

Deliverable D6.1: First revision of specifications (of the TeaM Cables Tool)

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

Grant Agreement number: 755183

NFRP-2016-2017-1

Euratom programme

Research and Innovation Action

Start date of project: 1st September 2017

Duration: 54 months

Lead beneficiary of this deliverable:

1 - EDF

Dissemination Level: Public

Document type: Report

Due date of deliverable: 31/08/2018

Actual submission date: 13/09/2018

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Description: Report describing specification of the software (Revision A)

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Glossary

Abbreviation/ acronym	Description
COMSY	Condition Oriented Monitoring and Plant Management System (Software)
ECS	EDF Coding System
GUI	Graphical User Interface
HW	Hardware
KKS	Kraftwerk-Kennzeichensystem
MS	Microsoft
OS	Operating System
PE	Polyethylene
PVC	Polyvinylchloride
SW	Software
Tbd	To be defined
VM	Virtual Machine
VP	Virtual Polymer (Software)
WP	Work Package
XLPE	Cross-linked polyethylene

1 Executive Summary

This document contains the first revision of the specifications for the TeaM Cables Tool.

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

1.1 COMSY: the Ageing Management tool

COMSY is the front-end software running on Windows OS platform at the customer. The COMSY platform is used as an Ageing Management tool for mechanical, electrical and civil components. COMSY provides a graphical model of the power plant and a degradation assessment for the included components. All data is stored in an MS Access or MS SQL Server database.

For the TeaM Cables Tool, the electrical module of COMSY will be used, currently the module is able to assess/manage lifetime for passive electrical systems in dependency of up to 5 different stressors using the ageing/degradation algorithms implemented directly in COMSY.

Within TeaM Cables, the assessment/management of residual lifetime for (XLPE) insulated cables shall be performed using the calculation results for XLPE ageing/degradation from VP.

Therefore, the definition of an interface for data exchange between COMSY and VP is required.

1.2 Virtual Polymer: the ageing calculation tool

VP is the back-end software running on Linux OS. VP 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 physic modelling of the polymer ageing process.

The further development and validation of the multi scale and multi physic 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.

Due to the complexity of the different models and equations, VP requires a server with a powerful Virtual Machine providing access for COMSY.

1.3 The TeaM Cables Tool

The TeaM Cables Tool will provide the following functions:

- 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.

2 Introduction

This document contains the first revision of the Specifications for the TeaM Cables Tool. The document describes the general functions and features of the TeaM Cables Tool.

The following figure shows the work packages of the TeaM Cables project and their interdependence. The work packages and interactions related to the TeaM Cables Tool are highlighted.

