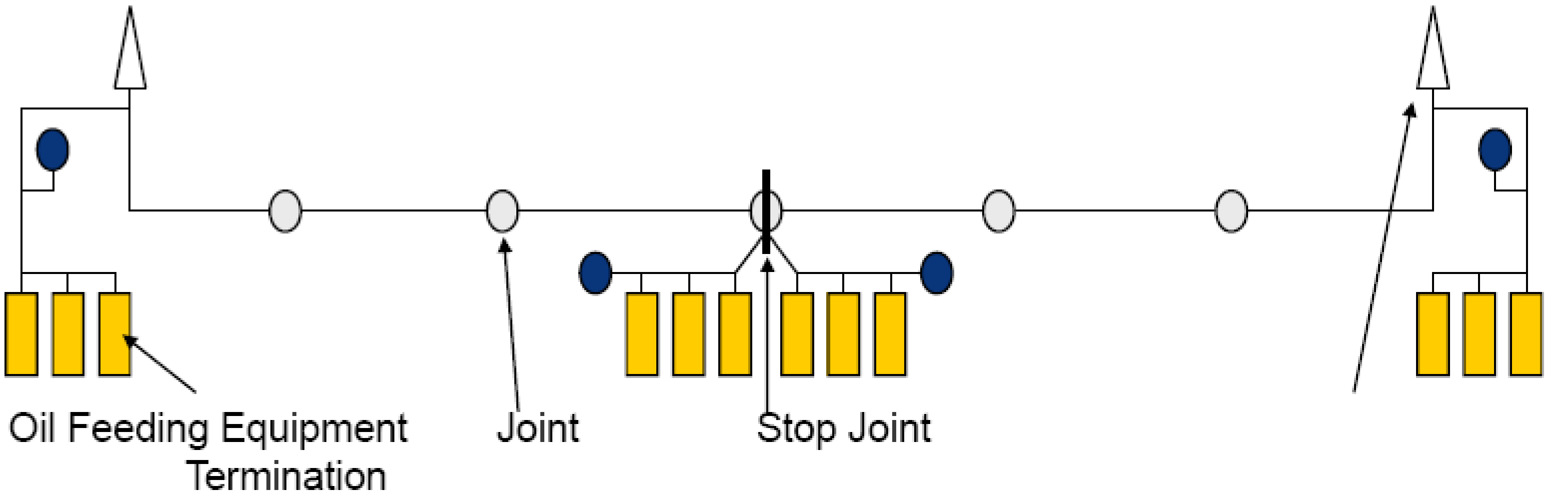
50kV self contained fluid (oil) filled Cables



- Oil channel
- Stranded copper conductor
- Paper-oil insulation
- Lead sheath
- Cable arming
- Outer sheath



Total Cable System



- Fluid-filled cable used in the Netherlands is termed a Static system.
- Under normal conditions the fluid in the system is totally contained.
- When the cable is heated either by the amount of current passing through it or the ambient air temperature the fluid expands and consequently moves

50kV self contained fluid (oil) filled Cables

- Approximately 1000km of cable in operation
- Oldest cable installed in the 50's, newest in the 90's
- Small amount of internal dielectric breakdown
- Reliable (electric strength)
- Oil leakages is the main problem
- Replacement of all SCFF estimated at $500.000.000,00

If we want to replace all within 20 years then we have to replace 50km each year.

To costly to replace all

Prioritizing is necessary !!

