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TITLE :	SPECIFICATION OF IBERDROLA FUNCTIONS: "DETECT PROBABILITY OF FUTURE THRUST BEARING DISTURBANCES (F8)"
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CONTENTS

0. OBJECTIVE OF THE FUNCTION

The objective of the function is to detect and report any anomalous event concerning the thrust bearing that can produce a future malfunction .

This objective is decomposed into another four functions corresponding to the micro needs associated to the macro need this function describes. The final objective of this function will be to detect any malfunction from the results returned by the micro needs functions. Thus, the output of this function will be the four micro needs (incidents) ordered by the certainty factors associated to each incident.

The incidents relative to thrust bearing malfunction are:

_ Parasite current through thrust bearing

_ Upper carter oil leakage

_ Babbit metal wearing in thrust bearing

_ Injection failure

This information will be enough for the expert to take a decision about the preventive maintenance of the plant in a concrete item (thrust bearing).

Also, the system will be able to make cause determination for each one of the possible incidents and to give a justification of the results.

1. FUNCTION ENVIRONMENT

The function will evaluate for each incident its own certainty factor showing the expert degree of confidence for that event to occur under the conditions given by the measures.

The information presented to the user will contain the list of incidents associated to the thrust bearing, ordered by degree of certainty. Also, the degree of certainty will be showed for the user to evaluate the importance of each possible event.

This evaluation will be developed as a user request or cyclically, and will use data collected by the SCADA instrumentation in real time and data collected in periodical tests if they are available (or included by the user).

The sequence of requests and responses of the function is the following:

Event	Request/Response (RQ/RS)	From	To
Forecasting Request (user request)	RQ	Maintenance Operator (M.O.)	Function
Forecasting Request (cyclic execution)	RQ	Function	Function
Collect Data (continuous extern function with a fixed sample interval)	RQ	Function	Data Acquisition System (D.A.S.)
Data Collected (continuous function with a fixed sample interval)	RS	Data Acquisition System (D.A.S.)	Data Base
Select Data (on forecasting request)	RQ	Function	Function
Data Selected (on forecasting request)	RS	Data Base	Function
Perform Forecasting	RQ	Function	Function
Manual Data Request	RQ	Function	M.O.
Manual Data (Manual Tests)	RS	M.O.	Function/ Data Base
Report Results (ordered list of incidents with their associated certainty degree)	RS	Function	M.O.
Store Results (certainty degree incidents)	RS	Function	Data Base

There are two processes involved in the data handling. There is a process that collects data from the D.A.S. and includes it into the real time data base (D.B). The other process selects the data needed by the function in a range of time. The first function will operate independently from the second and in a continuous way. The second will respond to the maintenance operator requests, when expiring the hibernating period and when occurs an event.

2. INPUT DATA DEFINITION

Input data to the function are divided into three types:

1. Digital signals from SCADA system: We will need the last updated value from the SCADA system contained in the real time DB.
2. Analogic signal from SCADA system: We will also need the last updated value from the SCADA system contained in the real time DB.
3. Digital and analogic data, inserted by the user into the real DB: We will need the last value updated by the maintenance operator as well as the date when it was updated.

All these data must be presented to the user before executing the function and the user must be able to modify any value to adjust the results obtained in the execution. These modifications must not be updated in the DB.

The input data will be the following SCADA signals and maintenance actions that could indicate possible malfunction incidents:

a) Injection system.
The following data are used in the algorithms for the forecasting function:

CODE:
" VOID_SPEED_T "
NAME:
Thrust bearing oil injection system working.
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-S0121 indicator of group void speed (Pelton)
XD-S0305 indicator of group void speed (Francis)
LABELS:
on
off
Default value: on

CODE:
" INJECTION_SYST_PRESS_STABLISH "
NAME:
Oil pressure established in thrust bearing oil injection system
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-S0506 INJECTION_SYST_PRESS_STABLISH (Francis)
XD-S0207 INJECTION_SYST_PRESS_STABLISH (Pelton)
LABELS:
on
off
Default value: on