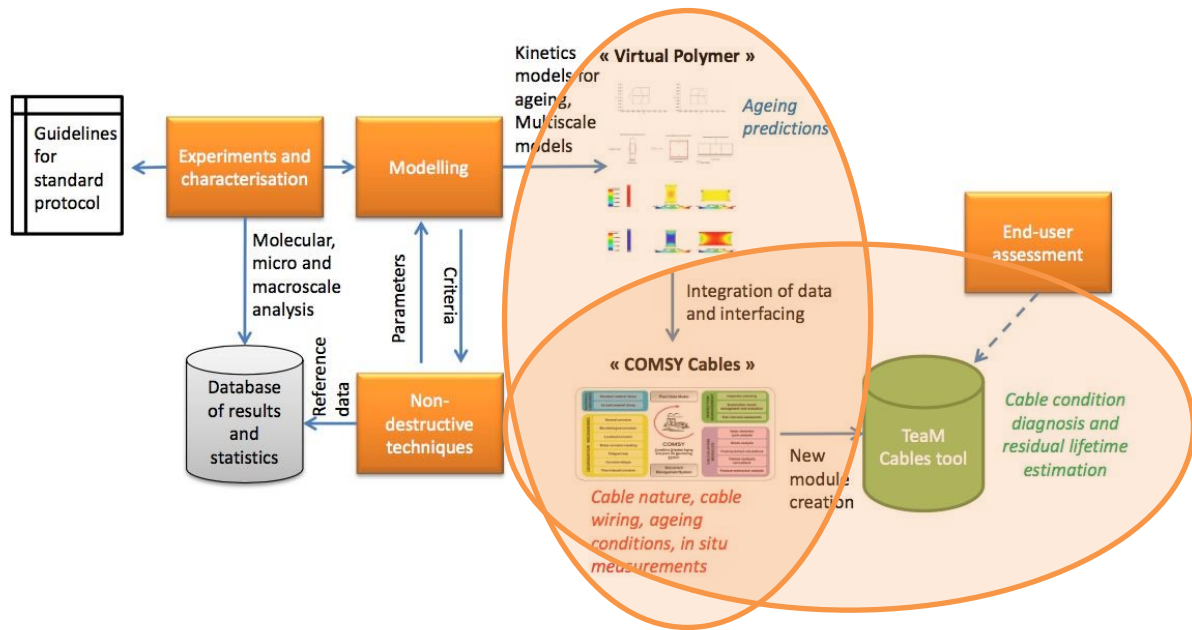


Figure 1: TeaM Cables Project overall approach and workflow

As presented above, the TeaM Cables Tool comprises the following two main functionalities:

- Front-end software running on Windows OS platform providing the customer interface for data input, display and evaluation (cable and plant related data).
- Providing the data interface to/from Virtual Polymer, the back-end software running on Linux OS. VP contains the platform, the models and the parameters for the multi scale and multi physic modelling of the polymer ageing/degradation process.

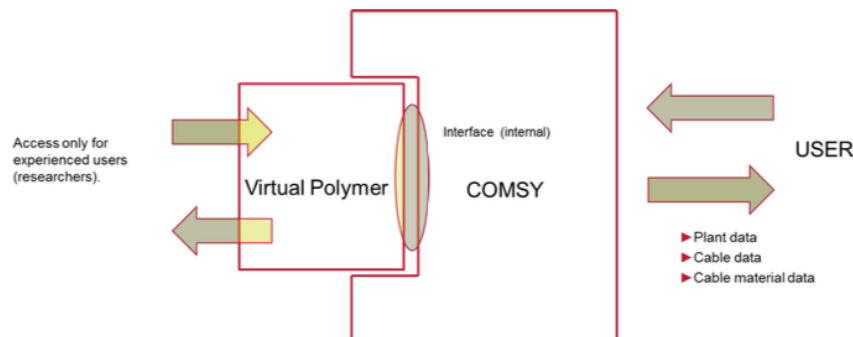


Figure 2: Interfaces in TeaM Cables Tool

Figure 2 presents the interfaces of TeaM Cables Tool.

- The user interface is used to create, save, maintain, and display customer related data as cable data (e.g. manufacturer, type, geometry, materials etc.), the related system data (e.g. KKS/ECS, rated voltage, rated current, level of utilisation, hours of operation, date of installation), as well as plant physical data (e.g. rooms, cable structures and trays, level of cable density), and the related plant environmental data (for the specific installation position e.g. temperatures, radiation dose rates, relative humidity etc.)
- The COMSY/VP interface works bidirectionally, it is used to transmit cable data and environmental parameters needed for the calculation of the polymer ageing/degradation process from COMSY to VP, and it is used to receive the calculation results (abacus, solver matrix) from VP to COMSY.

Based on the two main functionalities and interfaces of the TeaM Cables Tool, this report will present and discuss the following topics:

- Derivation of the main TeaM Cables Tool functionalities
- Model of interaction between COMSY and VP
- Model of interaction between customer and TeaM Cables Tool (user interface)
- Description of end-user assessment:
 - Calculation of residual lifetime - allocation of VP results to the specific application and evaluation based on the defined acceptance criteria
- Extension of user and COMSY/VP interfaces to cover model optimisation using customer data, e.g. from condition monitoring and from ongoing qualification tests (will be established at a later point of TeaM Cables Project).

3 Objectives and general description of the TeaM Cables Tool

3.1 Hardware set-up

The TeaM Cables Tool will be developed based on the existing:

- COMSY (Condition Oriented Monitoring and Plant Management System) software (SW) platform running on Windows OS, and
- VP (Virtual Polymer) modelling platform running on Linux OS.

