

Deliverable D6.5: Software Improvements

WP6: Development of the open Access TeaM Cables tool and
integration of models

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Author(s) of this deliverable: D. Goldscheck & R. Baier (FRA-G), M. Broudin (EDF), A. Paul (ARTTIC)

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Glossary

Abbreviation/ acronym	Description
AMR	Ageing Management Review
AO	Antioxidant
ASP	Average service period
BWR	Boiling Water Reactor
COMSY	Condition Oriented Monitoring and Plant Management System (Software)
EDF	Électricité de France
FRA-G	Framatome GmbH
GUI	Graphical User Interface
HW	Hardware
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
MS	Microsoft
NIA	no information available
OS	Operating System
PE	Polyethylene
PH	Polymer substrate
PWR	Pressurized Water Reactor
SW	Software
VP	Virtual Polymer (Software)
WP	Work Package
XLPE	Cross-linked polyethylene

1 Executive Summary

This deliverable provides a summary of the software development activities for the TeaM Cables Tool (from COMSY electrical) considering the further developments of the multiscale ageing model for XLPE (Cross-linked polyethylene) achieved in Virtual Polymer (VP) and the definition of end-of-life criteria.

The TeaM Cables Tool intends to combine COMSY (Condition Oriented Monitoring and Plant Management System), developed by Framatome GmbH, and VP (Virtual Polymer), developed by EDF.

The TeaM Cables Tool software development is based on the previous reports issued as deliverables within the TeaM Cables project, [1] to [4]. All WP6 reports can be found at <https://www.team-cables.eu/media-centre/>.

2 Introduction

COMSY is the front-end software running on Windows OS platform at the customer; all data is stored in a MS Access or MS SQL Server database. The COMSY software provides the platform for a number of applications and functionalities in the field of ageing and plant life management. It is a software product with modular architecture, which is designed in a way where each module can be operated independently or in combination with any number of further modules. The software program COMSY is designed to provide identification and prognosis of degradation processes in the technical equipment of power plants. The program does not only store and manage data, but also provides a number of analytical functions. Based on the input data, it provides prognosis of e.g. critical points; predicts degradation rates and performs lifetime analysis for components. On this basis, the in-service inspections and maintenance activities can be optimized.

For the TeaM Cables Tool, the electrical module of COMSY will be used. In the TeaM Cables Tool, the currently implemented ageing/degradation algorithms for assessment/management of the lifetime for XLPE insulated cables (as part of passive electrical systems) will be replaced/extended with the evaluation of calculation results from VP, using the algorithms developed and validated within the framework of the TeaM Cables project.

VP is the back-end software running on Linux OS: it is a one-dimension modelling platform composed of a model data base and different calculation components. The chaining of the different parts makes it possible to develop a multi scale and multi physical modelling of the polymer ageing process. The further development and validation of the multi scale and multi physical modelling of the ageing process of XLPE in dependence of specific material properties and environmental conditions is the main objective of the TeaM Cables project.

The features required in the TeaM Cables Tool were identified in Deliverable D6.1 as the following:

- the graphical user interface (GUI) needed for cable data entry and display,
- generates the data needed for degradation calculations in VP,
- receives the calculation results (abacus/solver matrix) from VP,
- allocation/mapping of VP results to the individual cables,
- display of results, calculation of residual life time.

TeaM Cables Tool will have a limited/restricted functionality in comparison to the features available in the commercial COMSY platform. A comparison of features/functionality is presented below.

Table 1: Comparison of features

Important Features (not complete)	COMSY	TeaM Cables
Multiple plants or databases	X	-
Basic user interface	X	X
Document management	X	X
Mechanical component assessment	X	-
Electrical components assessment	X	VP / XLPE only
Civil components assessment	X	-
Operating Experience feedback	X	-

Important Features (not complete)	COMSY	TeaM Cables
Active components assessment	X	-
Automatic commodity grouping GALL/IGALL	X	-
Risk Based assessment	X	Read only
Examination data management / Trending / Outage planning / Import	X	Read only
Material- / Equipment-/ other libraries	X	-

3 XLPE Cable Types from COMSY Electrical

3.1 Handling of customer data in COMSY Electrical

The software system acquires, manages and evaluates design, operating and environmental parameters relevant to the service life of equipment. Plant data pertaining to individual systems, structures and components (e.g. piping elements, electrical equipment such as cables, civil structures) and systems are stored in a “virtual plant data model” and a database as back-end.

The Graphical User Interface (GUI) to view this plant model is provided by the COMSY Explorer. It is a flexible form similar to the Windows Explorer and serves to navigate within the plant model. All user interactions in the program and evaluations can be conducted in the Explorer and the integrated main menu. Also modifications of the data such as adding and deleting of elements, data changes etc. are available, but will not be explained in this report. This will be part of the software manual. This chapter focuses on the relevant input forms for the handling of customer data needed for the assessment of Virtual Polymer in the scope of the TeaM Cables application.