Definition of risk for 50kV SCFF

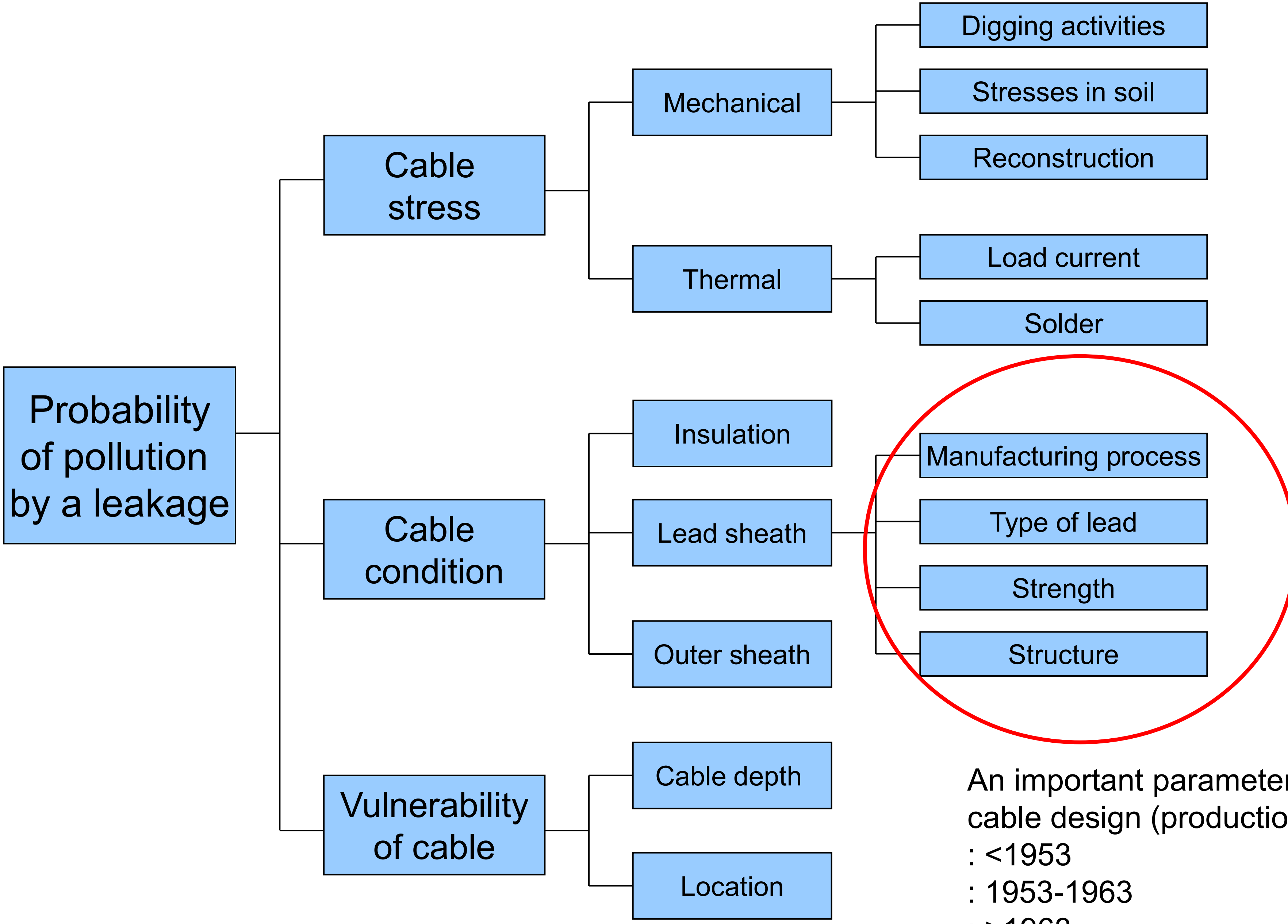
Environmental Risk caused by oil leakage is considered to be the most important risk of the oil filled cable.

