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REMOTE MAINTENANCE for FACILITY EXPLOITATION

DELIVERABLE 4.2

INNOVATIVE FUNCTIONS :

TECHNICAL SPECIFICATIONS

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EDITOR :	EIVIND SOLVANG (WP4 MANAGER) ERIC LUPINACCI
VERIFIED BY :	LUIS LEGORBURU (QA MEMBER) FELIX ARREGUI (ENG. CO-ORDINATOR) JACQUES PINOTEAU (PROJECT DIRECTOR)
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1. EXECUTIVE SUMMARY

The **REMAFEX** project aims at defining and proposing new IT solutions with **a Distributed Maintenance System** which manages the **global maintenance activity for industrial facilities**.

REMAFEX consists of 10 workpackages. Workpackage 4 (WP4) consists of two tasks, and the aim is to

- *identify* maintenance functions to be integrated in the Distributed Maintenance System (Task 4.1, with results presented in deliverable D4.1).
- *specify* the maintenance functions to be implemented in the Distributed Maintenance System (Task 4.2, with results presented in deliverable D4.2).

This deliverable (D4.2) presents the results of Task 4.2, which consists of five sub-tasks :

1. Establish specification guidelines (definitions, specification methods)
2. Allocate maintenance functions for specification to the REMAFEX partners
3. Specify maintenance functions according to the guidelines
4. Recommend maintenance functions to be implemented in REMAFEX (postponed to WP5).
5. Work out Deliverable D 4.2

The work concerning the specification of REMAFEX functions was shared between the Consortium partners. **Hydroelectric end users** (EDP, Iberdrola, EFI) analysed availability of data on sites, the feasibility of the functions identified in Task 4.1 and then, specified with the user point of view the selected functions.

Sema Group, **the system integrator**, analysed first these specifications and after, with all the REMAFEX partners studied them in more details, to avoid ambiguity, misunderstanding and consequently to finalise clear specifications agreed by all partners. This work allowed to launch the REMAFEX system IT specification with a common point of view and understanding within all Consortium partners. This way of working is presented in Chapter 2.

In addition, each function is specified according to common guidelines developed during the work and presented in Chapter 3. The main objective of the guidelines is to provide enough information for the specification of the REMAFEX IT functions and their integration into the REMAFEX platform. The guidelines should also establish a common framework in order to obtain a set of consistent and conform specification documents for the functions.

Availability of data on REMAFEX selected experimentation sites, possibilities of these experimentation sites, feasibility and interest of the Task 4.1 identified functions were analysed in depth by the REMAFEX Consortium. 26 of the 56 functions identified in deliverable D4.1 were kept and specified : 11 functions deal with the Maintenance Focus Area domain *Supervision/Monitoring*, 11 functions with *Forecasting*, 1 function with *Fault Diagnosis* and 3 functions with *Analysis/Decision*. These 26 functions are presented with their explicit title in Chapter 4. The complete specifications are presented in separate annexes, one for each partner. Annex 1 is dedicated to EFI functions, Annex 2 to EDP functions, and Annex 3 and Annex 4 to Iberdrola functions.