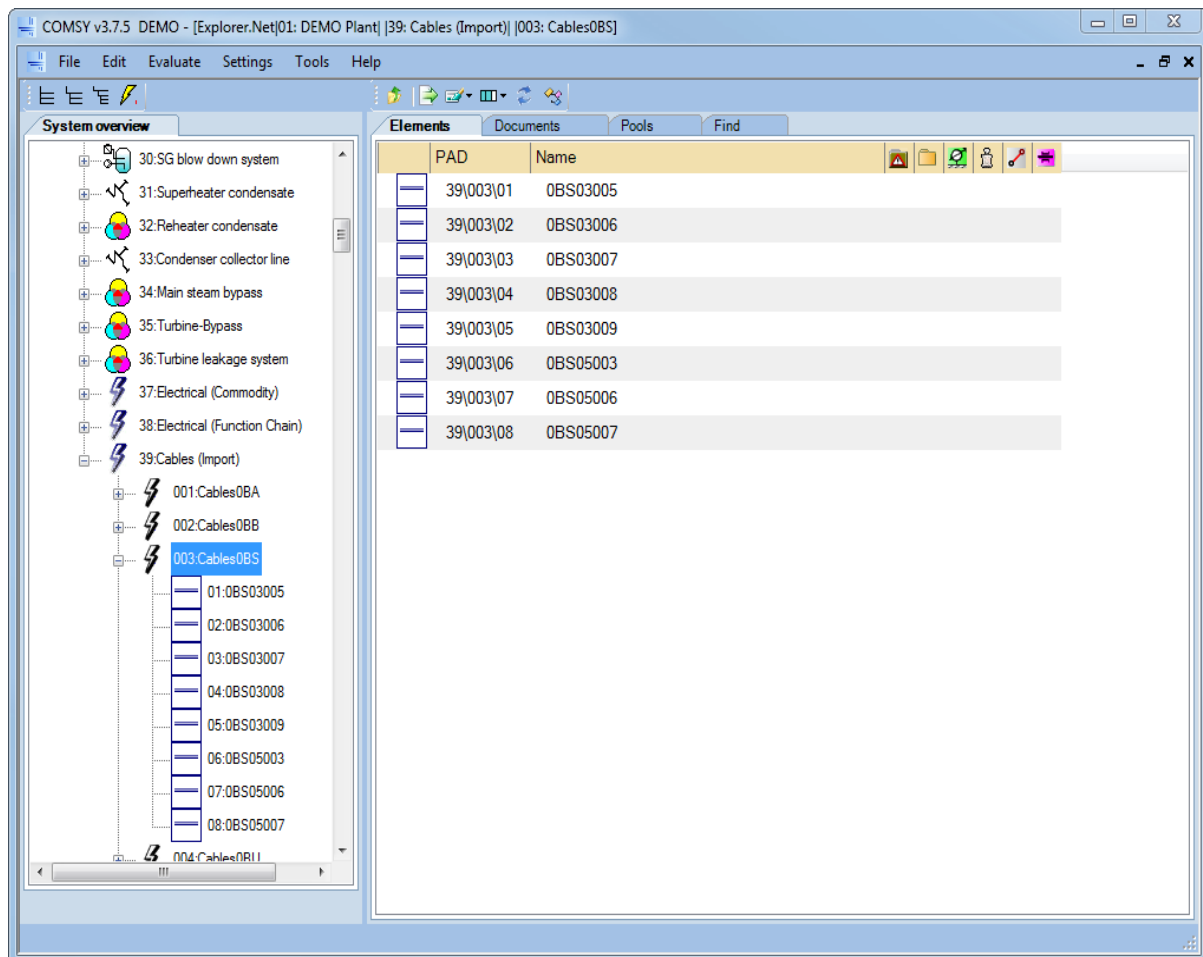


Figure 1: Example of COMSY Explorer and integrated main menu

3.1.1 Cable data, commodities

Passive electrical equipment is managed in a specific library. The commodity library serves to change or view the detail data for each commodity (e.g. cable type) and acts like a device library for passive components which can be analysed using a deterministic approach, whereas active components are rather analysed with statistical methods (e.g. failure rates). To open the commodity library, use Settings – General definitions – Electrical commodities from the main menu. An overview form opens and shows the most relevant information for each Commodity. It lists the device type (for TeaM Cables, only device type cable is of relevance), manufacturer type and other properties. Each cable type can be connected to a number of components. For each cable type, a list of all electrical components which are connected to the currently selected type can be opened from here.

