



## COBEM-2021-1212

# DEVELOPMENT OF AN INDUSTRIAL ASSET MANAGEMENT MATURITY ANALYSIS METHOD APPLIED TO HYDROELECTRIC POWER PLANTS MAINTENANCE

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**Abstract.** *This article presents the development of a Maintenance Capacity Maturity Model for Hydroelectric Power Plants (MCMMH) using a soft modeling concept. In the construction of the MCMMH, we sought to align as much as possible the data collection of the model with those obtained by the questions presented in the Declaration of Regulatory Self-Assessment and Operational Performance (DARDO) filled in by the person responsible for the Plant. One of the reasons for this alignment was to facilitate the data collection process since most of the information necessary for the analysis has already been collected and made available to regulatory agency when filling out the DARDO. Therefore, the MCMMH consists of a maintenance maturity assessment questionnaire that processes the data reported by the Hydroelectric Power Plant, through DARDO, and from this processing, the process maturity assessment is obtained considering 7 dimensions: i) Assessment and treatment of failures; ii) Goals and Indicator Management; iii) Workshops and tools; iv) Functional organization and maintenance team; v) maintenance planning; vi) Maintenance policy; vii) MPC (Maintenance Planning and Control) routines and maintenance execution. At the end of a period of application of the MCMMH, an improvement of the existing Maintenance Management System in the plant under study.*

**Keywords:** *Process Maturity Analysis; Maintenance Capacity Maturity Model; Asset Management; Hydroelectric Power Plant Maintenance Indicators Management.*

## 1. INTRODUCTION

The origin of the Business Process Maturity Models (BPMM) can be traced back to the 1990s with the US Department of Defense's request to the Software Engineering Institute (SEI), part of Carnegie Mellon University, to create a method to assess the ability of supplier. As a result, the Capability Maturity Model (CMM) has been developed and published as The Capability Maturity Model: Guidelines for Improving the Software Process - CMM (VERCRUYSSSE, 2018).

The Capability Maturity Models (CMM) can be applied to assess various processes of an organization, whether in the area of management, quality, safety, maintenance, communication, supplier relationships, research efficiency, product development, in the qualitative dimensions, in the modeling procedures or in the development of systems. It is emphasized that each of these evaluations focuses on a certain domain of knowledge (MAIER et al., 2009; OLIVEIRA, 2017).

CMMs follow a grading structure of levels or stages. The way to reach higher levels consists of gradually reaching established maturity goals, indicating that the organization is in the process of growth through the acquisition and/or improvement of its capabilities (RÖGLINGER; PÖPPELBUSS; BECKER, 2012).

In the subject-related terminology, the word maturity can be defined as a state of development. One of the main studies used in the construction of maturity or state of development models for organizations was presented by Argyris in 1973, which shows seven stages of maturity of human behavior as shown in Table 1.

Table 1. Seven steps of the theory of maturity of ARGYRIS.

Immaturity	Maturity
Passive state	State of growing activity
State of dependence on others	State of relative independence
Behave in few ways	Behave in various ways
It has dispersed, uncertain and superficial interests	Deeper and more intense interests
Very short time perspective	Time perspective increases, including past and future
Involving only the present	Equal or higher positions
Subordinate to everyone	Becoming aware of yourself, and able to self-control

Source: Adapted from Gressler (2020).

Therefore, this article takes into account Argyris's concepts referring to the seven steps presented in Table 01, together with the Declaration of Regulatory Self-Assessment and Operational Performance (DARDO) approach to present the construction of a Maintenance Capacity Maturity Model for Hydroelectric Power Plants (MCMMH).

This paper presents part of results from a research project (PD-06491-0341/2014 "Methodology for asset management applied to hydro generators based on reliability and maintainability mathematical models") development by Federal University of Technology – Paraná (UTFPR) and University of São Paulo (USP) in partnership with COPEL - Energy Company of Paraná State S.A (generation and transmission sectors). This research project aims to reach scope of the research and technological development program applied to electric sector, which is regulated by the Brazilian Electricity Regulatory Agency (ANEEL).

