Integration of a Risk Analysis method with Holonic approach in an Isoarchic context

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***Abstract* – Industrial Risk analysis becomes one of the major imperatives in several kinds of industries; it is due the complexity of the systems and the expansion of the interactions of physical components, the material and information flux, the information and system management architecture, the effect of methods, machine states and the products quality… we add some other constraints due to our context: decision making from isoarchic organization, intelligent and independent entities (Holons/Agents).**

In another hand, the determination of the maintenance policies is the results of an adopted risk analysis methods, deductive or inductive, made in a static manner. We call the analysis as static, because it requires time to judge the efficiency of the decisions. And in each step, the responsible has to collect the data to remake the same analysis after evaluating the last modifications (6 months, 1 year, etc.).

In this paper, we will try to study the modeling of a generic mechanism of risk analysis, by applying a large known method (FMEA), to see the possibility of its automation in an intelligent context using independent machines. This approach can be implemented also in a decision making module of CMMS software to give more efficient results and fluid modifications of the maintenance policies.

We used UML 2.0 to model functional description of the system and for the information flux and the messages exchange between the entities.

Keywords - Industrial Risk Analysis, FMEA, Maintenance, Holonic paradigm, UML 2.0.

I. INTRODUCTION

Industrial Risk Analysis is a set of approaches and methods that consist on anticipating the occurrence of an undesirable event that could cause the instability of the normal functioning of an entity in the future.

Several approaches attempt to model the occurrence of the defaults and degradations, by searching logical analysis and proposing by the way specific frame, in a specific environment, under typical assumptions in order to formulate the reality on a formal/scientific manner.

In general, the approaches used are grouped on the following categories:

- Frequencial or probabilistic approach: these methods essay to justify and calculate preventive maintenance term using statistical models, Frequencial/Bayesian [1], graph theory, Markov graphs…
- Systemic/process approaches: permit a graphical/schematic analysis and do emerge the dependences and interdependence between the entities of the system. Relations can be from different natures, organic or functional; and under mono component [2] aspect or multi component aspect [3].
- Combined approaches: like RCM (Reliability Centered Maintenance), Default Trees weighted by default rate [4].

These methods can be combined to give reliable results, but require consistent historic and deep implication of all stakeholders of the enterprise. This is the principal goal of the implementation TPM® philosophy [5].

II. PROBLEMATIC

In a practical point of view, the problem here is that the application of these methods is made statically: depending on a technical or financial indicator [6], in a given instant, the maintenance/reliability responsible decides to make a risk analysis to estimate the health of the installation and the efficiency of the current management of the maintenance process, from the spare part management to interventions management for example.

We can deduce here that analysis does not take into consideration the variation and the evolution of symptoms and material degradation. So, it gives only a static overview, in a given instant, of the material state.

This is why Labib [7] considers also that the CMMS software class doesn't give any consistent tools of decision making and it constitutes only simple platforms of data storage, and simple statistics of the stock management, inventories and interventions.

Knowledge management and strategic learning (using game theory for example [8]) can be taken into consideration; considered as powerful strategies of the exploitation of data and experiences, if they are combined with appropriate methods, especially in a case of multicriteria optimization.

So learning and the exploitation of knowledge management could contain the dynamical aspect that we are looking for!

The automation of risk analysis needs really the exploitation of the experiences cumulus, in order to integrate it in dynamic models and to correct errors or gaps between reality and modeling.

Grégory Claude has proposed a framework of failure sheets management, which permits to manage knowledge coming from maintenance interventions. The first objective of this framework is to generate and propose solutions of new failures based on the other existent and similar anomalies. The second objective of the framework is to understand the mechanisms of apparition of some recurrent anomalies and to modify after the input of the industrial process at the design level [9].

III. CONTRIBUTION OF THE HOLONIC APPROACH

The principal idea of this paper is to present the contribution of the introduction of dynamic entities, intelligent, autonomous and collaborative. Known as holons, Risk Analysis could be realized systematically or conditionally, depending on the need of the installation or if a change of the behavior of the production system occurs or according to quality indicators.

These entities can be the machines its-selves or the informative agents which are corresponding to.

The notion of the Holon was introduced for the first time by Professor Arthur Koestler in 1967, where he described the Holon as an identifiable part, of a system which, has a unique identity, but which can be composed by other subcomponents.

In his book "The Gost in the Machine", Arthur Koestler defines a Holon by: *« the holon is a system of relations which is represented on the next higher level as a unit »* [10].

PUJO presents in details the Holonic approach, the basic element (basic holons) that constitute a Holarchy, the different ways to model holons and their interactions (object modeling, multiagent paradigm…) and several standardizations associated to this paradigm [11].

The proposed approach will permit us to make Risk Analysis dynamically, and the notion of knowledge management and learning or strategic learning will be placed into the center of the modeling in a future step.