THE ENVIRONMENTAL RISK =

PROBABILITY OF POLLUTION CAUSED BY A LEAKAGE

*

THE EFFECT OF THE POLLUTION

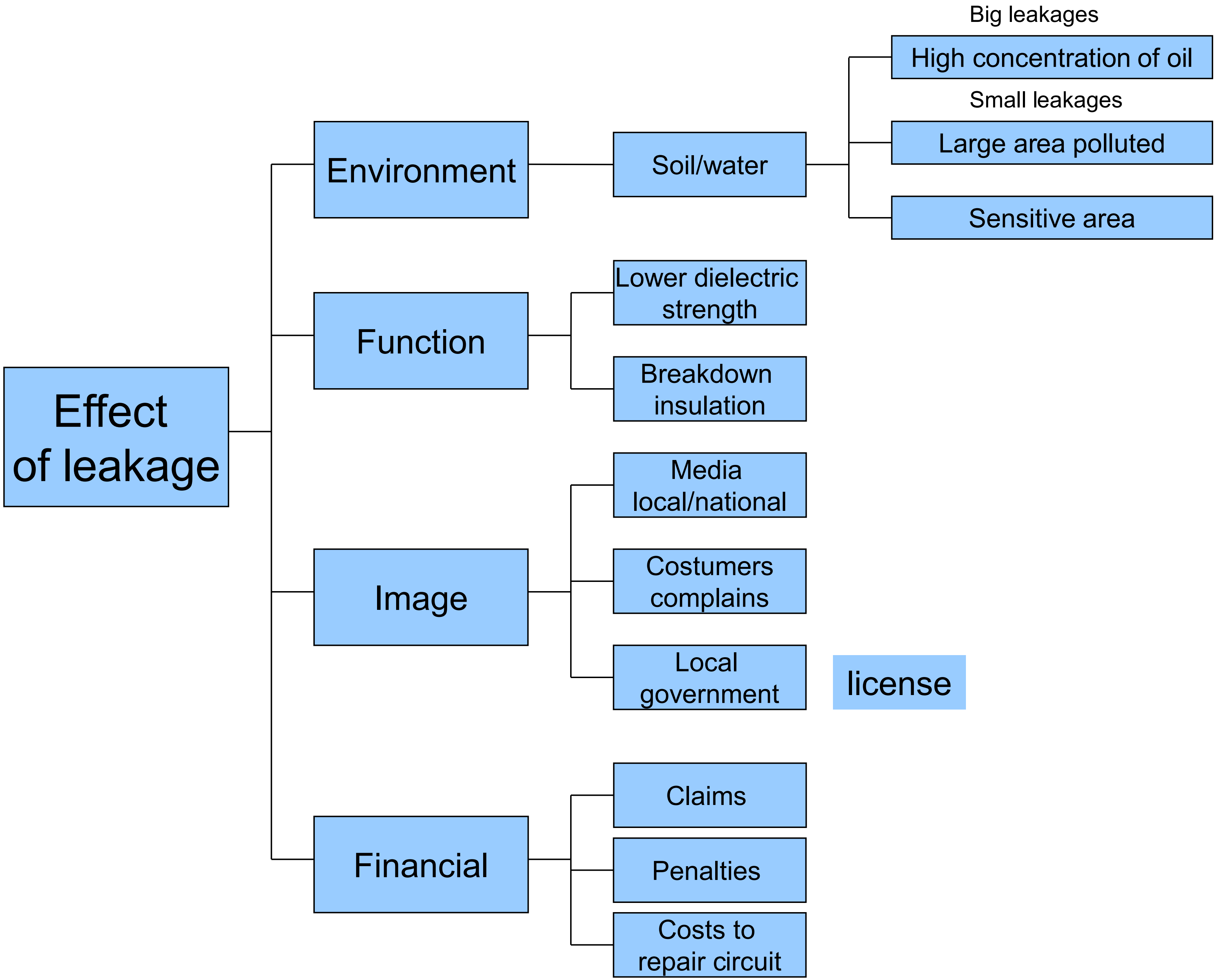


An important parameter is cable design (production year):

: <1953

: 1953-1963

: >1963

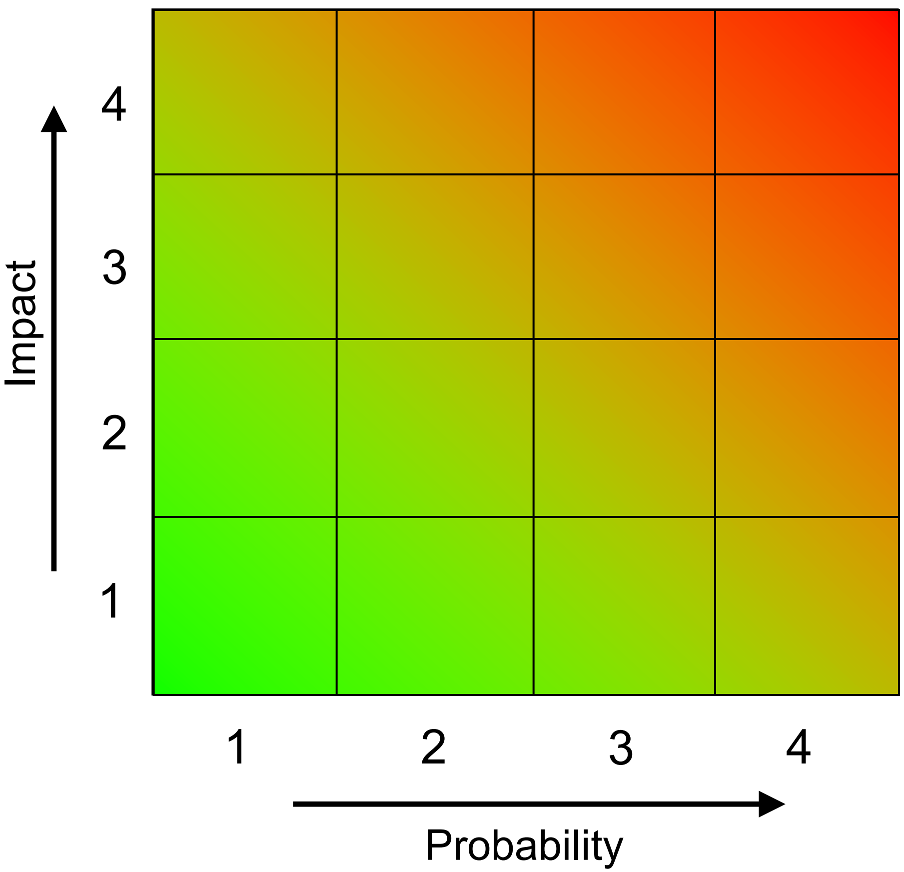

Effect of leakage
Environment
Function
Image
Financial
Soil/water
Big leakages
High concentration of oil
Small leakages
Large area polluted
Sensitive area
Lower dielectric strength
Breakdown insulation
Media local/national
Costumers complains
Local government
license
Claims
Penalties
Costs to repair circuit