### 1.1 Declaration of regulatory self-assessment and operational performance

As this is an analysis of the maturity of the Maintenance Management of hydroelectric plants, it is necessary to understand the context in which this project is regulated. For inspection of generation projects, the Brazilian Electricity Regulatory Agency (ANEEL) uses the Declaration of Regulatory Self-Assessment and Operational Performance (DARDO), a tool that allows gathering information on various matters of greater relevance within the reality of a generation installation of electric power.

This system values actions that encourage self-assessment, allowing for self-regulation prior to the inspection by the competent agencies. For this purpose, companies must compulsorily fill out the form on hydroelectric power plants (HPP) classified as "Type I" by the ONS (Module 26 of the Grid Procedures), that is, those programmed and centrally dispatched by the Brazilian National Electric System Operator (ONS), with the exception of the ITAIPU Brazilian HPP (ANEEL,2021).

## 2. CAPACITY MATURITY ASSESSMENT MODELS

Capacity maturity models (CMM) seek to represent, through a ranking, the phases of capacity growth, whether qualitative or quantitative, of some maturing element that is being evaluated against established criteria/targets (KOHLEGGER; MAIER; THALMANN, 2009).

For the creation of these models, two types of modeling can be adopted: hard or soft. The hard modeling is based on mathematical foundations, while the soft one considers behavioral and contextual issues. Table 2 below presents some differences between these approaches.

Table 2. Hard and soft approaches

Elements	Hard approaches	Soft approaches
Problem definition	Viewed as direct, unitary	Viewed as problematic, pluralist
Organization	Tacitly assumed	Requires negotiation
Model	A real-world representation	A way to generate debate and insight into the real world
Result	A product or recommendation	Progress through learning

Source: Adapted from Gressler (2020).

Analyzing these factors, the assessment of the degree of maturity of the maintenance management system should preferably follow the soft approach.

## 2.1 Maturity models for maintenance management

There are several maturity models applicable to the analysis of maintenance management systems as seen in Fernandez (2003), Hammer (2007, apud VERCRUYSE, 2018), Pintelon (2013), IAM (2014 - ISO 55000), Oliveira (2017) and Gressler (2020). The Table 3 presents a comparison among rating criteria used by DARDO form and rating criteria present in maturity analysis (authors maturity methods already mentioned in this paper).

Table 1. Summary of maturity models applied to maintenance compared to DARDO.

DARDO <sup>(1)</sup>	METHODS FOR MATURITY ANALYSIS				
Form Item	Fernandez et al. (2003)	Pintelon (2013) <sup>(2)</sup>	ISO 55.000 (2014) <sup>(3)</sup>	Oliveira (2017)	Gressler (2020)
2 - Environment		People and environment		Maintenance Policy	
3 - Operation Management		Functional and technical aspects	8.1 Operational planning and control		
4.1 Human Resources	Management Understanding and Attitude / CMMS	People and environment / Functional and technical aspects	7.2 Competencies / 10.1 Non-compliance and corrective action	Human Resources / Organizational Culture / Failure Analysis	Functional and maintenance team organization / Fault Handling Assessment
4.2 Maintenance process	Understanding and Attitude of Management / Attitude of the company regarding Maintenance / CMMS / Problem solving	Support	7.5 Information requirements / 7.6 Documented information	Maintenance Policy / Standardization and Control of Documents / CMMS	Functional and maintenance team organization / Goals and indicator management / Maintenance planning
4.3 Maintenance Procedures	Company posture regarding Maintenance / CMMS	Functional and technical aspects / Support		Standardization and Control of Documents / Planning and Scheduling of Preventive Maintenance activities / CMMS	MPC Routines and Maintenance Execution / Maintenance Planning
4.4 Policy of spare parts, special tools and assembly devices	Company posture regarding Maintenance	Functional and technical aspects	7.1 Resources	Inventory management	MPC routines and maintenance execution / Workshops and tools