Here we will present preliminary UML models (static and dynamic) to start and essay for the first time the Industrial Risk Analysis, using the holonic approach. This method will give us the dynamic aspect to build a new generic method combining FMEA and intelligent agents to contribute to the creation of new generation of CMMS software and also for integration within machine for intelligent maintenance management.

IV. PROPOSED ARCHITECHTURE

A. *Preliminary Architecture and Ressource holon model (not detailed)*

To clarify objective, we propose the following architecture, composed by:

- *Holarchy*: group of machines called Resource holons corresponding to the material part of the holons (denoted MResource).
- *IRessource*: it corresponds to the informative party of a Holon Resource, which is composed it-self of an ACE (Ambient Control Entity) that includes all methods and procedures used by the Holons. Local data base includes the description of failures, their modes of apparition, statistics…

The performance calculation is made locally, but it is possible to have a global data base including the information given by the local ones to communicate with other level of the holarchy.

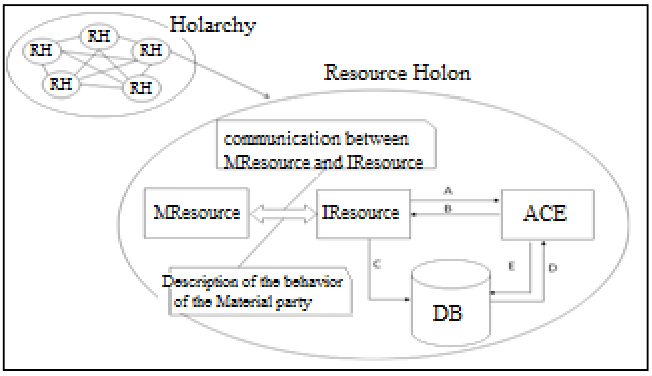

Fig. 1 Internal communication architecture in a Resource Holon
(the group of holons constitutes the physical holarchy)

A: Communication of the state of the Holon for real time performance measurement;
B: performance communicating for decision making;
C: Updating of the intervention data and state machine (*MResource*);
D: Sending the necessary data to the ACE for the calculation of the machine performance;
E: Performance values updating or storage.

Remarque:

Local Data Base: it has as principal role the information storage (continuously, periodically, according to an indicator…) coming from the Material part of the Holon or from the ACE which presents some ambient and common services to holons (calculations modules, methods and support services according to each type of Holon or to the holarchy it-self).

Adam considers the communication between holons has to be made by messages and not by a common data base, to give more autonomy and reduce the time response of the system [12].

The architecture we propose will shorten the information calculation and exchanging between entities, and will permit an efficient exploitation of informatics resources for a rapid, more reactive and real time decision making.

Ambient Control Entity (ACE): is a services provider which comes like a support holons which we don't adopt. It permits also the communication between holons and determines the management policies and evolution rules for each Holon.

The ACE presents the description of the different states of the holons according to the inputs and outputs.

For each Holon, corresponds an ACE or in the case of similar holons, they will have the same ACE included in their Informative part (*IRessource*).

B. The proposed Architectures: distributed or hybride

In my opinion, the holonic approach constitutes a global view of the different parts and actors in a system, with a description more or less detailed of the holons and for their relations and interactions. Nevertheless, for an eventual analyzes or machine programming and implementation, it is useful to proceed to the modeling or description by a common and efficient language or in a formal paradigm, like Object Modeling or Multi-agent system.

Jennings [13] considers that the solutions based on the Multi-Agents systems are very promising, because of the advantage of the distributed architecture that gives the possibility of the knowledge sharing with an adequate response time.

But in the same direction, the utilization of the centralized architecture presents other disadvantages other than a big value of the response time. We reported here some of these disadvantages formulated by Daihani [14]:

- The piloting process using a hierarchical decision structure creates heavy iterative loops with transmission of orders from the highest to the lowest level and, inversely asks for order modifications from the lowest to the highest level when problems appear in the detailed operational planning of these orders.
- The good processing of the data implies to duplicate them in the different concerned software; with the risk of possible errors in consequence of the complex release of multiple similar files.

In the same context, Adam, in his article [12], presents the construction and the evolution of a hybrid structure (HOLOMAS: HOLOnic Multi-Agent System). The research of hybrid structure minimize the risk of incoherence and heterogeneity of data generated from a decentralize architecture in the case of big number of agents and information flux.

In this study, we will adopt decentralized or hybrid structure with holonic paradigm, depending on the importance of the complexity of the flux information and exchanged messages between entities.

V. INTEGRATION OF A RISK ANALYSIS METHOD WHITHIN A HOLARCHY

FAULIN [15] considers that the Risk Analysis has a big importance especially for high risk industries. So it is an imperative to find new techniques and methods since the classical methods are no longer adapted to the current dynamic and don't offer real time visibility and they are applicable into assumptions and considerations which can't be acceptable in modern complex systems.