2. SPECIFICATION WAY OF WORKING

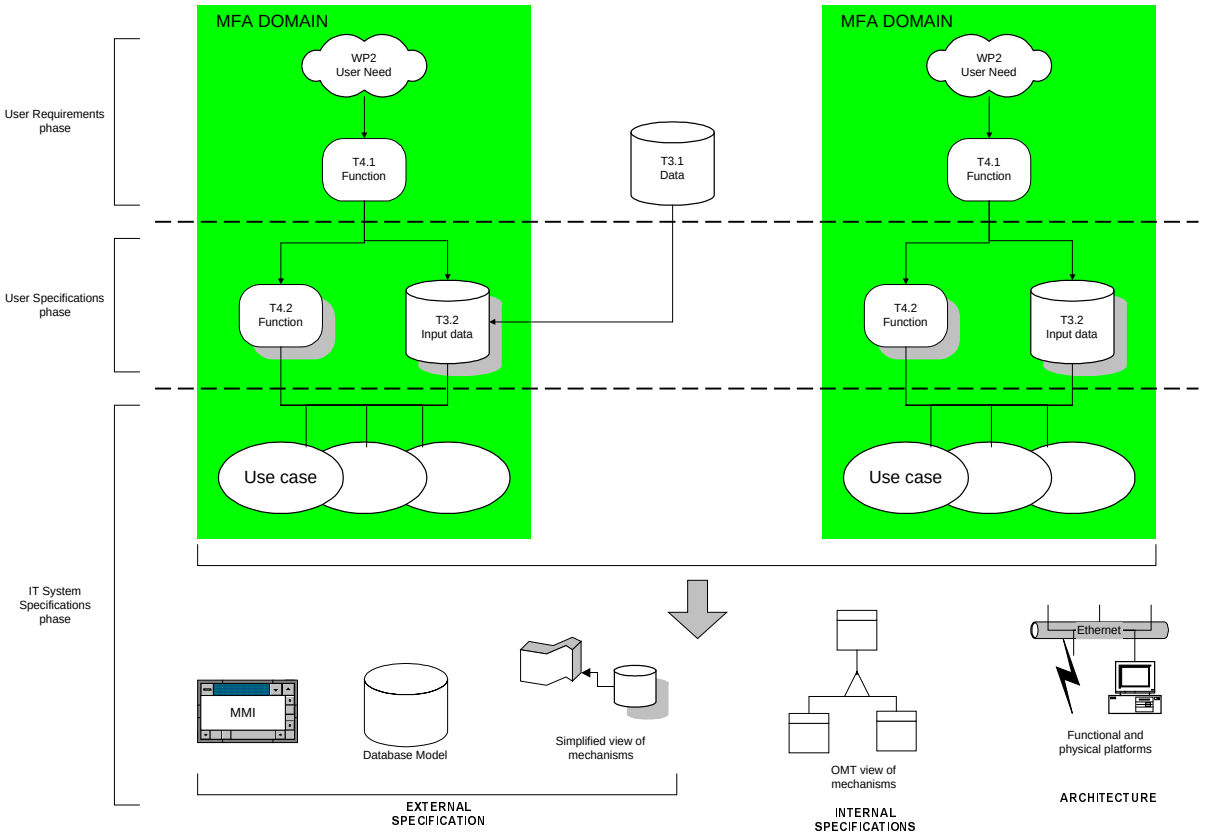
This chapter explains the pragmatic way of working performed during the specification period (tasks 4.2 + 3.2 + 5.1) by the REMAFEX Consortium allowing to move from the user needs expression to a clear user specification and a consistent IT functions specification.

2.1. SPECIFICATION COMMON FRAMEWORK

To work out an IT system meeting precise user needs is often a hard job punctuated with obstacles. The REMAFEX project, dedicated to maintain industrial facilities - and applied, first, to hydraulic plants maintenance - is in this case. Indeed, REMAFEX gathers ambitious even contradictory objectives : opened and CMMS architecture, innovative functions, expandable and upgradeable system.

That is why, we have specially focused on system definition, using a methodological approach, or at least a pragmatic one, and prioritising achievement of small and well defined steps. All these steps, from user needs analysis to IT functions specification can be formally gathered in three main phases (see also the scheme hereafter), namely :

- the User Requirements phase,
- the User Specification phase,
- the IT System Specification phase.



The User Requirements phase (for further details see deliverables D2.1, D3.1 and D4.1) began with WP2 by collecting user needs and ended with tasks WP4/T4.1 - Innovative maintenance functions identification - and WP3/T3.1 - Requirements and availability of new maintenance data -. The results were a set of user needs covering all MFA domains, a list of user functions coming from user needs, and data available or not on experimentation sites but consider at this stage as necessary for the user functions.

On a subset of user functions, chosen for their special interest or their innovative features among four MFA domains (Supervision/Monitoring, Forecasting, Analysis/Decision, Fault diagnosis), the User Specification phase has completed the job performed in requirements. Therefore, an important work has been done by users - tasks WP3/T3.2 and WP4/T4.2 - and has led to a set of specification documents, one per user function. The content of these documents, defined by all partners, aimed to describe, on the one hand, environment, behaviour, algorithms and constraints of each function, and on the other hand, to detail by function all input data.

At the end of these system definition phases performed by users, a set of user functions are at the disposal of partners, with their input data and some exploitation documents coming from the user needs analysis. IT System Specification phase could begin. One of the major issues of this phase was to ensure continuity with the work done before by users while bringing an IT added value to the system description. Indeed, this phase often gives rise to misunderstandings between users and vendors, mainly due to IT language used and outcomes' inconsistency. So, in order to avoid as possible ambiguities and to control consistency of specification results - architecture, mechanisms, MMI and database - the IT System Specification phase was split into:

- a step of IT System Requirements,
- followed by a step of IT System Specification itself,

each of them using totally or partially the object-oriented method : OMT/Use Case.