DARDO <sup>(1)</sup>	METHODS FOR MATURITY ANALYSIS				
Form Item	Fernandez et al. (2003)	Pintelon (2013) <sup>(2)</sup>	ISO 55.000 (2014) <sup>(3)</sup>	Oliveira (2017)	Gressler (2020)
4.5 Asset Management Policy		Plant project life	5.2 Policy		Functional and maintenance team organization
5.1 - Operation of the Center	CMMS	Functional and technical aspects / Support / Plant project life		Planning and Scheduling Preventive Maintenance / CMMS activities	MPC routines and maintenance execution
Generator / Hydraulic Turbine / Other Plant Equipment	Problem solving	Functional and technical aspects / Plant project life	10.2 Preventive action	Planning and Scheduling of Preventive Maintenance activities	MPC routines and maintenance execution
6.1 - Human Security		People and environment		Maintenance Policy	Functional and maintenance team organization
7.1 - Results Indicators		Functional and technical aspects	9.1 Monitoring, measurement, analysis and evaluation	Results (Costs and Quality of Maintenance) / Performance Management	Goals and indicator management
7.2 - Efforts, General and Complementary Indicators					

Notes: (1) Only DARDO items and sub-items relevant to this analysis were included in the analysis; (2) Method focused on performance indicators; (3) ISO 55000 is only focused on meeting the criteria of the standard.

Source: Own authorship.

In relation the DARDO form evaluation the Gressler (2020) and Oliveira (2017) methods are the ones that are most align with the rating criteria in DARDO database. Although Pintelon’s method also has a great DARDO’s criteria alignment, it was not used in the proposed MCMMH development in this work. The Pintelon’s method is based on process performance indicators and not consider non-qualitative and non-measurable factors in its evaluation process. In this research Pintelon’s referential is not applicable because the MCMMH proposed has soft approach in its essence, considering non-qualitative aspects and non-measurable on performance indicators analysis.

The model proposed by Fernandez (2003) focuses on maturity evaluating of the computerized maintenance management system (CMMS) and the leadership for its implementation. The model based on ISO 55000 standards (IAM, 2014) is focused on applying and meeting the standard requirements. The Asset Maintenance Maturity Model – AMMM (PINTELON, 2013) is based on strategic and tactical level indicators. The maturity assessment model presented by Oliveira (2017) is more comprehensive than the previous ones and considers these relevant themes: human resource development, procedures, maintenance techniques and management methods and the technology information application through the use CMMS in maintenance process. Finally, Gressler (2020) in his model considers three priority elements: people and their skills, processes or maintenance routines and digitization (computerization) resulting from the industry 4.0 technologies.

The nomenclature given to the five maturity levels differs among authors. Crosby (1979) and Fernandez (2003) use the nomenclatures Uncertainty; Awakening, Enlightenment; Wisdom and Certainty. Already Oliveira (2017) does not name the assessment levels. Lastly, Gressler (2020) adopted the following levels: Initial, Established, Managed, Optimized and digitized, Digitized and Connected.

### 3. THE DEVELOPMENT OF THE MAINTENANCE CAPACITY MATURITY MODEL FOR HYDROELECTRIC POWER PLANTS - (MCMMH)

In the construction of the MCMMH, it was tried to align data collection with those obtained by the issues presented in the Declaration of Regulatory Self-Assessment and Operational Performance (DARDO). One of the reasons for this alignment was to facilitate the data collection process for the MCMMH, as most of the information necessary for the analysis had already been collected and made available to the ANEEL when filling out the DARDO.

### 3.1 Methodology applied

The Figure 1 shows a method for creating the MCMMH. From the various methods available in the references used, according to item 2.1, a comparison was made with the items evaluated by the DARDO form. From this analysis, a new questionnaire was created that merges the criteria proposed by Oliveira (2017) and Gressler (2020), focused on the problem, that is, for the specific situation of hydroelectric power plants (HPPs). It makes a correlation between the maturity of the Maintenance Management System and the performance indicators already monitored by the ANEEL.

Based on this premise, the following were defined: (a) the weights for each criterion and evaluation item; (b) the pertinent items of the DARDO form; (c) the additional items required; and (d) the evaluation questionnaire.