Complex system or complex maintenance means that it is necessary to take into account the relations between components, considering the effect of a default of a component or a machine (MResource) on all the other components. In this case, we have to built a logic to accept or eliminate a (bilateral or unilateral) relation between two components and enlarging after on all the installation, starting from statistics (defining and finding a special type of correlation, specific to our context), or by a functional analysis (default trees, functional trees…).

A. Effect of the analysis method and the making decision level on the holonic system organization

If we decide to make a Risk Analysis by a given method, this method has to take into account different aspect of the installation; I mean physical behavior and interaction (components and defaults), and also the level of analysis. In the same time, the tools adopted must integrate the different aspects of this complexity.

So the hierarchy, the heterarchy or the isoarchy, etc. are very influenced by the level of decision making method and also by the risk analysis tools.

Figure 2 shows the influence of the level of decision making on holons organization:

- A hierarchy between two levels determines orders from the higher level to the executive sub level.
- The isoarchy exist between the elements of one level, but we have to define holarchies that are composed by a group of material elements which are independent from the other holarchies, and where the decision is flexible, and where the problems resolution is made locally.

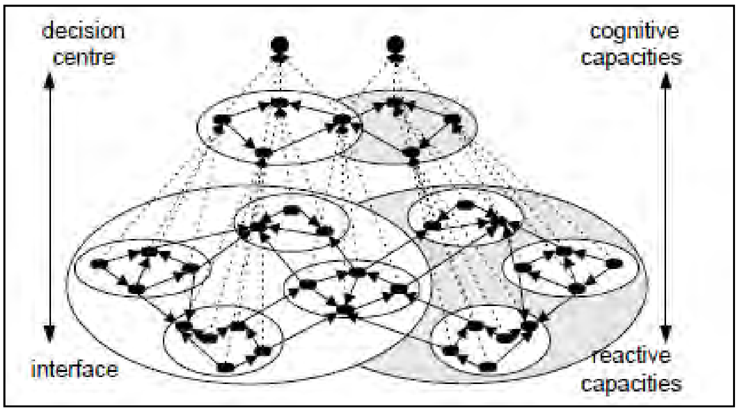

Fig. 2. Different organization of a holonic system [12]

B. FMEA analysis and isoarchy

Failure Mode, its Effects and Criticality Analysis is an inductive method of Risk Analysis, which starts from the causes to the effects, and it permits the passage from the qualitative/quantitative aspects (defaults description, modes, effects, interventions historic…), to the quantitative indicator formulated by the criticity/criticality.

By applying FMEA, and within a defined holarchy, the holons are more autonomous since they can decide it-selves of the interventions periods and determine the machines that they will beneficiate of a systematic or corrective maintenance. The orders integrate the other machines which require technical ameliorations, depending on the criticity of each one.

C. Modeling Approach

In this paper, we will build the preliminary UML diagrams for the description of a dynamic FMEA within a holarchy.

These models, static and dynamic, will serve also the programming of ACE modules that will be integrated in the informative party of the holons (*IResource*).

The advantage of UML diagrams is that they are dedicated especially for programming, and the design of these models constitutes the first step for computer simulation.

Concerning FMEA, the first step is to make functional analysis of the corresponding production material; for that, we are supposing here that the Resource holons contain already its own functional description, implemented for example by the machines supplier. So each Material must be furnished with a technical standardized note detailing functions and the corresponding components.

a) SysML, Bond Graph and future developments

Now, a new modeling frame, SysML®, is developed to link between different heterogeneous domains, and we think seriously that SysML® will constitute the most important language of systems modeling of in the near future. It includes physical and functional descriptions, components behavior, informatics and data base modeling, etc.

There are also several researches on the homogenization and unification of the modeling of multiple physics domains by bond graphs models. This new approach permits to build and to simulate complex multiphysics systems by some basic elementary models.

The composition of these two modeling approaches, SysML and Bond Graphs could gibe big development in the modeling and simulation of production systems.

b) Textual description of the proposed "D*ynamic FMEA"*

- Static aspect

In this paragraph, we present static description of the different actors that are influencing a FMEA action made dynamically: components, degradations, failures, apparition modes, symptoms, maintenance policies, etc.

We have used the class diagram to illustrate the arborescence of the system (actors, aggregation, composition and relations).

This section is very important for the comprehension of all the steps coming after. It contains the notation of classes, objects, methods and messages designations used in the diagrams.

The static model constitutes the first step toward dynamic description made by sequence diagram.