CODE:
" SPEED_LESS_20 "
NAME:
Hydroelectric set speed less or equal to 25% nominal (Francis) or 20% (Pelton)
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-S0301 SPEED_LESS_25 (Francis)
XD-S0122 SPEED_LESS_20 (Pelton)
LABELS:
on
off
Default value: off

CODE:
" AC_INJECTION_PUMP_DEFECT "
NAME:
defect in thrust bearing A.C. oil injection pump
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-V0713 AC_INJECTTION_PUMP_DEFECT (Francis)
XD-V0420 AC_INJECTTION_PUMP_DEFECT (Pelton)

LABELS:	
on (alarm)	
off	Default value: off

CODE:
“ AC_INJECTION_PUMP_CONTROL_DEFECT “
NAME:
Control defect in thrust bearing A.C. oil injection pump
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-V0802 AC_INJECTTION_PUMP_CONTROL_DEFECT (Francis)
XD-V0424 AC_INJECTTION_PUMP_CONTROL_DEFECT (Pelton)
LABELS:
on (alarm)
off
Default value: off

CODE:
“ DC_INJECTION_PUMP_DEFECT “
NAME:
defect in thrust bearing D.C. oil injection pump
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-V0714 DC_INJECTION_PUMP_DEFECT (Francis)
XD-V0421 DC_INJECTION_PUMP_DEFECT (Pelton)
LABELS:
on (alarm)
off
Default value: off

CODE:
“ DC_INJECTION_PUMP_CONTROL_DEFECT “
NAME:
Control defect in thrust bearing D.C. oil injection pump
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-V0803 DC_INJECTION_PUMP_CONTROL_DEFECT (Francis)
XD-V0425 DC_INJECTION_PUMP_CONTROL_DEFECT (Pelton)

LABELS:	
on (alarm)	
off	Default value: off

CODE:
" INJECTION_SYST_OFF "
NAME:
Thrust bearing oil injection system off
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-S0504 INJECTION_SYST_OFF (Francis)
XD-S0205 INJECTION_SYST_OFF (Pelton)
LABELS:
on (injection system stopped)
off (injection system not stopped)
Default value: off

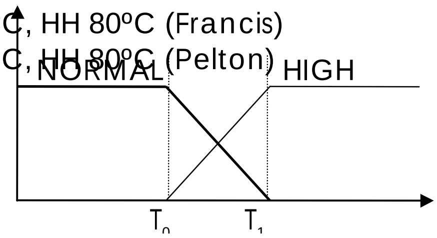
The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" AC_INJECTION_PUMP_WORKING ":
XD-V0800 indicator of A.C. Injection pump working (Francis)
XD-V0422 indicator of A.C. Injection pump working (Pelton)
" DC_INJECTION_PUMP_WORKING ":
XD-V0423 indicator of D.C. Injection pump working (Pelton)
XD-V0801 indicator of D.C. Injection pump working (Francis)
" INJECTION_SYST_ON ":
XD-S0505 Injection system on (Francis)
XD-S0206 Injection system on (Pelton)

B: oil temperature in upper carter

The following data are used in the algorithms for the forecasting function:

CODE:
" UGB_OIL_TEMP "
NAME:
oil temperature in upper carter
TYPE:
analogic
RANGE:(limits)
0-100 ºC
ACQUISITION, SOURCE:
SCADA
XA-V0206 UGB_OIL_TEMP , alarms H 70ºC, HH 80ºC (Francis)
XA-V0209 UGB_OIL_TEMP , alarms H 70ºC, HH 80ºC (Pelton)
LABELS:
NORMAL
HIGH



T_0 = **pending**
T_1 =70 ºC

Default value: NORMAL

The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

“ UGB_HIGH_OIL_TEMP “:
XD-V0707 high oil temperature alarm in upper carter (Francis)
XD-V0413 high oil temperature alarm in upper carter (Pelton)
(boolean, integer scalar)