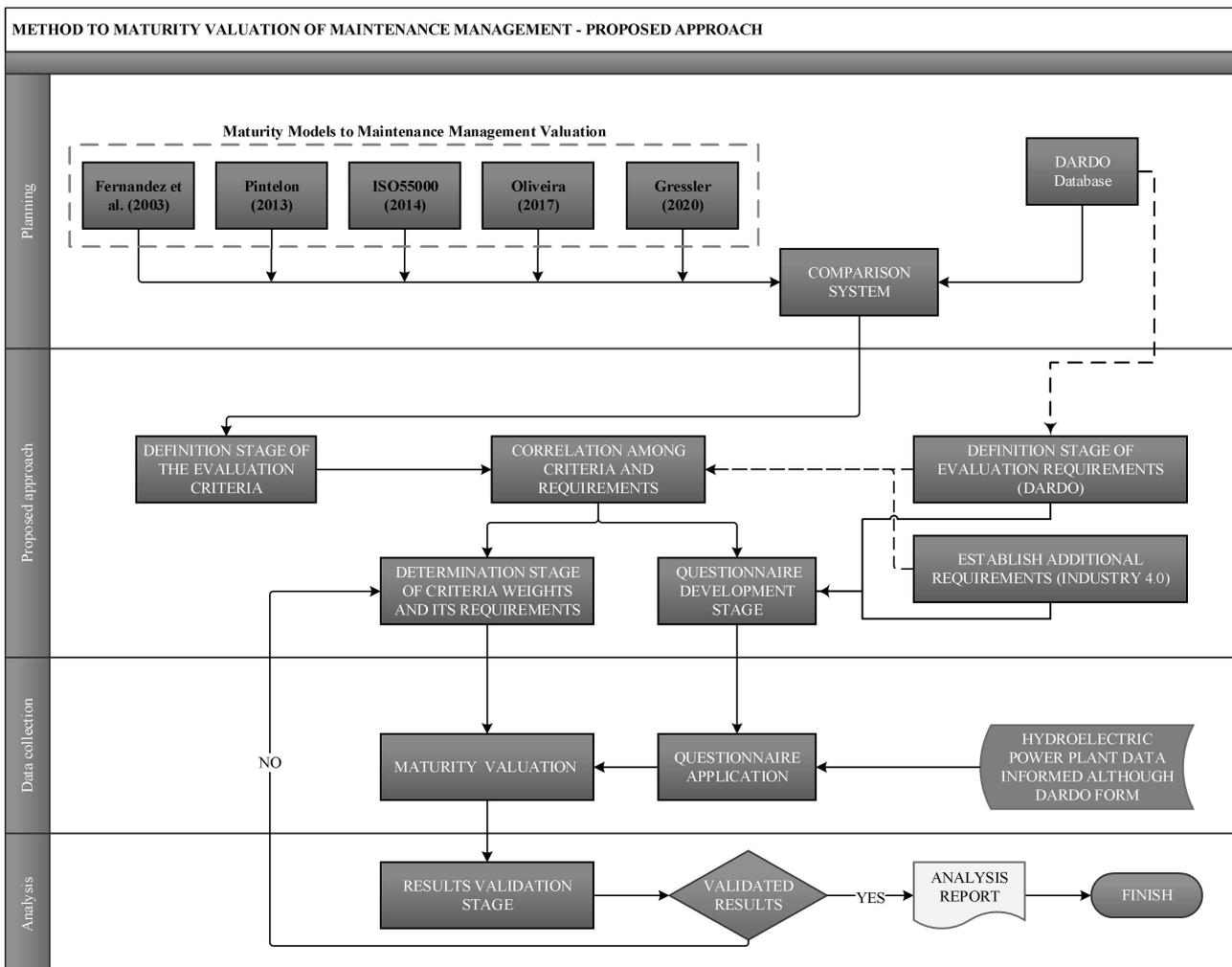


Figure 1. MCMMH Proposed approach  
Source: Own authorship.