We have listed below the principal actors (classes) and the corresponding relations:

Functional Holon description

1) A holarchy is composed by several machines called RH (Resource Holon);
2) Each of the RH is composed by an informative party named *IResource* and Material or physical party named *MResource*;
3) It is the *MResource* (the machine) that is affected by a failure (in physical sense);
4) The informative party is stocks the Data Base, the modules and programs of calculation, management, interaction, evolution lows… of the RH.
5) Each RH is composed by other RH: inherence, aggregation;
6) Each *MResource* is composed by other *MResources*. The analysis begins from complex systems that compose the *MResource* till the elementary components (parts, wires…);
7) Each system, module or component… ensure one or more functions;
8) An *IResource* contains one ACE that is composed by 2 principal modules :
   ✓ Interaction Module: Reception and management of the ***Bids Call*** which we mentioned here by ***BC***, the **Response of a Bids Call** named ***RBC*** received from other entities, the treatment of the ***BC*** and ***RBC***.

Remarque: Each Holon transfers the Bids Calls and Response to these Bids Calls to the whole holarchy. For that, the Holon has to separate between the messages coming from other holons and its own messages (Bids Call '*AO'* and Response '*RAO*'). We differentiate between these two messages by naming the **Local Bid Call**, named ***LBC*** and ***LRBC*** for the Response to the Bid Call. The letter **L** signifies '**Local Message**'.

   ✓ *CalculFMEA* Module: which calculates the necessary indicators for decision making after the activation of FMEA analysis, and not before.
9) The *IResource* includes the local Data Base of Performance (*DBPerf*) of the correspondent Holon.
10) *DBPerf* contains some stocked procedures which permit to calculate performance indicators of quality, production and maintenance.

Failures, failure modes and mechanisms description

11) A failure is described by :
   ✓ its technical designation,
   ✓ one or more apparition modes,
   ✓ its effects on the correspondent functions,
   ✓ An apparition frequency indicator, estimated for example by the MTBF,
   ✓ A detection indicator, estimated or example by the MTTR,
   ✓ A gravity, depending on the security aspect and the cost generated in the case of the accuracy of the failure,
12) A function is affected by one or more failure modes by acting directly on the physical components;
13) A failure mode is in the fact an evolution of one or more symptoms;

14) The evolution of a symptom of degradation, affecting equipment (*MResource*) generates what we call degradation levels.
15) A degradation mechanism is the results of the passage from a degradation level to another degradation level.
16) A failure mode can be the result of one or more degradation mechanisms.

Remarque:

✓ The phrases 12 à 17 correspond to a very interesting and detailed description of the degradation, failure mechanisms and modes, elaborated by Valérie Zille for her PhD thesis [3].

✓ We have not detailed the description of the actor 'maintenance', for which we will have to integrate the correspondent methods, agents, policies… and that for eventual simplification; but it will be not neglected in the future works to develop the correspondent simulation. But fortunately, we have introduced sufficient maintenance indicators to complete the dynamic risk analysis modeling.

- Dynamic aspect

This party of the analysis describes the interactions between machines of one holarchy, to choose, as a first event, the machines which present the big risk of failure, to integrate as a second step, the FMEA analysis.

The messages between ACE of the *MResources* are exchanged by Bid calls and the Response of the Bid Call, as we saw in the description of the static aspect of our approach. Other messages, sent from machine to another like simple or complex requests exist also, and it depends on the technology that we will use for the programming of the simulation.

The *BC*, the *RBC*, a FMEA actions… are activated according to some indicators calculated from different services. In our context, we focus on quality indicators like the capabilities, the production ones like the Synthetic Yield Ratio, production yield… and also the maintenance indicators, like failure ratio, reliability, MTBF, etc.

Multicriteria analysis of these indicators can give a real decision support for each Holon, furnished by its ACE, to decide if it is necessary to integrate the FMEA or if it is optimal to change or not the actual maintenance policy. The FMEA sequence is launched by each Holon when it presents a low level of performance, given by *calcperf()* function, which the value is compared to a critical threshold.

The indicators are calculated locally by the ACE corresponding of the Holon. So it is clear that all the necessary information, needed to the calculation of the indicators, must be up to date in real time, according to our proposed architecture presented on figure 1.

And now, let's see the description of a FMEA action:

Accepting or not to integrate Dynamic FMEA Analysis

1) The FMAE Action is launched after the demand of a Resource Holon, which expresses the necessity to valorize its degradation state and actual maintenance policy. The activation of its message to the holarchy depends on the level attaint by the local indicator (*calcperf()>critical_value*).
2) When a FMEA (BC) is send by an emitting Holon, the other holons, of the same holarchy, cannot emit any (BC) related FMEA analysis.
3) If the holarchy receives multiple FMEA (*BCs*) in the same time, a random function will be activated to choose arbitrarily the Holon which will adopt all the FMEA calculus methods. This point will be neglected in the sequence diagram for simplification, but we will include it on the next simulation.
4) A Holon emits and receives a multiple (*BC*s) and (*RBC*s). The emission and reception are managed by the '*Interaction'* module integrated in the ACE of each Holon.
5) The information stored in (*BCs*) and (*RBCs*) are transmitted to the '*Calculus*' module for the eventual exploitation and indicators calculation.
6) The module '*FMEAcalculation*' proceeds to the preparation of correspondent data (calculation, updating, classifying…) for the decision making support; integrate o not the FMEA analysis :

   ➢ The machine RH is agree to integrate dynamic FMEA: it means that the RH is not satisfied from its actual health (degradation state).