The IT System Requirements step aims to define « use cases » of the future IT system, showing by this way how actors (i.e. maintenance operator) interact with the IT system in order to perform user functions required. Supported by OMT/Use case method, this step has led to the breakdown of each user function into a list of « use cases ». Thus, the main interest of this step was to provide to users a first and understandable view of the IT system, linked with their specifications, but also to give them the key in order to better understand detailed IT system specification : the « use cases ».

The objectives of IT System Requirements step can be expressed as follow:

- to describe internal system mechanisms and MMI,
- to define functional and physical architecture for the proposed platform,
- and finally, to model the database.

Except for database, others above items are directly and strongly linked with « use cases » identified during the previous step. Thus, architecture proposes a « use cases » distribution, showing where to access to system functions. MMI, itself, gathers « use cases » in operator dialogues, showing how to access to system functions. At last, mechanisms describe dynamic behaviour of « use cases », showing the system working mode.

This last part has been done, on the one hand, using OMT method to carry on the IT requirements analysis, and on the other hand, using a more classical method in order to provide to users simplified explanations of IT mechanisms.

Therefore, this step has been achieved upon the working out of the three following outcomes:

- an architecture of the REMAFEX platform,
- an internal specification of the « use cases » using OMT method,
- and an external specification of functions and system mechanisms, MMI and database.

In conclusion, this pragmatic process, using an advanced methodology, has allowed us, within the scope of REMAFEX, to define strong and systematic link between user needs, user specifications (functions and data) and IT system specifications meeting the user needs expressed.

This methodological approach is now fully reusable for others projects.

2.2. USER FUNCTION SPECIFICATION (TASK 4.2)

The aim of Task 4.2 is to make detailed specifications necessary for the specification of the REMAFEX IT functions and their integration into the REMAFEX platform. The specification work is carried out in accordance with defined guidelines developed during the work.

Chapter 2 of deliverable D4.1 explains the total WP4 pragmatic way of working. The specific way of working with the specification of user functions in Task 4.2 and the preparation of deliverable D4.2 is described below.

EFI, EDP and Iberdrola identified and described 56 user functions during Task 4.1 based on the user needs expressed during WP2 (D2.2). The results from the identification of user functions, presented in deliverable D4.1 are used as a basis for the specification of user functions in Task 4.2, together with information in D3.1 about available data on the experimentation sites and new data to be captured through additional acquisition devices.

Availability of data, feasibility, possibility of experimentation sites, interest on functions allowed to the REMAFEX Consortium to select 26 of the 56 identified functions to start the specification works.

All consortium partners were involved in the assignment of functions to the partners for specification. EFI, EDP and Iberdrola carried out the specification work and made a separate document for each of the functions they had proposed for specification, i.e. they specified their 'own' functions. The separate specification documents are attached in Annexes 1 to 4 of this deliverable.

The specification of functions (Task 4.2) was carried out in close collaboration with Task 3.2 and Task 5.1. Specification of input data tables was a Task 3.2 activity, but the actual specification work was carried out in connection with the specification of functions. The specified input data tables are presented in deliverable D3.2.

3. GUIDELINES FOR THE SPECIFICATION OF REMAFEX FUNCTIONS

3.1. INTRODUCTION

The specification of the REMAFEX functions was carried out by the partners according to common guidelines. The guidelines are described in section 3.2 and consist of a list of information required to specify each function. This list is based on experience at Sema Group and EFI in this domain.

The main objective of the guidelines is to provide enough information for specification of the REMAFEX IT functions and the integration of the functions into the REMAFEX platform.

The guidelines should also establish a common framework in order to obtain a set of consistent and conform specification documents for the functions. Each partner in charge of the specification was requested to use the list of information in section 3.2 as common document structure (plan). This is accomplished for almost every function as presented in Annexes 1 to 4.

3.2. INFORMATION SPECIFIED FOR EACH FUNCTION

The information which is specified for each function by the partners is presented and explained in the following.

The input and output data is also specified in data tables according to Chapter 5 and Annex 7 of deliverable D3.1. These data tables are presented in deliverable D3.2.

- **Objective of function**

  Detail the objective of the function. We can here repeat the content of the fields "Aim" and "Task" of the T4.1 function sheet (Annex 1-3 of D4.1).

- **Function environment**

  Place the function in its operational context :

  - which operator or/and other system will use the function,
  - what are the data sources

- **Input data definition**

  List the input data (= data requested by the function) : Label + Meaning + Source.

  The data will be precisely defined in the Task 3.2. The Label + Meaning must be the same in both Task 4.2 and Task 3.2.

  It should be useful to distinguish Process data and Parameters:

  Process data

  Data coming from the process through other systems (Sensor, SCADA, MMT) or elaborated by other systems or functions.