Front-end (COMSY) and back-end (VP) SW are physically separated as they are developed and will be running in different OS. In consequence, in addition to the data interface, the HW set-up also needs to be defined and realised, and the following hardware (HW) set-ups are conceivable:

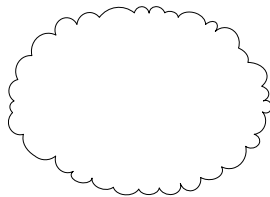


COMSY and VP installed on the same PC/notebook

- COMSY on WIN 10 OS
- VP on Linux Virtual Machine (VM)

+ independent of server (availability, security issues)

- strong PC/notebook needed



COMSY installed on PC/notebook, and

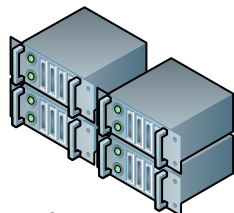
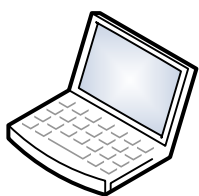
VP (as part of material Ageing Platform MAP) installed in the cloud

- COMSY on WIN 10 OS
- VP in the cloud (external server)

+ HW requirements for PC/notebook lower

- dependency from the availability and strength of the external server (calculation engine for VP)

- security (url address - Uniform Resource Locator - of the server and login rights need to be managed safely)



COMSY installed on PC/notebook, and

VP (as part of material Ageing Platform MAP) installed on a server provided by EDF

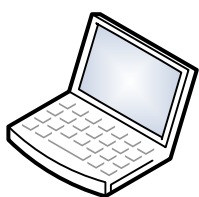
- COMSY on WIN 10 OS
- VP in the cloud (external server)

+ HW requirements for PC/notebook lower

- dependency from the availability external server (calculation engine for VP)

+ strength of the calculation engine (provided by EDF)

+ security (managed by EDF)



3.1.1 Front-end Requirements

Hardware Desktop/Notebook with:

- Minimum i5 processor or equivalent
- Minimum 8 GB RAM
- Minimum 512 GB SSD Drive

The TeaM Cables Tool runs under Windows 10 OS.

3.1.2 Front-end with Virtual Machine Requirements

In case VP running under Linux OS on the same Desktop/Notebook as COMSY:

- Minimum i5 processor or equivalent
- Minimum 16 GB RAM
- Minimum 512 GB SSD Drive.

3.2 Description of the main functionalities

As presented in Figure 2, the TeaM Cables Tool comprises the following two main functionalities:

- customer interface for data input, display and evaluation (cable and plant related data).
- data interface to/from Virtual Polymer
- scientists'/specialists' interface

In the following sub-sections, the requirements for the two main functionalities will be presented and explained in more detail.

3.2.1 Customer interface

The customer accesses the TeaM Cables Tool from his Workstation, Desktop Computer or Notebook as any other application running under Windows 10 OS.

The application will use a dynamic menu bar and context-sensitive menus to assist the user to create, save, duplicate, display and manage the necessary data sets.

The TeaM Cables Tool will enable the user to open the plant explorer of COMSY and access the module for passive electrical equipment. The module provides the capability to model the power plant with a flexible degree of detail down to the level of detail required for the lifetime assessment of individual elements, in this case XLPE insulated cables.

Applications using (XLPE insulated cables) are managed in the element data sheet for passive electrical equipment. The element data sheet holds all relevant information:

- System related data
 - Cable identifier (KKS/ECS code or similar),
 - Application voltage level
 - Safety classification
- Plant related data
 - Rooms/installation locations
 - Normal ambient conditions (temperatures, radiation dose rates, ...)
- (Element) cable data
 - Cable type,
 - Manufacturer,
 - Geometry/length,
 - Materials:
 - Insulation,
 - Conductor, and

- Jacket.

In the (element) cable data additional information such as:

- Installation data,
- Level of utilisation, and
- Hours of operation

Can be managed.

3.2.2 Data interface between COMSY and VP

The COMSY/VP interface works bidirectionally.