Prioritizing the cables

Influence	Factor	Category	Weight
Probability	Year of manufacturing	< 1953	2
		1953-1963	1
		> 1963	0
Probability	Number of oil fill events	> 2/year	2
		1-2/year	1
Impact	Amount of oil (liters) filled	> 1000	3
		300-1000	2
		10-300	1
		0-10	0
Impact	Velocity of leakage	< 5 ltr/day	2
		> 5 ltr/day	1
		No leakage	0

Start situation 2003

Number of cables in risk category



After the first actions 2004

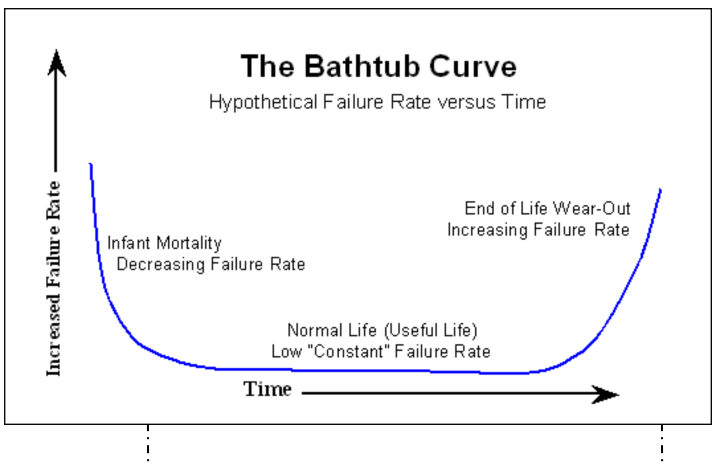
Number of cables in risk category

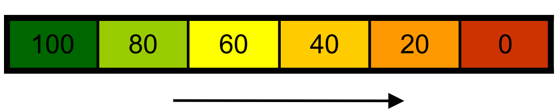
Impact \ Probability	1	2	3	4
4	0	0	0	0
3	23	16	4	0
2	3	0	0	0
1	0	0	0	0

Updated classification

In 2009 an updated model was developed. The model will also take into account:

- Arhenius law for aging paper-oil insulation
- Local Network situations





Lower reliability

Cable		Rank 2010
HHW-OTL-1	-2	1
DVD-WSP	+1	2
HRNG-PRDS	-2	2
AMV-DVD		3
HHW-SCH		3
IJM-VLN-2		3
KBG-PSH-2	+0	3
KW-ZVD-BD		3
ALPW-ZTW-1	-1	4
ALPW-ZTW-2	-1	4
GVL-HVIL-1		4
GVL-WSP-2		4
KAW-SAS-2		4
KBG-PSH-1	+1	4
LEI-LEIZW-3	+1	4
LEI-LMD-1	+1	4
LEI-LMD-2	+2	4
PRDS-WYW-2		4
SHLC-VHZ-3	+1	4
AK-AP-2		5
KBG-KEMA		5
KW-ZVD-AC		5
RS-ZVD		5
GVL-HZN-1		6

Classification on local network level

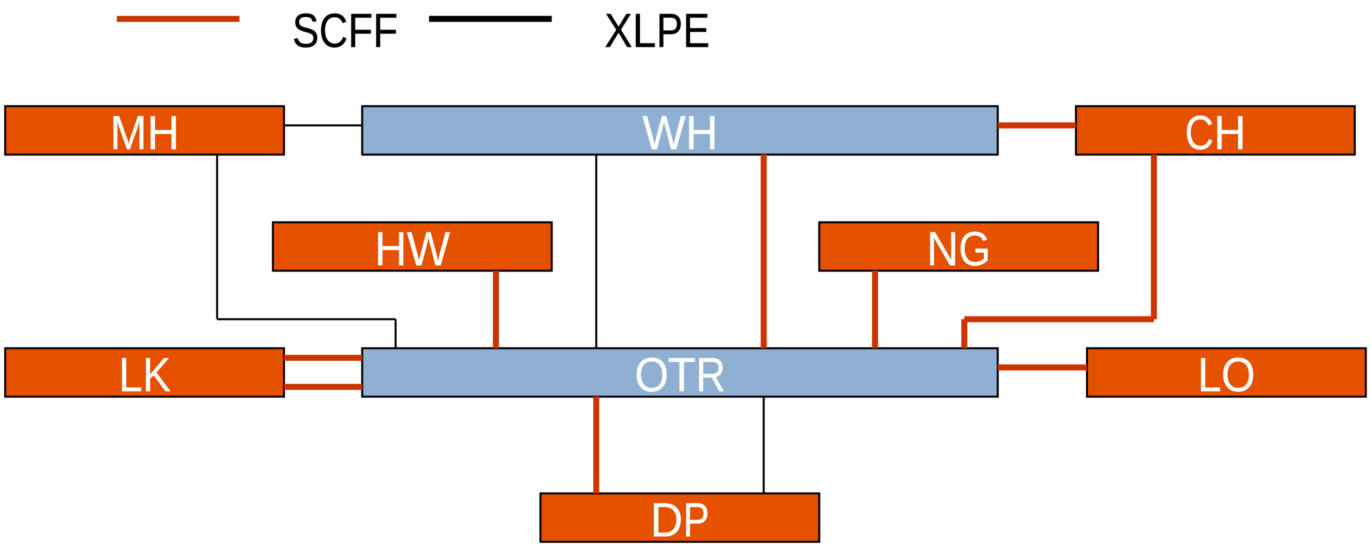
In this example two local networks shall be classified, namely the two networks belonging to the cables WH-OL-1 and VD-WE