  Parameters

  Parameters are data fixed by the operator (thresholds for instance). They can be modifiable or not "on-line" by the operator.

- **Output data definition**

  List the output data (= data elaborated by the function) : Label + Meaning.

  The data will be precisely defined in the Task 3.2. The Label + Meaning must be the same in both Task 4.2 and Task 3.2.

  These output data gather the data displayed to the operator and the result of the function going to an other function or system.

- **Dynamic behaviour**

  Detail the conditions of execution of the function (operator request, cyclic, on specific event) and the operating modes (make a state graph if necessary).

- **Data processing (algorithms)**

  Explain which algorithm(s) must be used to perform the function (simple thresholds conditions, finite element method, fuzzy logic, etc.), or detail the algorithm itself if it is a simple one.

- **Operator interface**

  Detail the requested operator interface to display the results (curves, diagram and tables) and to interact with the function (operator actions, dialogues).

- **System interface**

  Detail the requested interface with other systems if it is necessary.

- **Error management**

  Detail here what treatment must be applied in case of a fault or an error occurs (connection failure, invalid input data, divergent algorithm).

- **Constraints**

  Detail here the constraints to execute correctly the function (data acquisition time, number of sample, response time).

- **Hardware and software requirements**

  Detail what are the hardware and software constraints to realise the function (expert system engine, existing software product).

  If it is possible, give here an approach of a solution.

- **Test plan**

  Try to explain here how you intend to test the function (test data set, ...).

  Detail your conformance test plan.

4. FUNCTIONS SPECIFIED BY PARTNERS

The work concerning the specification of REMAFEX functions was shared between the consortium partners. 26 of the 56 functions identified in deliverable D4.1 are specified and presented in this deliverable (D4.2).

Each function is specified according to the guidelines described in section 3.2. Chapter 4 gives an overview of the explicit names (titles) of the 26 functions which are specified. The complete specifications are presented in separate annexes, one for each partner. Annex 1 is dedicated to EFI functions, Annex 2 to EDP functions, and Annex 3 and Annex 4 to Iberdrola functions. Annex 4 contains Iberdrola functions which were not analysed in WP5.

Except data which will be included in deliverable D3.2, the user specification presented in annex gathers all needed information allowing to avoid misunderstanding and ambiguity to specify the REMAFEX Maintenance IT functions.

Each function has a unique label (letter + number) according to deliverable D4.1. The letter corresponds to the Maintenance Focus Area (MFA) domain (F = Forecasting, etc), ref. deliverable D1.3. The number is a sequence number within the domain. In D4.1, all identified functions are numbered sequentially within each domain.

The overview of the specified functions is presented in the following tables, which include the unique function label, the name (title) of the function, the partner responsible for the specification, and a reference to the annex where the complete specification can be found.

The 26 specified functions belong to the MFA domains *Supervision/Monitoring (S), Forecasting (F), Fault Diagnosis (D)* and *Analysis/Decision (A)*.

Supervision/Monitoring (S)

S1	Trend analysis on insulation systems	EFI	Annex 1
S2	Monitor stator winding condition	EFI	Annex 1
S3	Monitor circuit-breaker operating mechanism condition	EFI	Annex 1
S4	Monitor hydraulic string and turbine condition	EFI	Annex 1
S6	Compute MSV[1] (turbine efficiency)	EDP	Annex 2
S9	Compute MSV[1] (guide vanes clearance)	EDP	Annex 2
S22	Detect dissipated energy in refrigeration coil	Iberdrola	Annex 3
S23	Determinate dirt level in refrigeration coils [2]	Iberdrola	Annex 3
S27	Detect dissipated energy in rotating seal	Iberdrola	Annex 4
S29	Calculate hydroelectric set, turbine and generator efficiency	Iberdrola	Annex 4
S37[3]	Detect rotor excitation power consumption	Iberdrola	Annex 4

[1] MSV = Maintenance State Variable.
[2] Title used in D4.1: "Detect water pressure drop in refrigeration coil"
[3] New function, not included in D4.1

Forecasting (F)

F1	Perform trend analysis of MSV (turbine efficiency)	EDP	Annex 2
F3[1]	Compute stator winding temperature	Iberdrola	Annex 4
F8	Detect probability of future thrust bearing disturbances	Iberdrola	Annex 3
F9[1]	Detect probability of future generator guide bearing disturbances	Iberdrola	Annex 3
F10	Detect probability of future braking system disturbances	Iberdrola	Annex 3
F11[1]	Detect probability of future generator cooling system disturbances	Iberdrola	Annex 4
F13[1]	Detect probability of future turbine guide bearing disturbances	Iberdrola	Annex 3
F14[1]	Detect probability of pelton turbine runner degradations	Iberdrola	Annex 4
F15[2]	Detect probability of future regulation system disturbances	Iberdrola	Annex 4
F17[1]	Detect probability of francis turbine runner and seals degradations	Iberdrola	Annex 4
F25[3]	Perform trend analysis of MSV (guide vane clearance)	EDP	Annex 2