   By integrating the FMEA analysis, the RH estimates that it is necessary to ameliorate its criticity, which depends on the three classical variables (frequency, Gravity and Detection).

   The results of the criticity classification appear in the final step of the 'Dynamic FMEA', when the RH launches Order Holon to the Maintenance service to precede to some management modifications.

   ➢ The machine RH does not want to integrate the FMEA: no modification will occur on the maintenance management or policy of this RH, because it gives till this moment good results.

7) If a Holon is not interested by the analysis, it will simply not responds to the (*BC*), and it will proceed to the destruction of the instances that it creates to analyze the message of the Initiator Holon and from the local database. The objects are in this case related to the '*Interaction'* and '*managementBC*' modules, '*FMEAcalculation*' methods, etc.

A Dynamic FMEA sequence for the interested Holons

8) If a RH is interested by the analysis, it will send all the necessary information to the calculation of the correspondent indicators within the (*RBC).*
9) Since the (*RBC)* received by the initiator RH, it will proceed to the construction of the FMEA grid.
10) For the future simulation and implementation, we will adopt the critical thresholds determinate by CNOMO standards E.41.50.530.N [16]. This standard can be used in the case of mechanical and electromechanical systems.
11) After criticity calculation and classification, the initiator RH, using its ACE, named here '*ACEInit*' as an instance of the ACE object class, will generate two types of Order Holons as a result to the FMEA analysis:
    - If "criticity > critical_threshold": technical modifications have to be made to upgrade the health state of the correspondent Resource Holons. We denote it in the sequence diagram as '*OHAmeliorationAction'*
    - If "criticity < critical_threshold": the maintenance service has two choice depending on the cost of interventions (ratio between corrective and preventive cost) :
        - ✓ The correspondent components will not be included in the intervention planning; so it will not beneficiate of a preventive maintenance (low corrective cost);
        - ✓ The generating of a maintenance planning according to the MTBF and the reliability level fixed by the hierarchy. In this case, Holons Resources will have an automated changing of intervention periodicity according to the degradation state of the *MResource* (material party of the RH). The Order Holon in this case is denoted on the sequence diagram by "*OHPlanning*"

Resource Holons with Preventive Maintenance policy

12) In the case of the choice of preventive maintenance for its parties and components, the *ACEInit* will send a request to the RH, that are concerned, demanding the value of the corresponding periodicity of components replacement '*Periodicity*'.
13) The '*Periodicity*' of a part is calculated by the methods and functions furnished by the ACE, exploiting the intervention historic and related information stored in the local performance database '*DBperf'*.
14) The estimation method of the '*periodicity*', MTBF… will be chosen according to multiple criteria: the field of application, the nature of elements (reparable and not reparable), starting from statistical low (Weibull, exponential…) or making simply the average of Times Between Failures…
15) Generating the preventive maintenance planning according to the description given in the point 11.

C. UML diagrams

- Static aspect: Class diagram

The class diagram, presented in figure 6, is divided on three principal specialized packages, for a future and independent exploitation of the model, not necessary related to our topic.

The package division allows us to make the analysis related to the specialized domains: maintenance management, failures description/analysis and Resources/Machines description. Thus, it will be possible to enlarge the study to other domains like quality control, production management, procurement, controlling… we will so create other packages and define new relations and messages with the first system.

By this way, we will create opened and generic model for including risk analysis within intelligent and autonomous machines. In addition, it is important to mention that these models are opened since we can add other packages for a deeper analysis in the future.

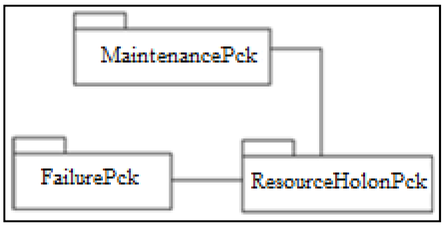

Fig. 3 Class Diagram (Packages)

- Dynamic aspect: Sequence diagram for the normal scenario

Figure 7 presents the sequence diagram for the normal scenario to realize a FMEA action, automated, autonomous within an isoarchy, without any preliminary elimination of any machine or component. The decision is made by the machines it-selves to choose if it is optimal to integrate it-self to the FMEA or not.