Given that both these cables rank high in the data set; it is interesting to find out how their riskiness compares to their peer cables

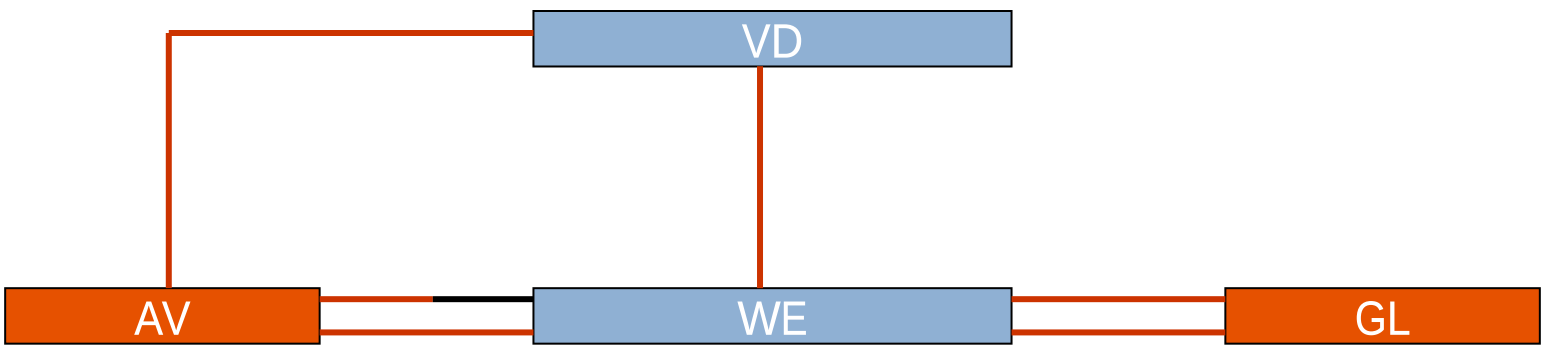
It is also interesting to compare one local network with another

Updated Classification on Network level

SCFF Cables in Local Network1



SCFF Cables in Local Network2



Classification Tool
Local Network1

Cable	Remaining Life	Failures 2003-2009	Oil Additions	Leakage Per Year	Technical reliability
WH-OL-1	17	10	9	282	20
WH-CH	27	7	8	177	20
LK-OL-2	35	4	5	138	20
OL-SH	40	2	11	98	60
LO-OL	29	1	1	11	60
NG-OL	41	2	2	20	80
LK-OL-3	46	0	2	9	100
DP-OL-1	45	0	0	0	100
WH-OL	?	1	0	0	?

Classification Tool
Local Network2

Cable	Remaining Life	Failures 2003-2009	Oil Additions	Leakage Per Year	Technical reliability
VD-WE	41	19	13	214	20
AV-VD	35	4	1	72	40
AV-WE-2	39	1	1	4	60
GL-WE-1	37	1	1	4	60
AV-WE-1	43	2	2	6	80
GL-WE-2	42	2	2	28	80

Classification on network level

Before the replacement of the most critical cable in network 1 and 2

Network	Average Life	Average Failures	Average Oil Additions	Average Leakage Per Year	Perc. cables ranked with 20
Network 1 WH	35	3	4.2	81.6	33.3%
Network 2 VD	39.5	4.8	3.3	54.6	16.6%

After the replacement of the most critical cable in the local network 1 and 2

Network 1 WH	37.6	2.1	3.6	56.6	25%
Network 2 VD	39.2	2	1.4	22.8	0%

Summary: Classification model

The classification tool has provided us with the following

- An overview on the contribution of risky cables on the performance and health of their respective local network environment
- A good way of comparing cable and network statistics
- A set of cables that deserve the focus of attention (monitoring)

<u>When</u> do we replace the cable ??