“ UGB_VERY_HIGH_OIL_TEMP “:
XD-V0708 very high oil temperature alarm in upper carter (Francis)
XD-V0414 very high oil temperature alarm in upper carter (Pelton)
(boolean, integer scalar)

C: oil level in carters

The following data are used in the algorithms for the forecasting function:

CODE:
“ UGB_LOW_OIL_LEVEL “
NAME:
Alarm of low oil level in upper carter
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-V0711 UGB_LOW_OIL_LEVEL (Francis)
XD-V0418 UGB_LOW_OIL_LEVEL (Pelton)
LABELS:
on (alarm)
off
Default value: off

CODE:
“ UGB_VERY_LOW_OIL_LEVEL “
NAME:
Alarm of very low oil level in upper carter
TYPE:
boolean, digital
RANGE:(limits)
on-off
ACQUISITION, SOURCE:
SCADA
XD-V0710 UGB_VERY_LOW_OIL_LEVEL (Francis)
XD-V0417 UGB_VERY_LOW_OIL_LEVEL (Pelton)
LABELS:
on (alarm)

off
Default value: off

The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" UGB_HIGH_OIL_LEVEL "

XD-V0712 UGB_HIGH_OIL_LEVEL (Francis)
XD-V0419 UGB_HIGH_OIL_LEVEL (Pelton)
(boolean, integer scalar)

" UGB_NORMAL_OIL_LEVEL ":

XD-S0503 indicator of normal oil level in upper carter (Francis)
XD-S0204 indicator of normal oil level in upper carter (Pelton)
(boolean, integer scalar)

D: water cooling flow

The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" UGB_LOW_WATER_FLOW ":

XD-V0709 Low water flow alarm in upper carter coil (Francis)
XD-V0415 Low water flow alarm in upper carter coil (Pelton)
(boolean, integer scalar)

" UGB_NORMAL_WATER_FLOW ":

XD-S0502 indicator of normal water flow in upper carter coil (Francis)
XD-S0203 indicator of normal water flow in upper carter coil (Pelton)
(boolean, integer scalar)

" COOLING_SYSTEM_FAULT ":

XD-V0810 refrigeration fault alarm (Francis)
XD-V0432 refrigeration fault alarm (Pelton)
(boolean, integer scalar)

" COOLING_SYSTEM_ON ":

XD-S0513 refrigeration system on indicator (Francis)
XD-S0214 refrigeration system on indicator (Pelton)

" UGB_COIL_DIRT_LEVEL ":

Dirt level value in upper guide bearing heat exchanger (from function S23)
(%, real scalar)

G: oil analysis (user input)

The following data are used in the algorithms for the forecasting function:

CODE:
" UGB_FOREIGN_PART_ANALYS "
NAME:
Apparition of particles in oil analysis, filters, etc
TYPE:
boolean, digital
RANGE:(limits)
YES-NOT
ACQUISITION, SOURCE:
MANUAL INPUT, periodical oil analysis report
UGB_FOREIGN_PART_ANALYS (Francis)
UGB_FOREIGN_PART_ANALYS (Pelton)
LABELS:
YES
NOT
Default value: NOT

CODE:
" UGB_VISIBLE_PART_PEEP_HOLES "
NAME:
Visible babbit metal particles in oil (peep-holes) and/or filters.
TYPE:
boolean, digital
RANGE:(limits)
YES-NOT
ACQUISITION, SOURCE:
MANUAL INPUT, periodical routes report
UGB_VISIBLE_PART_PEEP_HOLES (Francis)
UGB_VISIBLE_PART_PEEP_HOLES (Pelton)
LABELS:
YES
NOT
Default value: NOT

CODE:
" UGB_GASES "
NAME:
apparition of gases.
TYPE:
boolean, digital
RANGE:(limits)
YES-NOT
ACQUISITION, SOURCE:
MANUAL INPUT, periodical routes report
UGB_GASES (Francis)
UGB_GASES (Pelton)
LABELS:
YES
NOT
Default value: NOT