The transparency is present, because of all the holons are programmed by the same methods of performance estimation, under the condition/assumption that they have to be members of the same holarchy.

Remarque 1:

We have used the notation introduced by FIPA (Foundation of Intelligent Agents Physiques), presented by Pujo [10], for the exchange of Bid Call (*BC)* from the initiator Holon to the other m holons of the same holarchy.

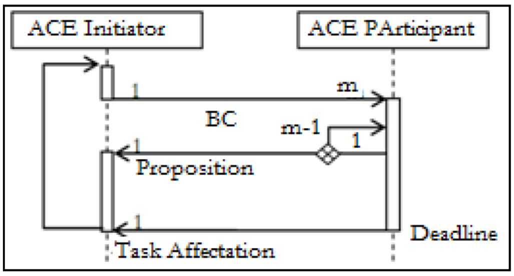

Fig. 4. FIPA representation of the interaction protocol between EPAs [10]

Remarque 2:

The fragment *ref 'ManagementBC Module Creation'*, presented at the figure 5, permits to the ACE to command the instantiation of the objects of the class *Interaction* and objects of the subclass *ManagementBC* by the method <<create>>.

Where these objects will finish the job ordered by the ACE, they will be destroyed by the <<destroy>> method.

We have made the object creation as a reference fragment in order to use it by all Holon when they need it.

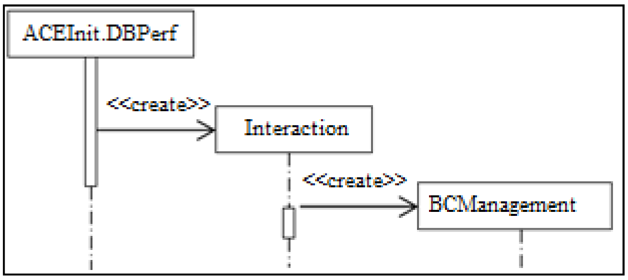

Fig. 5 – Referenced Fragment « BCManagement Module creation »