Device type	Manufacturer	Type	Application	Geometry	Insul. Thickness [mm]	Comment	Nominal voltage [V]	Allowable current [A]	Antioxidant type
Cable	Rockwell	OBLAG1		A/C 1-10A	0.20		240	5.00	Phenolic
Cable	3M	OBLAG2		A/C 4	0.20		400	5.00	None
Cable	Rockwell	OBLAG3		A/C 4	0.20		400	5.00	Thiouether
Cable	Rockwell	OBLAG4		A/C 14	0.20		400	5.00	None
Cable	Rockwell	OBLAG5		A/C 4/2 10A	0.20		100	5.00	Phenolic
Cable	3M	OBLAG6		A/C 4/2	0.20		400	5.00	Unknown
Cable	3M	OBLAG7		A/C 14	0.20		2000	10.00	Phenolic/Thiouether
Cable	Rockwell	OBLAG8		A/C 14	0.20		10	5.00	Unknown
Cable	3M	OBLAG9		A/C 14	0.20		10	5.00	Thiouether
Cable	3M	OBLAG10		4x4	0.20		400	5.00	None
Cable	3M	OBLAG11		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG12		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG13		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG14		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG15		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG16		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG17		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG18		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG19		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG20		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG21		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG22		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG23		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG24		A/C 14	0.20		400	5.00	None
Cable	3M	OBLAG25		A/C 14	0.20		400	5.00	None

Figure 2: Passive Equipment Library Overview Form

When opening the detail form, the following entries can be conducted to define a cable type:

General: Electrical components | Device-type: Cable

Application: Low Voltage | Manufacturer: Cable Manufacturer Inc.

Type: Coax | Geometry: 4x4

Comment: Any comment

Nominal voltage [V]: 240.00 | Allowable current [A]: 5.00 | Thickness [mm]: 1.000

Antioxidant: Unknown | Min [mol/l]: 20.0000 | Max [mol/l]: 60.0000

Material	Function
XLPE	Insulation
Cu	Conductor
XLPE	Jacket

Changes have been saved!

Figure 3: Example of cable type detail form for first field testing

These are the main entries used to identify a cable type, whereas the Antioxidant (AO) content is a specific field for the TeaM Cables tool and needed for the calculations in Virtual Polymer.

According to the remarks from the first end-user workshop, some additional fields needed to be integrated into the TeaM Cables Tool to address a cable type more precise for the calculation in Virtual Polymer. Therefore, additional fields have been created.

The screenshot shows the 'Edit commodities' form with the following fields and values:

- General:** Electrical components (dropdown), Device-type: Cable (dropdown)
- Application:** Low Voltage 0.6kV, Manufacturer: Cable Manufacturer Inc.
- Type:** Cu/XLPE/SWA/PVC, Function: Power
- Geometry:** 4x50, Add-on 2: 0.6/1 (1.2), Add-on 3: Nom. Dia: 31.7mm
- Comment:** Cores Identification: Brown, Black, Grey, Blue; Sector Shaped Stranded Compacted Copper (Class 2); Conductor Operating Temp. up to 90 °C; Conductor Max. DC Resistance at 20°C: 0.387 Ω/km;
- Drawing:** <http://CableManufacturerInc.com/PS2234jdk>
- Nominal voltage [V]:** 600,00, Allowable current [A]: 238,00, Year (manufacturing): 1982
- Batch-No.:** Ba3033-1, Number of conductor: 50, Thickness [mm]: 0,300
- Antioxidant:** Phenolic (dropdown), Min [mol/l]: 1,0000, Max [mol/l]: 4,0000

Material	Function
XLPE	Insulation
Cu	Conductor
PVC	Jacket

Notice! Changes affect the following units: calculation-results of electrical equipment

Figure 4: Example of cable type detail form after first field testing

A further discussion is needed for the Antioxidant content. As the detailed level of Antioxidants is probably not available on customer side, the suggestion is to use 4 categories for antioxidants: No AO (0%wt), Few stabilization (0.2%wt), Average stab. (0.4%wt), Strong stab. (>0.6%wt).

The following options are available:

The close-up shows the 'Antioxidant:' dropdown menu with the following options: Phenolic, Unknown, None, Phenolic, Thioether, Phenolic+Thioether, Other. The 'Min [mol/l]' field is set to 20.00 and the 'Max [mol/l]' field is set to 60.00.

The Virtual Polymer calculation in the framework of this project is able to address the options: None (no AO), Phenolic (AO1), Thioether (AO2) and Phenolic + Thioether (AO1+AO2). All other options cannot be calculated and can be used for documentation purposes of other cable types only (also refer to chapter 3.2).

A further addressed point was to indicate mandatory data for the calculation. An idea for implementing this could be to use a help box, which provides further information on each text field. By selecting the question mark on the top of the form and afterwards clicking in a field, a further comment appears showing additional information.