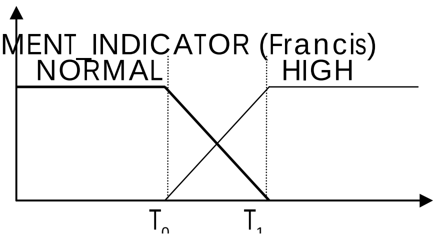
The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" UGB_WATER_IN_OIL ":
UGB_WATER_IN_OIL (Pelton)
UGB_WATER_IN_OIL (Francis)

H: vibration increase

The following data are used in the algorithms for the forecasting function:

CODE:
" SET_AXIAL_VIBR "
NAME:
Oscillations in thrust bearing, axial displacement indicator
TYPE:
analogic
RANGE:(limits)
-2 / +2 mm
ACQUISITION, SOURCE:
SCADA **(pending)**
XA-V0314 THRUST_BEARING_DISPLACEMENT_INDICATOR (Francis)
LABELS:
NORMAL
HIGH



T_0 = **pending**
T_1 =pending

Default value: NORMAL

The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" UGB_VIBR ":
XA-V0313 upper guide bearing vibration indicator (Francis)
XA-V0--- upper guide bearing vibration indicator (Pelton)
(µm, real scalar/ analogic)

" UGB_HIGH_VIBR ":
XD-V0408 high vibration alarm in upper carter (Francis)
XD-V0319 high vibration alarm in upper carter (Pelton)

" UGB_VERY_HIGH_VIBR ":
XD-V0411 very high vibration alarm in upper carter (Francis)
XD-V0322 very high vibration alarm in upper carter (Pelton)

" SET_VIBR ":
XD-V0--- set vibration indicator (Francis)
XD-V0--- set vibration indicator(Pelton)

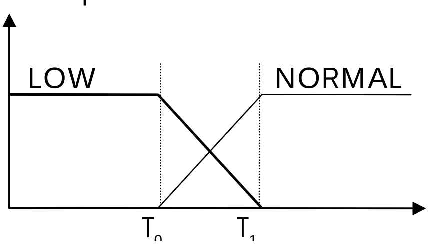
" SET_HIGH_VIBR ":
XD-V0--- set high vibration alarm (Francis)
XD-V0319 set high vibration alarm (Pelton)

" SET_VERY_HIGH_VIBR ":
XD-V0--- set very high vibration alarm (Francis)
XD-V0322 set very high vibration alarm (Pelton)

I: : Electric insulation. (Periodical maintenance test report) (user input)

The following data are used in the algorithms for the forecasting function:

CODE:
" UGB_ISOLATION_VALUE "
NAME:
isolation value in upper carter
TYPE:
integer
RANGE:(limits)
0-   (Mohms)
ACQUISITION, SOURCE:
MANUAL INPUT, periodical maintenance test report
UGB_ISOLATION_VALUE (Pelton)
UGB_ISOLATION_VALUE (Francis)
LABELS:
NORMAL
LOW



T_0 = **pending**
T_1 =pending

Default value: NORMAL

CODE:
" GENERATOR_DIFFERENTIAL_PROTECT "
NAME:
generator differential protection activation alarm
TYPE:
boolean
RANGE:(limits)
on- off
ACQUISITION, SOURCE:
SCADA
XD-V0727 GENERATOR_DIFFERENTIAL_PROTECT (Pelton)
XD-V1500 GENERATOR_DIFFERENTIAL_PROTECT (Francis)
LABELS:
ON
OFF
Default value: OFF

CODE:
" STATOR_GROUND_RELAY_PROTECT "
NAME:
Stator grounding relay activation alarm
TYPE:
boolean
RANGE:(limits)
on- off
ACQUISITION, SOURCE:
SCADA
XD-V0728 STATOR_GROUND_RELAY_PROTECT (Pelton)
XD-V1501 STATOR_GROUND_RELAY_PROTECT (Francis)
LABELS:
ON
OFF
Default value: OFF