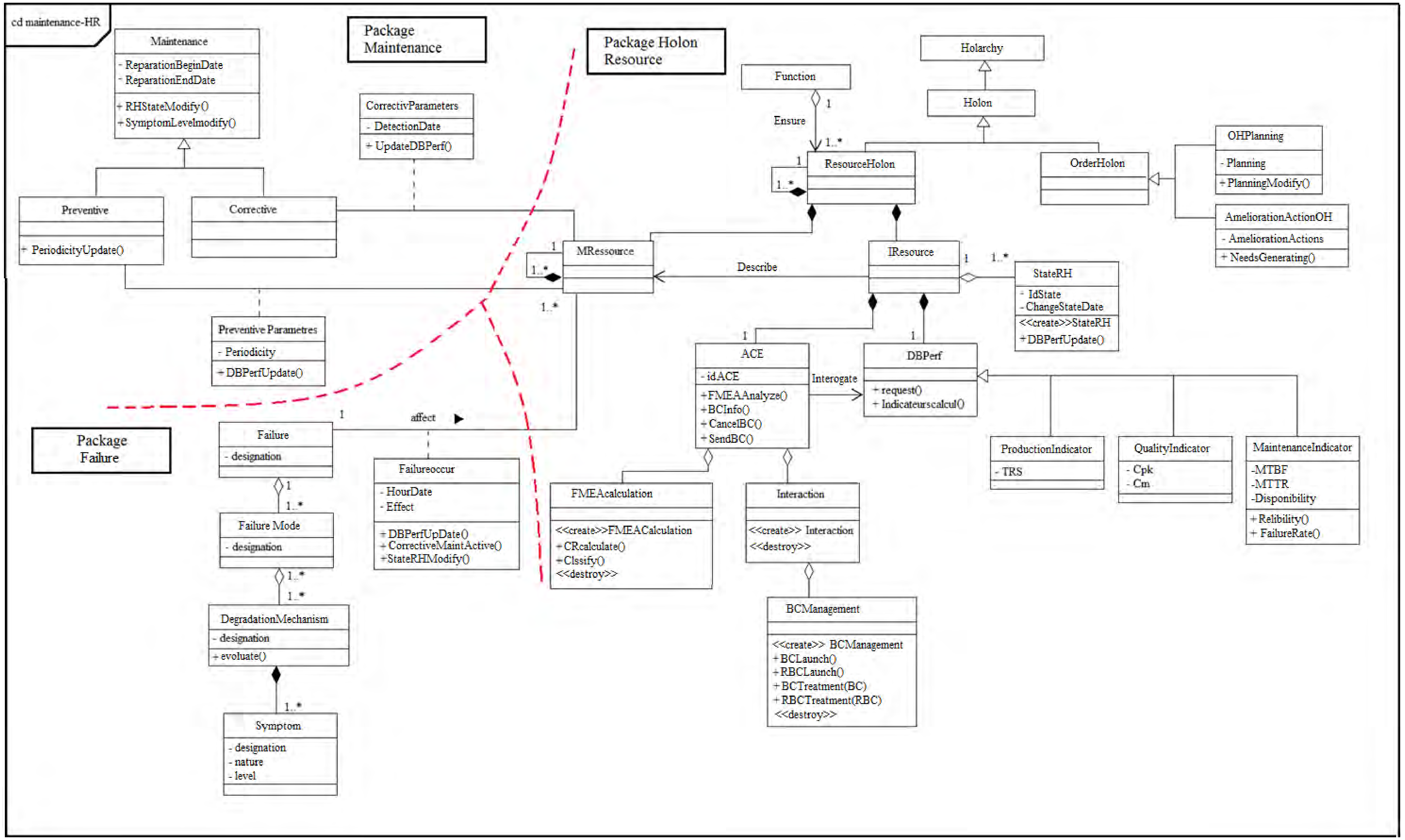

Fig. 6: Preliminary Class Diagram for Risk analysis

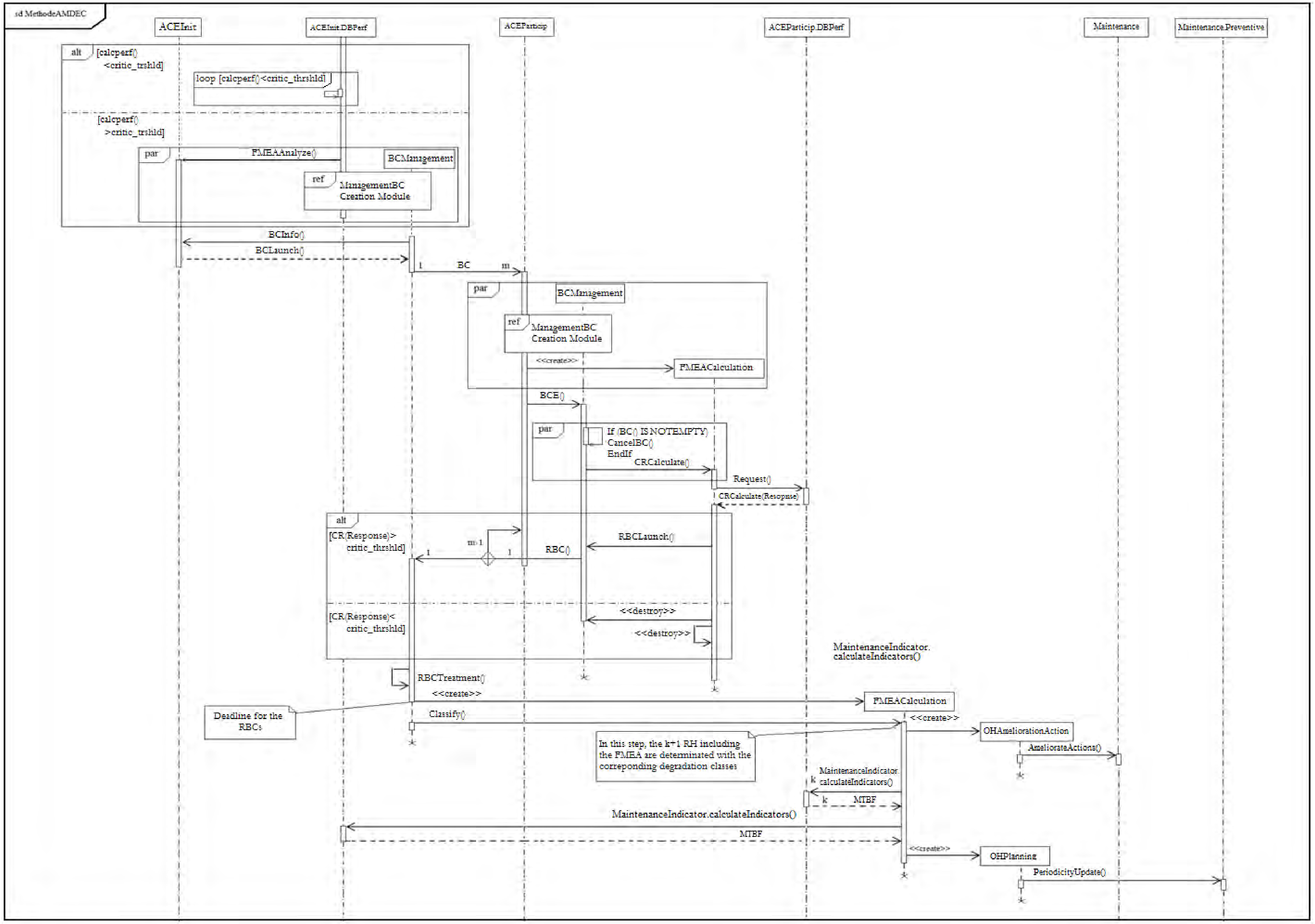

Fig. 7: Sequence Diagram for normal scenario of a FMEAC action

VI. CONCLUSION AND PERSPECTIVES

The adaptation of FMEA analysis to the holonic paradigm allows us to be in a special frame which is the isoarchy. This organization approach of physical entities (Resource/Machine holons) will guide all modeling and programming methods to ensure local decision making in a distributed machine network (depending on the level of analysis).