Thus, the MCMMH consists of an evaluation questionnaire described in item 3.3. It was developed in the planning and proposal stages identified in Figure 01. It processes the data provided by the HPP in the DARDO form and, from that processing, the evaluation of the maturity of the maintenance process is carried out according to the criteria in sub-item 3.2. To accomplish the MCMMH method test and validation steps, it is necessary previously to select a hydroelectric power plant (HPP). As selection criterion was chosen a HPP classified as "Type I" by the ONS (Module 26 of the Grid Procedures). This HPP has a maintenance management system structured but needs an update process.

In first step, the maturity analysis questionnaire should be answered by the area manager and the DARDO form must be used as information support. To complete the method questionnaire is no need for prior training, but it is important to note that the DARDO form must be filled out and submitted to ANEEL before it used in this step.

In the next step, the plant manager is responsible to assigning criteria weights and to compute the maturity level. To the assigning weights process is required a short-term training to explain procedures of the criteria score and of the HPP maturity level indicator calculation is required a short-term training. This training aims to explain procedures of the criteria score and of the maturity level indicator calculation. This indicator will indicate the hydroelectric power plant maturity level among the maturity classification levels listed on Table 4 (Maturity levels possible by MCMMH).

The MCMMH application by the HPP operational employees or by the maintenance and engineering department is justified because it is a self-assessment method. The application of the HPP maturity level method evaluation aims as a result to improve of the assets maintenance management system. Additionally, will also improve HPP's process indicators performance assessed by the regulatory agency (ANEEL).

The results validation is carried out by the conference of the answers to those previously reported in the DARDO form. The concept obtained by the proposed methodology and the self-assessment of the DARDO are compared. The result is considered valid if the difference between the levels is at most one level, as the two evaluation criteria are organized into five levels with increasing quality. The DARDO levels are poor performance, insufficient, regular, good and outstanding in the DARDO and the MCMMH levels are innocent, conscious, developed, competent and outstanding.

### 3.2 Criteria adopted in the maturity analysis

The following criteria were adapted from Oliveira (2017) and Gressler (2020) and correlated with DARDO indicators database to define the maturity level of maintenance management of hydroelectric power plants obtained by the MCMMH:

1. Assessment and treatment of failures – it intends to identify the way in which the organization acts in relation to the treatment of failures and preventive actions.
2. Indicator Management and Goals – it aims to identify the use of performance indicators in the management and definition of maintenance goals.
3. Workshops and tools – it intend to identify the physical organization of workshops and the availability of tools and safety equipment.
4. Functional and maintenance team organization – it is intended to assess the degree of organization, training and qualification of the maintenance team.
5. Maintenance Planning – it aims to identify the degree of organization of the equipment portfolio and maintenance routines in the company.
6. Maintenance policy – it intends to assess the strategic commitment of the maintenance system with the management of the project, correlating costs, performance, safety and the environment.
7. MPC (Maintenance Planning and Control) routines and maintenance execution – it aims to identify the degree of planning, programming and execution of maintenance routines in the company.

The characteristics provided for each of the five rating levels for each criterion are shown in Table 4.

Table 4. Maturity levels possible by MCMMH.

Criteria	Classification	Characteristics
Failure Assessment and Handling	Innocent	Failure analysis without defined method focus on symptom removal.
	Conscious	Reactive failure handling. Failure analysis when failures with significant impact occur.
	Developed	Periodic failure analysis, maintenance plans adjusted according to failure analysis.
	Competent	Problems are prevented, availability is increased and therefore productivity is increased.
	Outstanding	Use of maintenance analytics, Machine Learning and online performance monitoring to predict failures.
Goals and Indicator Management	Innocent	There are no defined indicators and targets.
	Conscious	There are some technical and maintenance cost indicators. Documentation of equipment and processes not organized.
	Developed	Technical and cost indicators calculated and monitored regularly. Organized documentation.
	Competent	Reliable indicators calculated and analyzed periodically. Continuous improvement established.
	Outstanding	Indicators monitored and controlled in real time. Flexible goals. Maintenance analytics and big data
Workshops and Tools	Innocent	Basic tools and devices for performing maintenance services are lacking.
	Conscious	Tools and devices available and in good repair.
	Developed	Purchase of parts and materials for preventive activities carried out according to planned actions and based on consumption history.