CODE:
" BAD_GROUNDING "
NAME:
Bad conditions of grounding brushes
TYPE:
boolean
RANGE:(limits)
yes-not
ACQUISITION, SOURCE:
MANUAL INPUT, periodical maintenance test report
BAD_GRUNDING_BRUSHES (Pelton)
BAD_GRUNDING_BRUSHES (Francis)

LABELS:
YES
NOT   Default value: NOT

J: thrust bearing metal temperature

The following data are used in the algorithms for the forecasting function:

CODE:

" THB_METAL_TEMP "

NAME:

thrust bearing metal temperature

TYPE:

analogic

RANGE:(limits)

0-100 ºC

ACQUISITION, SOURCE:

SCADA

XA-V0205 THB_METAL_TEMP , alarms: H 85ºC, HH 90ºC (Francis)

XA-V0208 THB_METAL_TEMP, alarms: H 85ºC, HH 90ºC (Pelton)

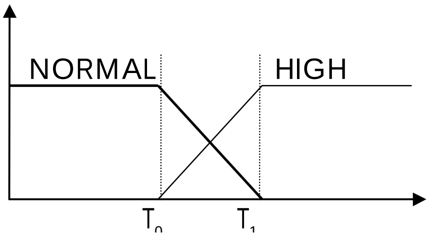
LABELS:

NORMAL

HIGH

T_0 = **pending**

T_1 =85 ºC



Default value: NORMAL

The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" THB_HIGH_METAL_TEMP ":

XD-V0705 High temperature alarm in thrust bearing metal (85ºC) (Francis)

XD-V0411 High temperature alarm in thrust bearing metal (85ºC) (Pelton)

(boolean, integer scalar)

" THB_VERY_HIGH_METAL_TEMP ":

XD-V0706 Very high temperature alarm in thrust bearing metal (90ºC) (Francis)

XD-V0412 Very high temperature alarm in thrust bearing metal (90ºC) (Pelton)

(boolean, integer scalar)

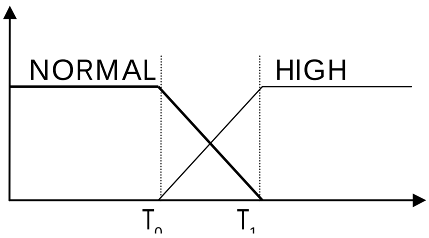
K: upper guide bearing metal temperature

The following data are used in the algorithms for the forecasting function:

CODE:
" UGB_METAL_TEMP "
NAME:
upper guide bearing metal temperature
TYPE:
analogic
RANGE:(limits)
0-100 ºC
ACQUISITION, SOURCE:
SCADA
XA-V0204 UGB_METAL_TEMP , alarms: H 80ºC, HH 90ºC (Francis)
XA-V0207 UGB_METAL_TEMP, alarms: H 80ºC, HH 90ºC (Pelton)

LABELS:
NORMAL
HIGH

T_0 = **pending**
T_1 =80 ºC



Default value: NORMAL

The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" UGB_HIGH_METAL_TEMP ":
XD-V0703 high temp. alarm in upper guide bearing metal (75ºC) (Francis)
XD-V0409 high temp. alarm in upper guide bearing metal (75ºC) (Pelton)
(boolean, integer scalar)

" UGB_VERY_HIGH_METAL_TEMP ":
XD-V0704 very high temp. alarm in upper guide bearing metal(80ºC) (Francis)
XD-V0410 very high temp. alarm in upper guide bearing metal(80ºC) (Pelton)
(boolean, integer scalar)

Q: water pressure in heat exchanger.

The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" UGB_COIL_WAT_OUTLET_PRESS ":
Outlet water pressure in upper guide bearing heat exchanger
(Bar, real scalar/ analogic)

R: power generated

The following data are not used in forecasting rules, but it could be used if rules are modified in test period. They will be shown by the function.