As we mentioned above, in the paragraph V.A, the choice of analysis method influences the most the information organization, independently from the physical organization. That is why we adopted the FMEA, in which the isoarchic aspect is conserved for all equipments, where the criticism is the principal indicator of decision making and where the machines have the same weight of influence.

Other indicators, like maintenance costs, quality factors… could after be chosen to make the decision more efficient and realistic.

The next phase of the study will be the simulation of the dynamic risk analysis using UML diagrams. It will be corrected according to real cases results and we project to add some other constrains for more realism of the proposed models.

Since the simulation validated, the models will be embedded for eventual tests on real holarchies like laboratory robots or intelligent production machines.

We will also try to compare different architectures, distributed and hybrids, within the holarchy, to compare quantitatively the results of each organization on the decision making and the response time of the whole system.

REFERENCES

[1] H. Pocaccia, ‘‘Introduction à l’analyse probabiliste des risques industriels’’, Editions Techniques et Documentations, Lavoisier, Paris, 2009.
[2] B. Herrou et M. Elghorba, ‘‘L’AMDEC un outil puissant d’optimisation de la maintenance, application à un motocompresseur d’une PME marocaine’’, CPI’2005 – Casablanca, Maroc, 2005.
[3] V. Zille, ‘‘Modélisation et évaluation des stratégies de maintenance complexes sur des systèmes multi-composants’’, Thèse de doctorat, partenariat entre l'Université de Technologie de Troyes, Institut Charles Delaunay, le département Management de Risques Industriels de la division R&D d'EDF, 2009.
[4] P. Lyonnet, ‘‘La maintenance (mathématiques et méthodes)’’. Edition Lavoisier, Paris, 2000.
[5] Bufferne, ‘‘Le guide de la TPM®’’, Editions d’Organisation, Paris, 2011.
[6] El Aoufir et Bouami, ‘‘Les coûts directs de la maintenance : De la comptabilité analytique vers la gestion par les activités’’, CPI’2005 – Casablanca, Maroc, 2005.
[7] A. W. Labib, ‘‘A decision analysis model for maintenance policy selection using a CMMS’’, Journal of Quality in Maintenance Engineering, Volume 10, Number 3, 2004, pp. 191–202.
[8] H. Tembine, ‘‘Distributed Strategic Learning for Wireless Engineers’’, CRC Press, Taylor and Francis group, 2012.
[9] G. Claude, ‘‘Modélisation de documents et recherche de points communs Proposition d'un Framework de gestion de fiches d'anomalie pour faciliter les maintenances corrective et préventive’’, Thèse de doctorat, Université Toulouse 3 Paul Sabatier, 2012.
[10] A. Koestler, “The gost in the machine”, Arkana books, London, 1969.
[11] P. Pujo, ‘‘De l’Isoarchie pour le Pilotage des Systèmes de Production’’, Mémoire d’Habilitation à Diriger des Recherches, Université PAUL CEZANNE AIX-MARSEILLE III, 2009.
[12] E. Adam, René MANDIAU, Christophe KOLSKI, ‘‘Application of a Holonic Multi-Agent System for Cooperative Work to Administrative Processes’’, Journal of Applied Systems Studies, 2, pp. 100-115, 2001.
[13] N. R. Jennings, P. Faratin, M. J. Johnson, T. J. Norman, P. O'Brien, M. E. Wiegand, “Agent-based business process management”. International Journal of Cooperative Information Systems, 105-130, 1996.
[14] D. U. Daihani, J. P. Kieffer, P. Pujo, ‘‘A conceptual approach of a new architecture of the computer aided quality management systems, toward their better integration with the other production management functions”, Quality and its Applications, University of Newcastle Upon Tyne, 1993.
[15] J. Faulin, A. A. Juan, S. Martorell, J-E. Ramirez-Marquez, ‘‘Simulation Methods for Reliability and Availability of Complex Systems’’, Edition Springer, 2010.
[16] Comité de Normalisation des moyens de production, commission 41F, Ref. E.41.50.530.N, *Moyen de Production-Méthode AMDEC*, CNOMO Standards, April 2011.