From the COMSY data base the TeaM Cables Tool shall generate XLPE cable type files containing the data necessary for the calculation of the polymer ageing/degradation process in VP. The XLPE cable type file must contain:

- An identifier (for the allocation of the files to/from VP)
- Cable material data – e.g. XPLE insulation. If necessary/known other, additional information of the XLPE compound can be given (e.g. degree of cross-linking, level of antioxidants, monomer concentration etc.). Remark: it has to be assumed that such additional information will not be available from the start; therefore, conservative default values shall be used in VP. These must be explained and displayed. In case such data become available, e.g. through micro sampling in the plant, a calculation re-run in VP will be required.
- Cable geometry data – thickness of XLPE insulation
- Range of ambient environmental conditions
 - Ambient temperatures [K]
 - Ambient dose rates [Gy/h]
 - Relative humidity [%]
 - Oxygen content of the ambient environment [%] (default value = 20.95 %; in reactor designs with small containments the oxygen concentration in air is reduced below the level needed for hydrogen combustion - inert atmosphere)

Per XLPE cable type VP will resend the calculation results as abacus/solver matrix COMSY. The abacus/solver matrix will contain the deterioration degree of XLPE in function of time; temperature; dose rate. Scales of the degree of XLPE deterioration from VP may be elongation at break, and/or reduction of antioxidants, and/or insulation properties.

COMSY will evaluate/allocate the calculation results from VP to the individual cables/system and generate an evaluation per application.

Generating XLPE cable types in COMSY for the TeaM Cables Tool brings the following advantages:

1. Separation of responsibilities – COMSY is responsible for all customer and plant related data; VP is responsible for the calculation of the polymer ageing/degradation process.
2. Optimisation of resources – COMSY will generate XLPE cable types from customer and plant related data (from thousands of cables in the plant the expectation is to get a handful of cables types); VP will run calculations per cable type (not per KKS/ECS), thus reducing drastically the required server time (the resources could be put to better use, e.g. choice of finer increments for the VP calculations).
3. The allocation/evaluation of VP results in the TeaM Cables Tool is performed on the customers HW system, as is the calculation of residual lifetime. These tasks are under the responsibility of the customers (refer to item 1.).

3.2.3 Scientists/specialists interface

This part will be elaborated/described in a later version of the report. Under discussion is the implementation of an access to VP for model development/optimisation which should be based on additional customer data.

3.3 TeaM Cables Tool – Additional Features

This part will also be elaborated/described in a later version of the report and will include:

- the definition of user roles (read only, read-write, administrator)
- the definition and description of import/export functions
- attachment of files (e.g. cable data sheets, qualification reports)
- the generation of evaluation reports.

4 Description of end-user assessment

A calculation of residual lifetime is already implemented in COMSY for passive electrical equipment such as cables. Using a customer specific material data base, and the plant specific environmental and installation data of the cables, thermal ageing is calculated using the Arrhenius law and irradiation ageing is calculated using the power law. The assessment is made per KKS/ECS.

As described in section 3.2.2, in the TeaM Cables Tool the customer/plant specific data is handled by COMSY, which will generate XLPE cable types containing the basic information necessary for the ageing calculation in VP, which will return an abacus/solver matrix per XLPE cable type.

COMSY shall:

- store the abacus/solver matrix for each XLPE cable type in a suitable way to its DB,
- allocate the ageing calculation results to the specific applications (per KKS/ECS)
- determine/evaluate a residual lifetime for the specific applications (per KKS/ECS), under consideration of the customer specific data and based on defined acceptance criteria.

5 Extension of interfaces

Extension of user and COMSY/VP interfaces is discussed to account for VP model development/optimisation, see also section 3.2.3, using customer data.

The additional customer data could be obtained from e.g.:

- condition monitoring,
- ongoing qualification tests, and/or
- micro sampling of cables.

This topic will be established at a later point of the TeaM Cables Project. However, this feature will not be automated, it will only be available in expert mode.

6 TeaM Cables Tool - Use Cases

The definition of use-cases for the TeaM Cables Tool is based on the existing COMSY software platform.

In this first revision of the specification, the Use Cases are described verbally, with a general content. Programming flowcharts, if required for specification and documentation purposes, may be added in a future revision of the specifications.