" ACTIVE_POWER ":

XA-V0114 Indicator of active power generated by set (Pelton group)
XA-V0107 Indicator of active power generated by set (Francis group)
(MW, real scalar/ analogic)

Some of this data must be included by the user to obtain a response from the system. This kind of data is indicated in the list as "user input". The rest of them are SCADA signals.

3. OUTPUT DATA DEFINITION

The output of this function will be used to report directly to the user the evaluation results of the different incidents relative to the thrust bearing malfunction. These results are the ordered list of the related incidents with the certainty factor associated to each one. The output will be then for example:

1.Upper carter oil leakage (0.5) MEDIUM

2. Babbit metal wearing in thrust bearing (0.3) LOW

3. Injection failure (0.1) VERY LOW

4. Parasite current through thrust bearing (0.1) VERY LOW

As in the input, the output interface for the function will be a file, that must be created by the function when finishing execution and will contain the name of the incident, the certainty factor and the label associated to the certainty factor.

As mentioned earlier, the list of the possible causes for each incident must be displayed if the user requests it. This information will be also given by the function in the output file.

The list of possible causes is the following:

Parasite current through thrust bearing:

Loss of characteristics caused by ageing
Flats

Contamination:
-oil
-water
-metallic residues
Inadequate material
Successive disassembles
Attachment bench-bridge bolts bad isolated
Bridging because bad isolation in: -sensors for measuring temperature, oil level, ...
-injection oil pipes
-other conductor devices (obturators, etc.)

Oil Leakage:

Loss of seal in the carter
Loss of seal in bearing junctions
Defect in upper cover obturator
Leakage through peep-holes, oil level and temperature indicators and other devices.

Babbit Metal wearing:

Failure in pressure oil injection equipment
Bad working of auto-lubrication
-low oil level
-contaminated oil
· too much acidity
· water amount
· sediments, tars, particles, etc.
High unitary pressure
-machine hydraulic unbalanced
-lost of bearing shaft perpendicularity
-defect in bearing adjusting:
· not uniform flotation
· bench deformation
. Recoverable (bending)
. Permanent (bridge welding)
Wearing in friction surface
-housing of particle through injection
-erratic body in carter
-currents through the shaft (isolation)
-loss of adherence
-erosions and hot points
-axial efforts (low r.p.m.)
-failure in cooling water
Lack of cooling
Bad maintenance

Injection failure:

Defect in motor-pump group
Aspiration failure(filter, valves and pipes)
Impulsion failure(collector, flexible connections)
Not uniform pressure in skates (imperfect film)
Contamination and loss of oil characteristics
Safety valve bad regulated

The output file will also contain a justification text of the deductions made by the fuzzy module to obtain the conclusions.

4. DYNAMIC BEHAVIOUR

As mentioned in section 1. , there are two processes involved in the forecasting functions. The first of them is the responsible of gathering data at sample intervals (given by the availability of SCADA signals) and inserting them into the D.B. in real time. This function allows us to dispose of all the data needed to carry out the forecasting and cause determination needs.

As mentioned above, we will have 2 types of executions:

1. As a user request.
2. Cyclically.

For the configuration of the cyclic execution, the system must provide the way to define:

- The event/s (a group of SCADA signals that satisfy some conditions) that starts the execution of the functions under a certain type of cycle.
- The period of activation for each type of cycle.

Thus, when the event defined by the user for a type of cycle is true, the functions will be executed cyclically within a period of activation. This period could be null, in the case of the group stop event, for example.

5. DATA PROCESSING (ALGORITHMS)

For the data processing, we have to consider the deduction mechanism used to determine the possibility of any thrust bearing malfunction due to a concrete incident of the four listed previously in section 0.