Simulation model

We need to model failure rate development and regard its possible impact

What needs to be done?

->Combine cost statistics with failure statistics with Arrhenius

How can we do that?

-> By simulating possible failure scenarios and investigating the results (with MONTE CARLO simulation)

Main Advantages

1. Simulating the future without experiencing the consequences (costless)
   Testing various decisions under various scenarios

Main Disadvantage

1. Not a full representation of reality
2. Limited by the availability of information and validity of statistical models

Scenario's

All simulations are run until the year 2030

	Scenarios		
	Very Pessimistic	Normal	Very Optimistic
Inflation*	6%	5%	4%
Interest Rate**	2%	5%	8%

*Based on the long average of the Netherlands (4%-6%): *this indicates the price rise over time*

**Based on the risk free rate (~5%): *this is an indication of the price risk over time*

Scenario's

	Scenarios		
	Very Pessimistic	**Normal**	**Very Optimistic**
Cable end-of-life estimate	Arrhenius -5 years	Arrhenius +0 years	Arrhenius +5 years
Failure increase before end-of-life	5%	3%	1%
Failure increase after end-of-life	Strong Exponential (α = 6; τ = 10)*	Normal Exponential (α = 4; τ = 10)	Weak Exponential (α = 2; τ = 10)

*$f(t) = f(0) \times \alpha^{(t/\tau)}$: *values roughly based on work R.A Jongen "Application Statistical Tools"*

Simulation Tool
Case Study1: Two Single Cables

Cable 1 WH-OL-1
Cable 2 GVL-HZN-1

	Scenarios		
	Very Pessimistic	**Normal**	**Very Optimistic**
Strategy 1	Replacement **10** years	Replacement **10** years	Replacement **10** years
Strategy 2	Replacement **20** years	Replacement **20** years	Replacement **20** years

Simulation Tool
Strategy1: Replacement in 10 Years

Cable 1 WH-OL-1
Cable 2 GVL-HZN-1

	VP1	VP2	N1	N2	VO1	VO2
NPV: Maintenance/ Replacement	9.1%	1%	8.1%	0.9%	8.1%	1.2%
Average failure costs per km	€3.150	€226	€2.837	€124	€2.444	€125
Average probability failure >€100,000	4.5%	1%	4%	0.5%	3%	0.5%

Simulation Tool
Strategy2: Replacement in 20 Years

Cable 1 WH-OL-1
Cable 2 GVL-HZN-1

	VP1	VP2	N1	N2	VO1	VO2
NPV: Maintenance/ Replacement	26.5%	3.2%	22.8%	2.1%	19.3%	1.3%
Average failure costs per km	€13.298	€ 275	€ 5.693	€206	€ 3.392	€122
Max probability failure >€100,000	30-35%	0-2%	10-15%	0-1%	4-8%	0-0.5%
NPV maintenance costs per km	€206.714	€ 10.210	€63.878	€6.233	€30.919	€3.509

Simulation Tool

Case Study1: Two Single Cables

A short overview of some of the results

- One can see that due to the high uncertainty in the model parameters the difference between the pessimistic and the optimistic model is great
- A decision to replace late (strategy 2) will lead to a very high percentage of maintenance costs with respect to the replacement costs for WH-OL-1
- In the pessimistic scenario, but also in the normal scenario, there is a higher probability of a big failure (>€100,000) occurring for WH-OL-1

-> One cannot yet say what the optimal replacement time would be for either one of these cables, but it is clear the WH-OL-1 carries a significant amount of risk. Far in excess to that of GVL-HZN-1

How about simulating and comparing two networks?

Simulation Tool
Case Study2: Two Local Networks

Network 1: WH-OL-1

Network 2: VD-WE

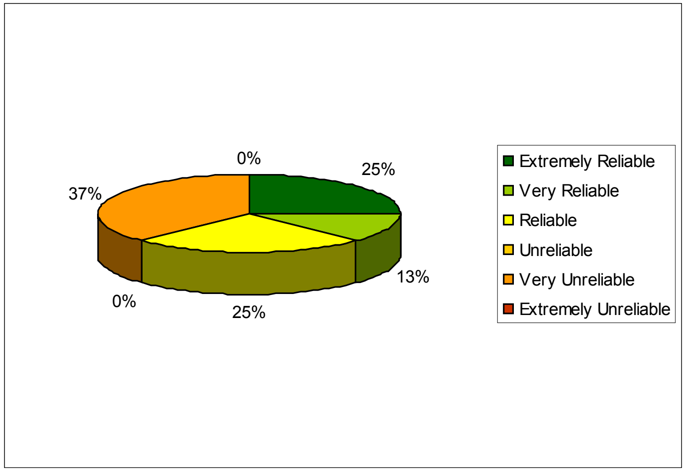
	Scenario		
	Very Pessimistic	Normal	Very Optimistic
Strategy 1	-	**No** Replacement	-
Strategy 2	-	Replace 1 Cable	-