The following Use Cases shall be considered:

- Use Case 001: Create or Copy new Cable Data Set
- Use Case 002: Create new Version of Cable Data Set
- Use Case 003: Search Cable Data Set
- Use Case 004: Display Cable Data Set
- Use Case 005: Create Cable Type Dataset for VP
- Use Case 006: Send Cable Type Dataset to VP
- Use Case 007: Receive Abacus/Solver Matrix from VP
- Use Case 008: Evaluate/Allocate VP Data to Cable Data
- Use Case 009: Determine the Residual Lifetime of the Cable
- Use Case 010: Display Residual Lifetime of the Cable
- Use Case 011: Create Report for Residual Lifetime of Cables

6.1 Use Case 001: Create or Copy new Cable Data Set

This is an example for the description of the Use Case “Create or Copy new Cable Data Set”. All other use cases will be defined in a future revision of the report.

Use Case 001: Create or Copy new Cable Data Set

Description	This Use Case describes how the user can create a new Cable Data Set, either by entering all required data or by copying an existing Cable Data Set (and adapting it)
Business Trigger	User needs to create a new Cable Data Set
Result	<ul style="list-style-type: none"> ▪ TeaM Cables Tool created a new Cable Data Set
Pre-Condition	<ul style="list-style-type: none"> ▪ For “create new”: TeaM Cables Tool displays list of Cable Data Set ▪ For copy: TeaM Cables Tool displays Cable Data Set to be copied in Single View ▪ User has the rights to create Cable Data Set ▪ User selected “create a new Cable Data Set” or “copy a Cable Data Set”
Main Scenario	
Alternative Scenarios	
Exception Scenarios	If user aborts, rollback data of new Cable Data Set
Post Conditions	<ul style="list-style-type: none"> ▪ New Cable Data Set is in state “Opened” ▪ New Cable Data Set is ready to start QAWF (Quality Assurance Work Flow)

6.2 Use Case 002: Create new Version of Cable Data Set

Use Case 002: Create new Version of Cable Data Set

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.3 Use Case 003: Search Cable Data Set

Use Case 003: Search Cable Data Set

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.4 Use Case 004: Display Cable Data Set

Use Case 004: Display Cable Data Set

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.5 Use Case 005: Create Cable Type Dataset for VP

Use Case 005: Create Cable Type Dataset for VP

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.6 Use Case 006: Send Cable Type Dataset to VP

Use Case 006: Send Cable Type Dataset to VP

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.7 Use Case 007: Receive Abacus/Solver Matrix from VP

Use Case 007: Receive Abacus/Solver Matrix from VP

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.8 Use Case 008: Evaluate/Allocate VP Data to Cable Data

Use Case 008: Evaluate/Allocate VP Data to Cable Data

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.9 Use Case 009: Determine the Residual Lifetime of the Cable

Use Case 009: Determine the Residual Lifetime of the Cable

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.10 Use Case 010: Display Residual Lifetime of the Cable

Use Case 010: Display Residual Lifetime of the Cable

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

6.11 Use Case 011: Create Report for Residual Lifetime of Cables

Use Case 011: Create Report for Residual Lifetime of Cables

Description	
Business Trigger	
Result	
Pre-Condition	
Main Scenario	
Alternative Scenarios	
Exception Scenarios	
Post Conditions	

7 COMSY front end GUI for cables

Applications using (XLPE insulated cables) are managed in the element data sheet for passive electrical equipment. The element data sheet holds all relevant information:

- System related data
- Plant related data
- (Element) cable data
- additional information.

COMSY manages all relevant data in different data pools. After a correct mapping of the system all relevant information is compiled in the element data sheet, see Section 7.5.

7.1 System related data

System related data is managed in a separate data pool and contains customer (power plant specific) information such as:

- Cable identifier (KKS/ECS code or similar),
- Application voltage level (medium voltage, low voltage, I&C)
- Safety classification of the cable (dependent on the plant philosophy, safety standards to be applied). In the figure below an example of safety categorisation following IEEE is shown. User-defined categorisation e.g. in accordance to RCC-E or YVL can be set.

safety category	safety requirements
1E	1E components with SR = Yes
N1E (SR)	N1E components with SR = Yes + high criticality
N1E	N1E (SR = No and CC1/CC2 or SR = Yes and NC/RTF)
N1E (NC)	not classified

7.2 Plant related data

Plant related data is managed in a separate data pool and contains customer (power plant specific) information such as:

- Building/Rooms/installation locations – with regard to cables COMSY offers the possibility to refine the degree of detail down to cable tray structures; and
- The related normal ambient conditions
 - temperatures,
 - radiation dose rates,
 - relative humidity,
 - ...