Mandatory parameters for calculation of Virtual Polymer:

- Antioxidant type and content (unit mol/l, default values to be clarified, further information can be given on the form by using the help button as specified above)

Optional parameters:

- All other input boxes

In later development, the thickness (of the insulation) could also be a mandatory calculation parameter. Currently only a specific thickness (0.3mm) can be calculated from Virtual Polymer. All other relevant input fields are either fixed (device type, insulation material XLPE) or deal to specify the cable type as detailed as possible, but are only used for the cable identification.

Additional manufacturer information can be added when using the drawing field and using a website link or a link to an internal document management system which contains further information on a data sheet or similar. The link can be opened directly using the right-click menu.

3.1.2 Cable routing – rooms - environmental loads

The TeaM Cables Tool is using so called room-pools in order to specify the environmental condition for a certain compartment in the power plant building or an outdoor area of the plant site. The specification of the environmental condition comprises the typical temperature, the typical humidity and the expected average dose rate. For the outdoor area, weather conditions and maritime climate can be specified. If a relevant difference in room climate exists e.g. between summer and winter or between earlier service periods in the history of the plants operation, different room climate periods can be generated by inserting lines in the table shown in the upper part of the form.

The screenshot shows a software window titled "room parameter pool: YARD". At the top, there is a table with 13 columns: end-date, Temperature [°C], Medium, Dose rate [mSv/h], Moisture [%], Outdoor, Maritime air, Impurified, Stagnant, ASP [%], Oxygen [%], and Carbon dioxide [%]. The first row has values: "NIA", 30,00, air, 0,00, 70,00, unknown, unknown, no, 100,00, 21,00, 0,04. Below the table is a form with various input fields and dropdown menus corresponding to the table headers. The form includes fields for End-date period, Temperature, Ambient medium, Moisture, Dose rate, Impurified, Oxygen, ASP for period, HOO for period, Outdoor, Maritime air, and Carbon dioxide. A comment field for the period is also present at the bottom.

end-date	Temperature [°C]	Medium	Dose rate [mSv/h]	Moisture [%]	Outdoor	Maritime air	Impurified	Stagnant	ASP [%]	Oxygen [%]	Carbon dioxide [%]
0	*NIA*	air	0,00	70,00	unknown	unknown	no		100,00	21,00	0,04

Figure 5: Example for the room pool form (environmental data)

The room climate pool is designed to give an overview on environmental conditions for certain rooms in the power plant building or in virtual compartments. For each room, climate conditions can be

specified for any number of periods in the plants operation history (indicated by the end-date) in combination with different average yearly periods (indicated by the ASP – Average service period - %).

Mandatory parameters for calculation in the TeaM Cables Tool:

- Temperature (unit: °C; specify the typical temperature in the room or virtual compartment considered for the current period)
- Dose rate (unit: mSv/h; specify the typical radiation dose rates per year for the room or virtual compartment considered)
- Oxygen content (unit: %; specify the oxygen content in the environmental medium if specific atmosphere exists (e.g. nitrogen preservation area); default value 21% for atmospheric air.

Optional parameters:

- End-date service period (unit: date [mm-yyyy]; specify end date for a distinct room climate period in service history of the plant; for TeaM Cables Tool use *NIA* (no information available) to consider only one current time period with the best estimated average temperature over the life time)
- ASP for period (unit: %; specify the average service period per year (ASP) for a distinct room climate period in the course of plant operation; for TeaM Cables Tool use 100% as default value as different climate phases over year cannot be addressed when using the VP Abacus calculation)
- HOO (unit: h; the program calculates the operating hours from the respective time period considering the date delimiters and the average service period of the element)
- Ambient medium (Specify ambient medium of room, default air)
- Moisture (unit: %; specify the typical moisture in the room or virtual compartment considered)
- Outdoor (specify if you are dealing with a virtual compartment which is located outdoor)
- Maritime air (specify if the outdoor area concerned experiences maritime air with salty compounds)
- Impurified (specify impurity by chloride or boron)
- Carbon dioxide (unit: %; specify CO₂ content in the environmental medium if specific atmosphere exists (e.g. nitrogen preservation area); default value 0,04% for atmospheric air.

Note: the mandatory values will be considered when the Virtual Polymer Abacus is mapped to a real component, which is explained in chapter 5.2.

Multiple room pools can be connected to any component existing in the plant model using the COMSY Explorer Pool Tab. Especially for cables, this can be used to address cable routing in case a cable runs through different areas. Vice versa, as a pool is typically connected with more than one component, also all components located in a specific room or area can be determined easily.