[1] Title used in D4.1:
F3 "Compute stator winding temperature alarm level"
F9 "Detect probability of future guide bearing distrubances"
F11 "Detect probability of future cooling system disturbances"
F13 "Detect probability of future bearing disturbances"
F14 "Detect probability of future runner disturbances"
F17 "Detect probability of future runner disturbances"

[2] F15 also includes S26 "Detect external oil losses in regulation system" (D4.1)

[3] New function, not included in D4.1

Fault Diagnosis (D)

D1	Identify and display fault localisation	EDP	Annex 2

Analysis/Decision (A)

A3	Compute optimal maintenance interval	EFI	Annex 1
A5	Quantify failure value	EDP	Annex 2
A6	Analyse and display consequences of failure to the system	EDP	Annex 2

5. CONCLUSION

The work concerning the specification of REMAFEX functions was shared between the consortium partners. Each function is specified according to common guidelines developed during the work.

In total, 26 of the 56 functions identified in deliverable 4.1 are specified:

- 11 functions are specified for the domain *Supervision/Monitoring*.
- 11 functions are specified for the domain *Forecasting*.
- 1 function is specified for the domain *Fault Diagnosis*.
- 3 functions are specified for the domain *Analysis/Decision*.

The complete specifications are presented in separate annexes of this deliverable, one for each partner. Annex 1 is dedicated to EFI functions, Annex 2 to EDP functions, and Annex 3 and Annex 4 to Iberdrola functions.

All specified functions are feasible and meet expressed user needs. Necessary input data is available on the experimentation sites or can be captured through additional acquisition devices. Each function presented in Annexes 1, 2 and 3 is analysed in Task 5.1 as a basis for the specification of the IT platform and IT functions of the Distributed Maintenance System.

ANNEX 1

FUNCTIONS SPECIFIED BY EFI

S1 **Trend analysis on insulation systems**

S2 **Monitor stator winding condition**

S3 **Monitor circuit-breaker operating mechanism condition**

S4 **Monitor hydraulic string and turbine condition**

A3 **Compute optimal maintenance interval**

ANNEX 2

FUNCTIONS SPECIFIED BY EDP

S6 **Compute MSV[1] (turbine efficiency)**

S9 **Compute MSV (guide vanes clearance)**

F1 **Perform trend analysis of MSV (turbine efficiency)**

F25[2,4] **Perform trend analysis of MSV (guide vane clearance)**

D1 **Identify and display fault localisation**

A5[3] **Quantify failure value**

A6[3] **Analyse and display consequences of failure to the system**

[1] MSV = Maintenance State Variable.
[2] S9 and F25 are specified in a same document
[3] A5 and A6 are specified in a same document.
[4] New function, not included in D4.1.

ANNEX 3

FUNCTIONS SPECIFIED BY IBERDROLA (I)

S22 Detect dissipated energy in refrigeration coil

S23[1] Determinate dirt level in refrigeration coils

F8 Detect probability of future thrust bearing disturbances

F9[1] Detect probability of future generator guide bearing disturbances

F10 Detect probability of future braking system disturbances

F13[1] Detect probability of future turbine guide bearing disturbances

[1] Titles used in deliverable D4.1:
S23 Detect water pressure drop in refrigeration coil
F9 Detect probability of future guide bearing disturbance
F13 Detect probability of future bearing distrubances

ANNEX 4

FUNCTIONS SPECIFIED BY IBERDROLA (II)

Functions not analysed

S27 Detect dissipated energy in rotating seal

S29 Calculate hydroelectric set, turbine and generator efficiency

S37[2] Detect rotor excitation power consumption

F3[1] Compute stator winding temperature

F11[1] Detect probability of future generator cooling system disturbances

F14[1] Detect probability of pelton turbine runner degradations

F15[3] Detect probability of future regulation system disturbances

F17[1] Detect probability of francis turbine runner and seals degradations

[1] Titles used in deliverable D4.1:
F3 Compute stator winding temperature alarm level
F11 Detect probability of future generator cooling system disturbances
F14 Detect probability of future runner disturbances
F17 Detect probability of future runner disturbances

[2] New function, not included in D4.1

[3] F15 also includes S26 "Detect external oil losses in regulation system" (D4.1)