Simulation Tool
Case Study2: Two Local Networks
Without replacement

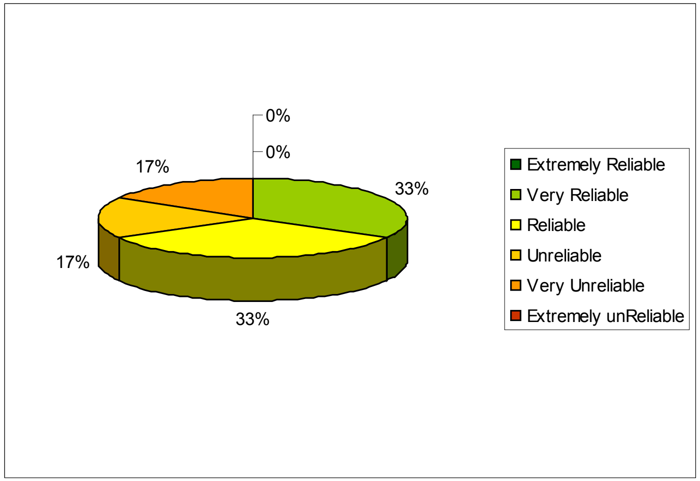
Network 1

Network 2

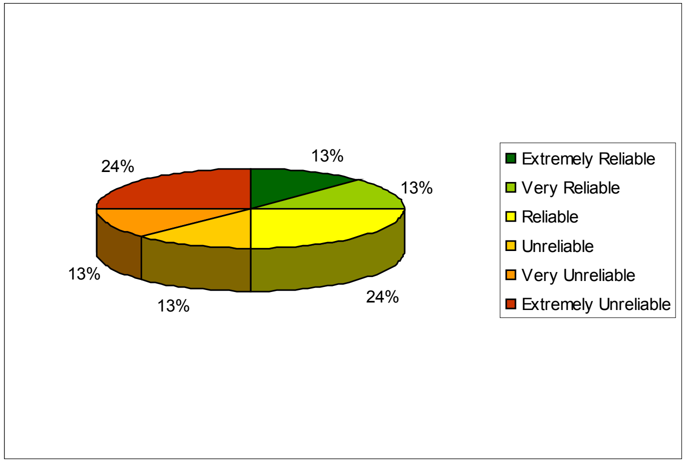
2010



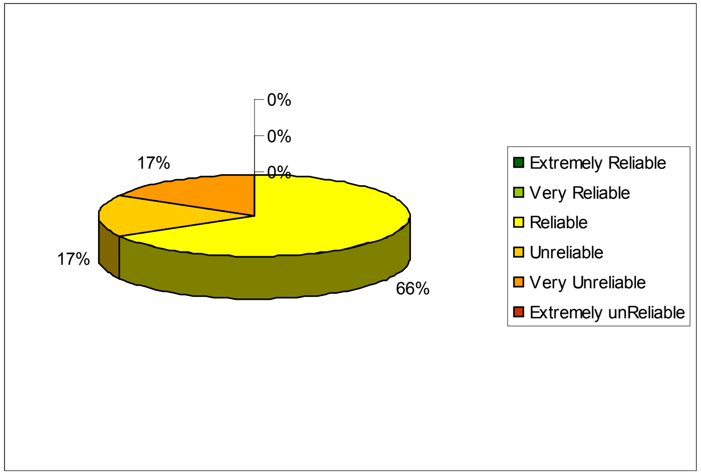
2010



2030



2030

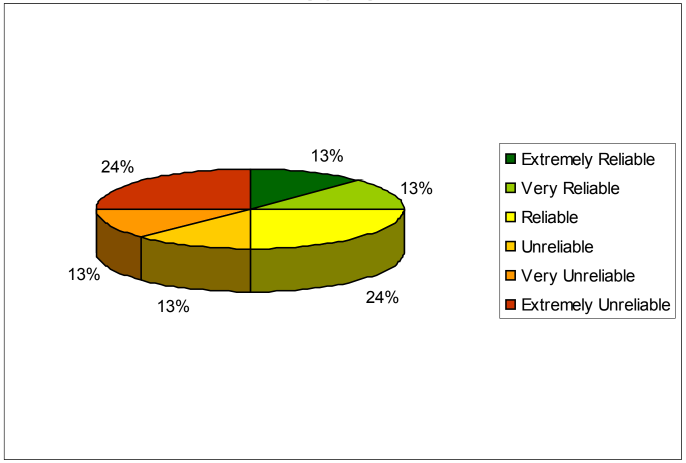


Simulation Tool
Case Study2: Two Local Networks
Replacing most critical cable in local network