3.1.3 Cable classification and operational data

TeaM Cables Tool is able to address a variety of classification data sets. The naming of the categories is plant specific and can vary depending on each country. Some categories are valid for each different discipline like e.g. safety, seismic or quality class. But many are depending on the type of equipment, e.g. mechanical, electrical or civil equipment. Typical examples are environmental class, equipment qualification, importance, explosion, fire mitigation, flooding, seismic fall down or intended function.

Classification data can be independently added to any single component. There is no influence to the calculation of Virtual Polymer as the classification data serves to document the component status only. Each classification value can be referenced by a source file name to allow for a link to the original classification document.

The second component specific area is the so-called AMR data, which is important for the Aging Management Review as there are start-up date, design, operation, water chemistry and environmental

data. For electrical passive components, only start-up date and environmental data (room) are of interest and visible.

Scoping Data	
Plant identification code	AE1003A
Component type	
Safety category	N1E
Seismic class	2
Quality level	NC
Maintenance category	Not set
Aging category	Not set
Intended Function 1	Not set
Intended Function 2	Not set
In-Scope	Not set
Comment (Scoping)	
Comment (General)	AMP: YES
Comment (PID)	
AMR Data	
Start-up	2011-07
Room	Bid. A100
Group	Components_not_environmentally_qualified - Cable

Figure 6: Example of classification and AMR data set for a single component

Mandatory parameters for calculation in TeaM Cables Tool:

- Start-up date

Optional parameters:

- All input boxes

Note: the start-up date of a component will be considered when the Virtual Polymer Abacus is mapped to a real component, which is explained in chapter 5.2. But there is none of these data needed for the calculation of the Abacus values in VP.

3.2 Creation of XLPE Cable Types for VP (custom fields)

In order to cover a wide range of applications (in context with end-user “wishes”), the following:

- Dose rate range from 0 to 100mSv/h (~0.1Gy/h), which means 2.7E-7 to 2.7E-5 Gy/s (EPR design).
- Temperature range from 20°C to 90°C
- Time: calculation for 60 years duration (simulation time)

Will be considered in the “basic” VP calculation run.

As the multiscale ageing models developed in the framework of the TeaM Cables project prove to be sensitive of the material formulation, the following fields are provided in the TeaM Cables Tool:

Polymer substrate, [PH]: This parameter is not specified in the material datasheet and probably hard to determine for a plant, therefore default value of [PH] = 60 mol/L (cf. Deliverables D4.2, D4.3, D4.6 – [5] to [7])

Type of antioxidant, [AO1; AO2; AO1+AO2]

Thus, there are four options left to the user:

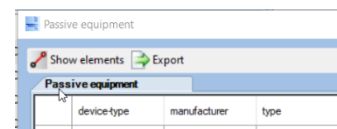
- No AO
- AO1 corresponding to phenolic antioxidant;
- AO2 corresponding to thioether antioxidant;
- AO1+AO2 corresponding to the combination of the two antioxidants.

Antioxidant content, [AO]

- Select default value (realistic ranges must be defined by Nexans), cf. discussion in chapter 3.1.1:
 - AO1: [0, AO_{min}, AO_{max}];
 - AO2: [0, AO_{min}, AO_{max}];
 - AO1+AO2: [0, AO_{min}, AO_{max}].
- **Oxygen concentration, [CO2]**
- **Thickness, [p]**
- **Fillers content, [ATH]**
- **Boundary conditions, [film].**

3.3 Interface to VP

The export of cable data can be conducted using the Passive commodity library, refer to chapter 3.1.1. A button for exporting is available for each individual cable type that needs to be examined.



An export file is generated which also converts the relevant data in the units used by Virtual Polymer.

 A screenshot of a Notepad window titled 'inputs_data.txt - Notepad'. The text content is as follows:


```
File Edit Format View Help
[team_cables_2021]

"ID_manufacturer" : [manufacturer] # or default value [none]
"ID_year_of_manufacturer" : [year of manufacture] # or default value [none]
"ID_cable_specification" : [cable specification] # or default value [none]
"ID_cable_classification" : [classification] # or default value [none]
"ID_cable_function" : [function] # or default value [none]
"ID_components" : [insulation] # or [sheath] default value [none]
"ID_voltage" : [voltage] # or default value [none]
"ID_number_of_conductors" : [number of conductors] # or default value [none]
"ID_material_of_conductors" : [material_of_conductors] # or default value [none]

"T" : [288.15, 333.15, 5.]
"I" : [0.00000027, 0.0000273, 0.0000027]
"t" : [0, 1.89e9, 3.15e7]
"PH" : [58] # or default value [default value]
"type of antioxidant" : [none] # or [AO1] or [AO2] or [AO1+AO2]
"content of antioxidant" : [none] or [1.6e-2]
"oxygen concentration" : [default value] # or enter a value [.00038]
"thickness" : [0.3]
"fillers content" : [0] # or [50]
"boundary conditions" : [film]
```