This mechanism uses the certainty associated to each event of the system to make deductions for each incident. That is, we will have a deduction tree for each incident going from lower to upper nodes, evaluating the rules and spreading the certainty to upper levels. In those cases where we have independent variables for a common conclusion, we will accumulate the certainty for the conclusion. Where we have dependent variables (for example: A defined as A1 AND A2) we must not.

The implementation of the function is based on the deduction rules and their probabilities. The deduction must be made with forward chaining going from the signals to the incidents certainty. All the rules for an incident will be applied accumulating the resulting certainty because they represent independent events.

The rules to apply are listed below grouped by incidents:

Parasite current through thrust bearing:

IF (“ **BAD_GROUNDING** “) IS YES OR
(“ **UGB_ISOLATION_VALUE** “) IS LOW OR
(“ **GENERATOR_DIFFERENTIAL_PROTECT** “) IS ON OR
(“**STATOR_GROUND_RELAY_PROTECT** “) IS ON THEN
PARASITE CURRENT THROUGH THRUST BEARING (CERTAINTY=HIGH, RELIABILITY=HIGH)

IF (“ **THB_METAL_TEMP** “) IS HIGH THEN
PARASITE CURRENT THROUGH THRUST BEARING (CERTAINTY=MEDIUM, RELIABILITY=LOW)

IF (“ **UGB_GASES** “) IS YES THEN
PARASITE CURRENT THROUGH THRUST BEARING (CERTAINTY=HIGH, RELIABILITY=MEDIUM)

Upper carter oil leakage:

IF (“ **UGB_LOW_OIL_LEVEL** “) IS ON THEN
UPPER CARTER OIL LEAKAGE
(CERTAINTY=HIGH, RELIABILITY=HIGH)

IF (“ **UGB_VERY_LOW_OIL_LEVEL** “) IS ON THEN
UPPER CARTER OIL LEAKAGE
(CERTAINTY=VERY HIGH, RELIABILITY=HIGH)

IF (“ **UGB_OIL_TEMP** “) IS HIGH OR
(“ **THB_METAL_TEMP** “) IS HIGH OR
(“ **UGB_METAL_TEMP** “) IS HIGH THEN
UPPER CARTER OIL LEAKAGE
(CERTAINTY=MEDIUM, RELIABILITY=MEDIUM)

Babbit Metal wearing:

IF (“ **SET_AXIAL_VIBR** “) IS HIGH THEN
BABBIT METAL WEARING
(CERTAINTY= MEDIUM, RELIABILITY=HIGH)

IF (“ **THB_METAL_TEMP** “) IS HIGH THEN
BABBIT METAL WEARING
(CERTAINTY=HIGH, RELIABILITY=HIGH)

IF (“ **UGB_FOREIGN_PART_ANALYS** “) IS YES THEN
BABBIT METAL WEARING
(CERTAINTY=HIGH, RELIABILITY=HIGH)

IF (“ **UGB_VISIBLE_PART_PEEP_HOLES** “) IS YES THEN
BABBIT METAL WEARING
(CERTAINTY=VERY HIGH, RELIABILITY=HIGH)

Injection failure:

IF (“**AC_INJECTION_PUMP_DEFECT** “) IS ON OR
(“**AC_INJECTION_PUMP_CONTROL_DEFECT** “) IS ON THEN
INJECTION FAILURE
(CERTAINTY=HIGH, RELIABILITY=HIGH)

IF ((“**AC_INJECTION_PUMP_DEFECT**“) OR
(“**AC_INJECTION_PUMP_CONTROL_DEFECT**“) OR
(“**DC_INJECTION_PUMP_DEFECT**“) OR
(“**DC_INJECTION_PUMP_CONTROL_DEFECT** “)) ARE ON THEN
INJECTION FAILURE
(CERTAINTY=VERY HIGH, RELIABILITY=HIGH)

IF (“ **INJECTION_SYST_OFF** “) IS ON AND
(“ **SPEED_LESS_20** “) IS ON AND
(“ **VOID_SPEED_T**”) IS OFF THEN
INJECTION FAILURE