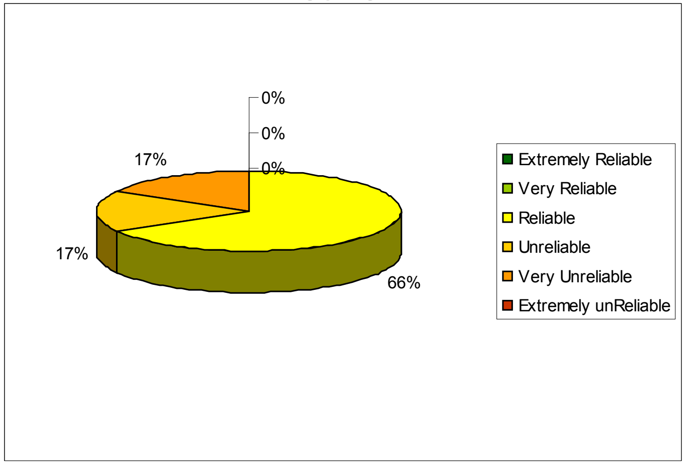
Network 1

Network 2

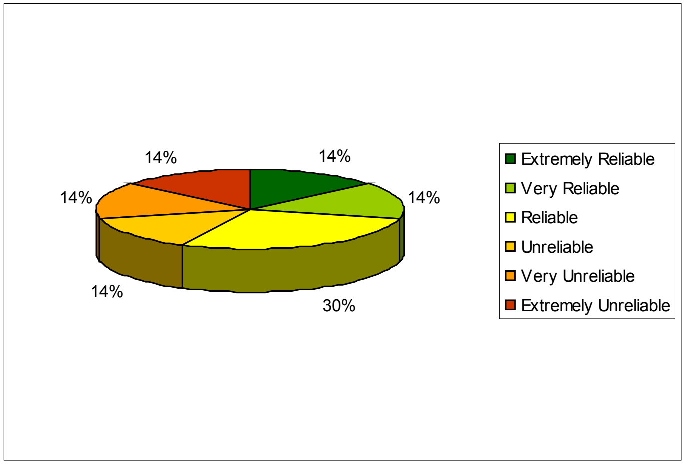
2030
Without replacement



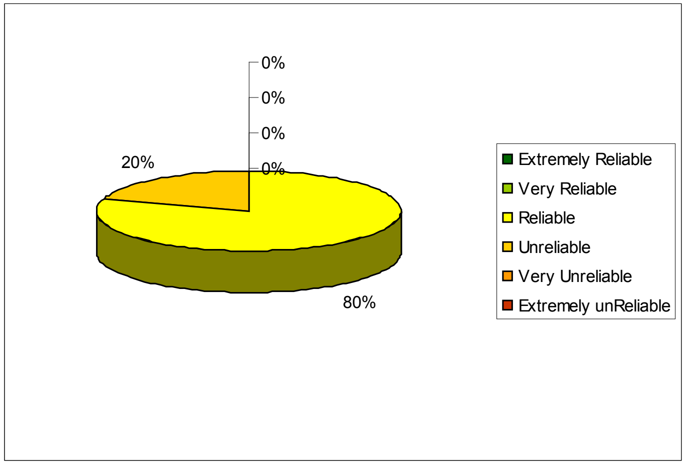
2030
Without replacement



2030
With replacing most critical cable



2030
With replacing most critical cable



Simulation Tool
Case Studies: Summary

What have we learned until now?

- We have seen that the risk from cable to cable or network to network can vary considerably
- Use the classification tool to identify risky cables and networks and make comparisons
- Use the simulation tool to investigate the impact of replacement strategy

Conclusion

- Model available to classify (prioritize) all SCFF cables in our network. Classification is based:
  - Component
  - Network data
  - Load behavior
  - Failure data
- First steps in development of a simulation tool for different scenarios and strategies in order to determine best replacement strategy for the future. Simulation is based on:
  - Different replacement scenario's
  - Failure rate scenario's: Estimations by Weibull statistics
  - Financial aspects

- Further development of the simulation tool is necessary to improve the accuracy of the results !!
  - More scenario's analyzed
  - Better financial scenario's (i.e. marked related inflation instead of total inflation)
  - Improve the failure rate estimations
  - More simulations run (by Monte Carlo: 10,000 simulations in stead of 100)