Figure 7: Example of an export text file

The exported values and conducted conversions are as following:

- T – Temperature: from °C to K ($T([K]) = T[°C] - 273,15$)
- I – Radiation: from mSv/h to Gy/s ($I [Gy/s] \sim I [mSv/h] / 3.600.000$)
- t – Time: $t([s]) = t[y] * 3,15e+7$ (calculation for 60 years refers to 1,892e+9 seconds)
- PH – Polymer substrate: [mol/l], no conversion needed, default value of 60mol/l used, cf. deliverable D6.3
- Type of antioxidant: text value, “none” or “AO1” or “AO2” or “AO1+AO2”

- Content of antioxidant: [mol/l], tbd – realistic ranges needed to define the possibility of using predefined values with few stabilization (0.2%wt), average stab. (0.4%wt), strong stab. (>0.6%wt), see also chapter 3.1.1
- CO₂ – oxygen concentration, oxygen dissolved in polymer [mol/l] $\sim 1.8 \times 10^{-8} \text{ mol}/(\text{l} \cdot \text{Pa}) \cdot \text{CO}_2$ in air[%] (21% oxygen in air with partial pressure of $0.21 \times 10^5 \text{ Pa}$ refers to $3.8 \times 10^{-4} \text{ mol/l}$)
- p – Thickness of insulation: [mm], no conversion needed
- ATH – fillers content: [%wt], no conversion needed
- Boundary conditions: text value, “film”.

The exported file can be directly processed from Virtual Polymer when integrated into the EDF MAP platform environment.

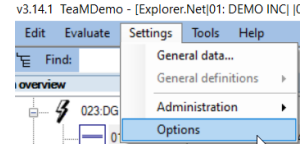
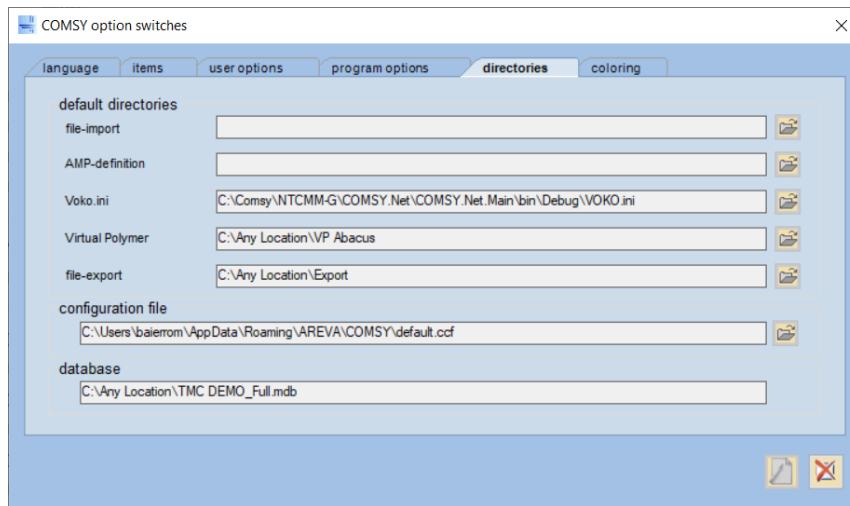
4 VP multiscale model and ageing algorithm

Virtual polymer uses the input data from the TeaM Cables Tool and performs a calculation run in the MAP platform environment. The output file (.csv), which is a so-called Abacus, contains the lifetime calculation result for the specified range. The models used in VP will be/are described in D4.2, D4.3, D4.4 and D4.6 ([5] to [8]).

5 VP abacus in COMSY Electrical

5.1 Handling of VP abacus in COMSY Electrical

The resulting Abacus from VP will be read in from the TeaM Cables Tool. Therefore, the program needs to know where the Abacus files are located. This can be specified in the program options.



Afterwards, for each cable type, the corresponding VP Abacus file will be searched by using the values defined in the export file, cf. chapter 3.3. All cables with identical export conditions (range of T, range of I, t, PH, type of antioxidant, content of antioxidant, p, Boundary conditions) do have the same Abacus and will be used for the mapping of the results, see chapter 5.2.

The results will be calculated directly and not stored in the database as all values are instantly available and no intermediate results or similar are needed.

5.2 Mapping of the VP results to individual XLPE Cables

One of the goals of the TeaM Cables project is to improve the accuracy of life time predictions for XLPE insulated cables. Especially the combination of thermal and radiological ageing in one model is not considered in the currently integrated approach. In COMSY Electrical, the calculation of remaining qualified life is performed by comparing the qualification parameter values like ageing temperature and duration, and ageing dose and duration with the corresponding accumulated environmental loads measured at the location of the equipment since it was installed, using Arrhenius law and the material specific activation energies for thermal ageing assessment and the power law and the material specific dose rate exponents for radiation ageing assessment respectively.