(CERTAINTY=HIGH, RELIABILITY=HIGH)

IF (“**INJECTION_SYST_PRESS_STABLISH**“) IS OFF AND (“**SPEED_LESS_20** “) IS ON AND
(“ **VOID_SPEED_T**”) IS OFF THEN
INJECTION FAILURE
(CERTAINTY=HIGH, RELIABILITY=HIGH)

6. INTERFACES

6.1 OPERATOR INTERFACES

The operator interface is defined by the input and output data listed in the previous sections:

•Input:

- The user must be able to view and modify all input data.
- Also, the user must be able to define and modify the different types of cycles for the cyclic execution.
- The user must be able to define and modify the thresholds for the resulting certainty factors that will produce the triggering of an alarm in the monitoring system. So, the result of every incident must be defined and used in the DB as SCADA inputs.

• Output: The user must be able to view the list of possible incidents, related certainty factors and certainty labels. Also the list of possible causes for each incident, and justification of the deductions must be listed is the user requests it. This information must be displayed :

- When the user executes the function.
- When the user retrieves an alarm report or a certainty factor evolution graph.
- When the highest certainty incident is greater than its associated threshold (alarm detected).

The implementation of this function can be done in C or C++. This would allow us to incorporate to the program some libraries already implemented by IBERDROLA. We can also use an inference engine for the resolution of the rule handling and any tools to build the knowledge base and to fuzzyficate variables.

The simulation of the system for testing purposes can be done easily by including in the D.B. some historical incident data. So, the mechanisms to update the DB with simulation values must be provided by the system.

6.2 SYSTEM INTERFACES

The system interface will be the mentioned input and output files and the parameters given in the function call.

• The parameters will indicate the number of the function to be executed and the type of turbine (Pelton/Francis).

• The input file will contain the data listed in the input data section.
• The output file always contains the incidents, certainty factors of the incidents, labels associated with the certainty factors, lists of possible causes and justification of the deductions.
• The certainty factors must always be inserted into the DB by the system.
• The rest of the information must only be inserted when an alarm is detected.

So, the system must provide the way to access to the forecasting data stored in the DB to study the tendencies of the incidents.

7. ERROR MANAGEMENT

- Input data into normal limits (for analogic data it's specified in the fuzzy sets, for alarms 0/1).
- The resulting certainty accumulated or inferred from the application of any rule must be into normal values [0,1] during the inference process.
- Errors must be included in separate files/tables and identified by a key.
- Control null values or not existent (for a given period) in D.B.
- The tuning of the fuzzy sets and the adjusting of the certainty factors associated to each rule will be done according to the special conditions of the equipment in the plant.
- The grouping , partition or including of any rule could be done while testing if the results are not the most accurate to the working conditions of the plant, so the system must be flexible in this aspect.
- All kind of error signals from the computer must be captured in the function.

8. CONSTRAINTS

The only time constraint is the availability of data into the D.B. This means that the process for the data gathering from SCADA must insert data into the D.B. in real time and the last 10 minutes must be available for some inputs.

9. HARDWARE AND SOFTWARE REQUIREMENTS

The mentioned above for the building of the Knowledge Base and the inference engine, C,C++ (Borland), Oracle, PC architecture, Windows-NT.

10. TEST PLAN

The testing of this function will be specified in the WP6 IBERDROLA documents for the Adaptation and Experimentation Specifications of the System.

Some of the features we will try to test are the following:

- Control of incorrect input data.

- To prove that for a set of symptoms related to an incident the probability of the incident is high enough.
- To prove that for a set of symptoms related to an incident the probability of the incident is higher than the rest (conclusion is clear).
- To prove that for a set of symptoms related to several incidents the probability is higher for the all the incidents implicated.
- To prove that for a set of symptoms indicating normal working there are not high probability values for any incident.
- To prove that exist any symptoms set that returns a high probability for a given incident.
- To prove that the fuzzyficated symptoms describe precisely the existence of a fault. In that item.