room parameter pool: Bld. T107

	end-date	Temperature [°C]	Medium	Dose rate [mSv/h]	Moisture [%]	Outdoor	Maritime air	Impurified	Stagnant	ASP [%]
▶ 0	*NIA*	46	air	0	60	unknown	unknown	*NIA*	*NIA*	100,00

end-date period: *NIA* ASP for period [%]: 100,00

temperature [°C]: 46,00 HOO for period [h]: 268.309,5

ambient medium: air

moisture ≤ [%]: 60 outdoor: unknown

dose rate [mSv/h]: 0,000 maritime air: unknown

impurified: no stagnant: unknown

comment for period:

This way the cable route can be followed/mapped through the buildings/rooms/areas. The figure below shows the installation locations and the related ambient conditions for one example.

	end-date	Temperature [°C]	Medium	Dose rate [mSv/h]	Moisture [%]	Outdoor	Maritime air
room							
Bld. T107							
*	*NIA*	46	air	0	60	unknown	unknown
YARD							
*	*NIA*	30	air	0	70	unknown	unknown

While the installation locations are mapped into the data pool from the plant layout and cable routing plans with the possibility to further refine details, it is recommended that the related ambient conditions should be the result of real measurements over a fuel cycle taking into account known hot spots in the different buildings/ rooms of the power plant.

7.3 Material data base

COMSY possesses a material data base for passive electrical equipment. For cables COMSY gives lifetime predictions based on the analysis of operational loads (ambient temperature and dose rate at the corresponding installation positions) in context with the exposure duration and known material properties. COMSY evaluates each stressor individually, without taking synergetic effects into account.

The TeaM Cables Tool will not use the material data base of COMSY and the implemented algorithms for life time prediction for cables with XLPE insulation.

The polymer ageing/degradation process of XLPE is implemented and will run in the VP platform.

7.4 Element data for cables

Element data for cables consist of general data sheet information such as:

- Cable type,
- Manufacturer,
- Geometry,
- Main materials:
 - Insulation,
 - Conductor, and
 - Jacket

And plant/cable specific information such as:

- Cable length,
- Installation data,
- Level of utilisation, and
- Hours of operation.

7.5 Element data sheet for cables

The element data sheet compiles all system/application relevant information from the different data pools and displays the overview, see the figure below.

The screenshot displays the 'element data sheet 02/025/267' interface. The main data entry area includes fields for Segment (02), Section (025), Element (267), ID Code / Application (1EEM1029X), and From / To (TB107). A table with a red border shows the following data:

pheno	prio	Δ (43 a)	Rec-ISI	remark
TA		31 °C	> 43 a	TA not expected
RA		4068mSv...		RA not expected
MA				MA not expected
EA				EA not expected
OA				OA not expected

Other sections include 'Element data' (Start-up: 2000-07, AAP [%]: 86,89, HOO total [h]: 135111), 'Material data' table, 'Room' table, 'Comment', and 'Supplementary information' table.

Remark: the above display also contains the results of the **lifetime predictions** in a sub-window.

8 Interface between VP and COMSY

This document briefly describes the existing tools Virtual Polymer and COMSY. In order to create an interface between both tools, the technical options and the necessary parameters are discussed here.

8.1 General description of the tools

8.1.1 Virtual Polymer (VP)

VP is developed in Linux OS with the programming language Python.

VP is a one-dimension modelling platform composed of a model data base and different calculation components. The chaining of the different parts makes possible a multi scale and multi physical modelling of the polymer ageing process.

Due to the complexity of the models and equations, the calculation is time consuming and requires some hardware capacities. Therefore, a server with a powerful Virtual Machine for external access for the TeaM Cables partners is under investigation within EDF.

VP was designed for three types of users:

- **Researchers:** VP can be used without automatically chaining the different components. Each component can be used separately by individual input text file. This makes possible the use of VP for model development and identification.
- **Nuclear maintenance engineers:** a multi scale simulation can be run on VP by a single input text file which can be widened by a GUI. At the end of the calculation, VP provides all the intermediate input files and intermediate results for safety demonstration purposes.
- **Other software:** VP uses YACS informatics scheme for the chaining. Therefore, it is possible to use this protocol for chaining VP to other software.