The above mentioned approach is accepted to be used for instance in German NPPs. It evaluates the thermal and radiological ageing separately. These objectives are in accordance with the general requirements of the German standards KTA 1403 and KTA 3706, the US standard IEEE 323, and the international standards IEC 60780 and IEC 62342.

The models included in VP consider synergistic effects between these two ageing stressors in the calculation.

In the TeaM Cables tool, a specific component data sheet exists, which summarizes all relevant input values for a single component and shows the lifetime calculation results. This form can be opened by double-clicking a component in the Explorer.

element data sheet 02/001/01

Segment: 02 Cables Train A (Import)

Section: 001 AE

Element: 01 AE1003A XLPE Type 1 (from MOTORX121 to FGPE 3)

Code / Application: AE1003A Electrical systems LV

From / To: MOTORX121 FGPE 3

Rec-ISI: 98

pheno	prio	Δ (32 a)	Rec-ISI	remark
TA		0 °C		TA feature does...
RA		0mSv/h		RA feature does...
MA				MA feature doe...
EA				EA feature does...
OA				OA not expected
TA+RA	B		2027	TA+RA may exist.

Element data Aging management Inspection data

Start-up: 2011-07 AAP [%]: 86,89 HOO total [h]: 74.218,00

Type: CBLA21RB

Manufacturer: Rockbestos

Geometry / Length: 4/C-2 1E 6

Material	T (index) [°C]	phi [eV]	+Tsh [°C]	dose [kGy]	DR [Gy/h]	exp	rel.
Insulation	XLPE	150	1,2	17	1000	4700	0,3
Conductor	Cu						
Jacket	CSPE	80	0,9				

Room

name	temperature [°C]	dose rate [mSv/h]	moisture ≤ [%]
Bld. A100	40	0,236	60

Comment: AMP: YES

Supplementary information

- categorization pools: I1E, I1C
- documents: (4)

Figure 8: Example of Element Data Sheet for an electrical component

The element data sheet for electrical equipment is similar to the data sheets of mechanical or civil components. The data displayed is specially adapted to electrical properties and contains detailed information about the selected electrical equipment.

The element data sheet for electrical equipment consists of two tabs. *Element data* contains the general and detailed technical information about the electrical component and functions for modifying these properties. The *inspection data* of the component is administrated in the second tab.

The COMSY program as well as the TeaM Cables Tool use colours as system-internal input identifiers. They describe the source of each input such as values which are assigned by means of default values or which result from a system-internal cross check calculation.

color code

- default value: example
- manual input value: example
- internally calculated value: example
- internally calculated - read only value: example
- error - cross check failed: example
- manually overruled: example
- no information available: example
- linked property: example
- individually calibrated value: example
- extrapolated value: example
- calculation possible: example
- double-click for list box: example

The codes used for managing the data records are displayed in the top part of the data input sheet.

Segment: 02 Cables Train A (Import)

Section: 001 AE

Element: 01 AE1003A XLPE Type 1 (from MOTORX121 to FGPE 3)

Code / Application: AE1003A Electrical systems LV

From / To: MOTORX121 FGPE 3

The upper right corner of the element data tab shows element lifetime calculation field on the left and the degradation assessment table on the right hand side.

Rec-ISI	<input type="text"/>	pheno	prio	Δ (32 a)	Rec-ISI	remark
Priority	<input type="text"/>	TA		0 °C		TA feature does...
Sched-ISI	<input type="text"/>	RA		0mSv/h		RA feature does...
Next ISI	<input type="text"/>	MA				MA feature doe...
	98	EA				EA feature does...
		OA				OA not expected
		TA+RA	B		2027	TA+RA may exist.

Rec-ISI - Recommended In-Service Inspection date. No input field. Shows date by which an element should be inspected at the latest. The recommended inspection date is used as a benchmark for sorting the elements by risk level.

Priority – Colour coded priority indicator ranging from A (red, high priority), B (yellow, second priority) and C (blue, third priority). If no priority is indicated, the element is not considered sensitive to degradation. No input field.

Sched-ISI – Scheduled ISI (In Service Inspection) date. Displays the date scheduled for inspection of the item, according to the current inspection plan. This date is to be specified manually by the responsible inspection manager.

Next ISI – A fixed date where the component has to be inspected next time, according to abnormalities determined during component examination and evaluation.

The following degradation phenomena categories are assessed in respect to degradation potential:

- TA - Thermal ageing due to temperature calculated with COMSY internal calculation (read-only comparison value in TeaM Cables Tool for default XLPE qualification parameters)
- RA - Radiation ageing due to radiation with COMSY internal calculation (read-only comparison value in TeaM Cables Tool for default XLPE qualification parameters)
- MA - Moisture ageing if material is sensitive to moisture with COMSY internal calculation (read-only comparison value in TeaM Cables Tool)
- EA - Sensitivity to electrical fields is indicated with COMSY internal calculation (read-only comparison value in TeaM Cables Tool)
- OA - Other ageing mechanisms that have been detected for the component
- TA+RA – The resulting highest priority and shortest lifetime according to the Virtual Polymer Abacus mapped to component.

Prio - Colour coded priority indicator for each stressor ranging from A to C, indicated for each degradation phenomena category individually. If no priority is indicated, the element is not considered sensitive to the specific degradation category within the next years.

Δ (60 a)- Allowed reserve delta until the end of plant operation, indicates the reserve margin for the component to reach a lifetime of 60 years. Negative margins account for a calculated lifetime that is below 60 years, Positive margins above 60 years. Please notice that this reserve margin is only calculated for thermal and radiation ageing. If the component was installed later than the plant start date, the Δ (60 a) will be reduced. E.g. if the component was installed 10 years after plant start, it has only 50 years to operate and the column header will show Δ (50 a).

Rec-ISI - Recommended In-Service Inspection date indicated for the specific degradation phenomena category. Shows date by which an element should be inspected with an inspection technique, which is adequate for the degradation category in question.

Remark - A specific remark with additional information to the calculation. If the remark is not fully displayed, the mouse pointer should be held over it and the full text will be shown.

The remaining fields in the element data sheet show the main element properties. With the start-up date and the AAP (Average Availability Percentage of the Plant) the HOO (Hours Of Operation) are

calculated automatically based on today's date. Below these fields the cable commodity, materials, environmental conditions (all rooms or environments the cable is connected to) are summarized and were already explained in chapter 3.1. Further information will be given in the TeaM Cables Tool Manual.

Once an Abacus has been found that is valid for the individual component, the calculation steps within the TeaM Cables Tool are as following:

- All rooms to which a cable is connected to are calculated one by one with their individual conditions (Temperature / Radiation)
- For each room condition, the relating values in the Abacus are searched, first by the radiation, then by the temperature, if needed interpolated (linear, by using the slope between the nearest values)
- Smallest calculated lifetime is taken into consideration
- Received lifetime is added to the component start date
- Recommended inspection data (RecISI) is displayed (End of life criteria reached)
- Priority is shown (A = Lifetime < Current date, B = RecISI within next 5 years, C = RecISI in next 10y).

With this approach, the worst case result will be displayed on the element data sheet.

One response of the first field testing was that more information is needed for visualisation and interpretation of the calculation results. As a consequence, an additional form is created in the TeaM Cables tool which shows all results for the individual cable when double-clicking on the life time result grid. This will enhance the traceability of the mapping from the generic VP Abacus to the individual component condition.

5.3 End-of-life criteria and algorithms in COMSY electrical

The End-of-life criteria are defined in VP, not in COMSY TeaM Cables tool. The final End-of-life criteria is still in discussion and will be gathered when all results from the Work Packages have been implemented in the VP model (cf. D4.4 [8]).

Also the Ageing algorithms/models are not implemented in the TeaM Cables Tool. The tool is used to create a usable platform which helps to have graphical interface and a model for the plant to deal with their collected information on XLPE cables. The models used in VP are described in D4.2, D4.3, D4.6 ([5] to [7]).

The search algorithm in COMSY will find the ageing condition result(s) from the VP abacus closest to the installation conditions of the cable. In case the exact results cannot be found from the VP abacus, linear interpolation from the closest values will be made, as described in the previous chapter.

6 Next steps

Software development is currently ongoing. A first distribution of the TeaM Cables Tool to the partners and end-user group is planned prior to the second end user workshop.

Then the software testing and feedback from the second end user workshop to be held in March 2022 at Framatome in Germany will be included in D6.6: Second Field testing.

7 References

- [1]. TeaM Cables D6.1: First revision of specifications (of the TeaM Cables Tool), 2018
- [2]. TeaM Cables D6.2: Implementation of the software, 2019
- [3]. TeaM Cables D6.3: Revision of the specification for Virtual Polymer as a result of input from WP4
- [4]. TeaM Cables D6.4: First Field Testing
- [5]. TeaM Cables D4.2: Thermo and radio-oxidation kinetics models for model 1 (confidential)
- [6]. TeaM Cables D4.3: Kinetics modelling of formulated polymer ageing in nuclear environment
(without fillers)
- [7]. TeaM Cables D4.6: Kinetics modelling of formulated polymer ageing in nuclear environment
(materials with fillers)
- [8]. TeaM Cables D4.4: Multiscale modelling of polymer ageing