No equations or models are written in VP components. They are stored in the data base. At the beginning of TeaM Cables project two solvers are available in VP:

- An analytic solver
- A solver for stiff Ordinary Differential Equations.

VP typical chaining is at the beginning of the project:

- analytic solver for calculation preparation
- solver for stiff ODE for chemical ageing calculation
- analytic solver for post treatment calculation (scale change).

8.1.2 COMSY

COMSY is developed in Visual Studio under the Microsoft Windows OS. It is a front-end software which offers a graphical user interface to control all in- and output values. All data is stored in an MS Access or MS SQL Server database.

COMSY is used as an Ageing Management tool for mechanical, electrical and civil components. The main objectives of COMSY are to provide a graphical model of the power plant and a degradation assessment for the included components. Many tools and functions serve to support the user in this process, e.g. imports, measurement evaluation, risk-informed methods, reporting and exports features.

The screenshot displays the 'element data sheet 37/005/06' in the COMSY software. The interface is divided into several sections:

- Header/Identification:** Includes fields for segment (37), section (005), element (06), ID Code / Application (1RCV75D), and location.
- Parameters:** Rec-ESI (2015), Priority (B), Sched-ESI, Calibration (1), and Safety class (E2).
- Material Data Table:**

	Material	T(design) [°C]	+Tsh [°C]	dose [kGy]	rel.
Insulation	EPR	65	17	67,5	<input checked="" type="checkbox"/>
Conductor	Cu				<input type="checkbox"/>
Jacket	HYP	65	17	200	<input checked="" type="checkbox"/>
- Room Data Table:**

name	temperature [°C]	dose rate [mSv/h]	moisture \leq [%]
default room (no dat...	40	100	50
Hotspot 1RCV75D	63	100	50
- Supplementary information Table:**

phenomenon	prio	Δ (60 a)	Rec-ESI	remark
TA	B	-15 °C	2015	TA degradation ...
RA		28mSv/h	> 60 a	RA not expected
EA				EA not expected
MA				MA not expected
VA				VA not expected
- Other Fields:** start-up (1583-01), AAP [%] (100.00), HOO total [h] (288350), type (1P), manufacturer (BW), geometry / length (16 AWG), and a comment field with 'spliced on penetration'.

Figure 3: Example of COMSY for cable

For passive electrical systems, COMSY is able to assess/manage lifetime in dependency of up to 5 different stressors.

For cables, the tool gives lifetime predictions based on the analysis of operational loads (ambient temperature and dose rate at the corresponding installation positions) in context with the exposure duration and known material properties:

- Thermal ageing (Activation energy; Arrhenius law)
- Radiation ageing (Dose Rate Effect; Power law)

Other potential stressors can/could be evaluated:

- Moisture (H₂O)
- Electrical fields
- Chemicals
- Mechanical loads or vibrations

At this point COMSY evaluates the "worst case" for each stressor individually and makes a corresponding lifetime prediction/indication. Synergetic effects are not taken into account.

8.2 Combination of COMSY and VP in one environment

Due to the different OS, the collaboration of both tools requires a specific protocol.

The first option would be to use the existing server at EDF to send input data by COMSY and receive output from VP.

- Advantage: Could be established soon for first test runs
- Disadvantage: This option requires an internet connection for data transfer, beyond the scope of this project, this could be complicated for an NPP end customer (IT security etc.).

The second option is a local MS Windows PC with an installed COMSY version and also an installed local Linux VM containing the VP software or the opposite (a local Linux containing the VP software and a local MS Windows VM with an installed COMSY version).

- Advantage: independent from internet connection
- Disadvantage: Local VM and VP on the standard PC might have performance problems.

For both cases, the acceptance of the final product would require a fast evaluation of the component within VP to ensure a performant live calculation of hundreds or thousands of components. Test cases for both scenarios should be established very soon to have a feedback on the feasibility.

A third option would be to calculate an abacus based on min – max value given by COMSY then run hundreds or thousands of VP calculations. COMSY would have to match its database to the abacus. As the calculations are generic, the IT security problem would be lower. As it is done in the back office, it could be done on a server or on a Linux calculation machine.

For this scenario, COMSY runs an analysis (manually triggered) for the desired material (XLPE in the scope of this project) and outputs the relevant temperature / dose rate couples. For each couple, the input file described in 8.4.1 is generated and sent to VP.

8.3 Existing interfaces of both tools

VP uses text files for the input and different output formats for calculation results (MED or CSV + text for metadata). It is assumed that the output data of VP can be adapted easily to extract further required values which are elaborated during this project.

The existing interfaces in COMSY are currently mainly working for import of components (also cables), measurement data, plant operating experience etc. They are specialised in importing from Text files, XML, Excel or Access databases.

As microscopic or macroscopic values which are planned to be obtained during the project are currently not part of an import, it has to be developed in COMSY. Due to the experience and program code of already existing interfaces, a new interface to a VP Text file can be established very easily.

If macroscopic values can be obtained from WP1-4, the preferred output would be elongation at break value over time. These values will be imported in COMSY and the “end of life” criteria defined (e.g. 50% elongation at break) will be applied for the COMSY RecISI (recommended in service inspection date). The technical description of the interface will be part of the next chapter.

8.4 Elaboration of a basic model for data needed for lifetime calculation in COMSY

8.4.1 Input to VP

At the beginning stage of the project, the input file needs some key-values. An example is given:

```
[s_polymers_study]
physical_model = ['master_model']
analytic_model = True
mechanistic_model = True
MD5 = True
data_base = local/
folder_output = ./           #the folder where we want to store the data
model_name = ['XLPE_standard']
study_name = master         #name of the calculation
```

```

coefs_names = [['t'], []]
coefs = [[3233.], []] #temperature in K
calculation_parameter_names = [[], ["tempH", "Gh", "Tp", "Xo", "p", ]]
calculation_parameters = [[], [1262304000.0, 360.0, 323.0, 10, 3.0]] #time in s, debit
of dose in Gy, temperature in K, number of elements, thickness
boundary_condition_nodes = [1, 10] # the last value have to be the number of elements
boundary_condition_parameter = ["DO2"], ["DO2"]]
boundary_condition_types = ["flux_volume"], ["flux_volume"]]
boundary_condition_values = [[0.], [0.]]

```

A test input file will be provided. In a first step it is assumed that only temperature, debit of dose and insulation thickness are changing due to the known boundary conditions in the plant. All other parameters remain constant and are chosen conservatively to reflect the power plant conditions.

8.4.2 Output of VP

Virtual Polymer calculates the deterioration of the material (XLPE in this project) based on reaction kinetics as function of time, temperature, dose rate and position through thickness.

Depending on the other WPs models, the output data of VP could be the following (e.g. if elongation at break can be used as the primary lifetime parameter):

Filename.csv (identifies the calculated situation)

Virtual_Polymer version: V2

data_base = Teamcable

model_reference = XLPE

Time (e.g. years):	0	5	10	15	20	25	30	35	40	45 ...;
Elong. at break:	200	200	200	200	200	190	185	150	90	46 ...;

Depending on the results of the project WPs, the output parameter Elongation at break could also be replaced or supported with:

- Chemical parameter: percentage of antioxidants over time,
- Electrical parameter: insulation properties over time,
- Other parameters from the VP modelling platform.

First description of the data exchange interface between front-end (COMSY) and back-end (VP) software

- a. Data COMSY → VP
- b. Data VP → COMSY

Virtual Polymer calculates the deterioration of the material XLPE. The deterioration degree e.g.:

- Elongation at break (mechanical parameter), and/or
- Reduction of Antioxidants (chemical parameter), and/or
- Insulation properties (electrical parameter)

Shall be calculated in function of:

1. Temperature, proposed increment 1K (20 increments for a temperature range of 20 °C)
2. Dose rate, proposed increment 1 mGy/h (100 increments for 100 mGy/h)
3. Time, proposed increment 1 week (3380 increments for 65 years)

Giving the abacus/solver matrix for COMSY.

VP shall define and transmit conservative default values as acceptance criteria for the evaluation/allocation of the results in COMSY.

9 Conclusion

This document contains the first revision of the Specifications for the TeaM Cables Tool.

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

The following functions/features of the TeaM Cables Tool are addressed:

- 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.