Criteria	Classification	Characteristics
Workshops and Tools	Competent	Existence of sophisticated and modern equipment. IT infrastructure and connection to all management and monitoring systems.
	Outstanding	Network-connected and IT devices available to all maintenance personnel. Use of augmented reality for inspections.
Functional and Maintenance Team Organization	Innocent	Maintenance team with low knowledge. Changes are not well accepted.
	Conscious	Maintenance system based on people's experience and knowledge. The need for continuous improvement identified.
	Developed	Well-defined organization chart and team roles. Skills are developed in teams. Continuous improvement implemented.
	Competent	Maintenance and production work together. Actions for continuous improvement with defined methodologies.
	Outstanding	Commitment to change, adapting to new priorities. Use of simulation and augmented reality in training.
Maintenance Planning	Innocent	No CMMS is used. There are no defined maintenance plans for the equipment.
	Conscious	Use non-integrated CMMS. Equipment with defined criticality. There is no maintenance policy.
	Developed	CMMS complete with all maintenance needs, but not widely used, contains maintenance plans and generates maintenance orders periodically.
	Competent	CMMS with all functions available and properly used. Analysis and systemic review of plans.
	Outstanding	CMMS supports all maintenance management functions. Planning using maintenance analytics and big data.
Maintenance Policy	Innocent	There is no concern with improving quality and reducing accidents and environmental impact.
	Conscious	The need to act preventively is recognized. There is concern about cost reduction.
	Developed	Preventive maintenance actions with a view to increasing productivity and reducing costs.
	Competent	Maintenance work proactively with a view to increasing productivity, reducing costs and improving quality.
	Outstanding	Proactive and efficient maintenance performance with a view to increasing productivity and quality and reducing costs, accidents and environmental impact.
MPC Routines and Maintenance Execution	Innocent	Corrective maintenance is more valued than preventive actions.
	Conscious	Prompt corrective maintenance is seen as a necessary evil. There is a schedule for performing maintenance, however, changes are frequent.
	Developed	Preventive maintenance is a maintenance priority Execution control based on quality, time, rework and costs.
	Competent	CMMS with all functions available and properly used. Analysis and systemic review of plans.
	Outstanding	Online programming of services complying with production, materials and labor restrictions. Visual control with online update.

Source: Own authorship.

The Table 5 illustrates the alignment of the DARDO and the Criterion of MPC (Maintenance Planning and Control) routines and maintenance execution. It also shows how each DARDO form topic will contribute to the step of analyzing Figure 01.

Table 5. MPC routines and maintenance execution criteria.

MMCMH		DARDO Form				
Weight	Criterion	Item	Subitem	Answer Pattern		
MPC routines and maintenance performance	50	4.3 Maintenance Procedures	4.3.1 Maintenance instructions	NE	OO	UA
		5.1 Plant Operation	5.1.2 Alarm monitoring	NE	NA	UA
		5.1 Plant Operation	5.1.3 Database for storing events	NE	NA	UA

MMCMH		DARDO Form				
MPC routines and maintenance performance	50	5.1 Plant Operation	5.1.5 Frequency of inspection of the generating unit and auxiliary systems	NE	Daily	Weekly
		5.2 Generator	5.2.2 Predictive Maintenance	NE	OO / NA	UA
		5.2 Generator	5.2.3 Preventive Maintenance	NE	DO	UA
		5.3 Hydraulic Turbine	5.3.2 Predictive Maintenance	N E	OO / NA	UA
		5.3 Hydraulic Turbine	5.3.3 Preventive Maintenance	N E	OO	UA
		Other Plant Equipment (items 5.4 to 5.21)	5.X.x <sup>(3)</sup> Predictive Maintenance** <sup>(5)</sup>	N E	OO / NA	UA
		Other Plant Equipment (items 5.4 to 5.21)	5.X.y <sup>(4)</sup> Preventive Maintenance	N E	OO	UA
		2 Environment	2.9 Procedure for the acquisition, storage, use and disposal of hazardous chemicals <sup>(1)</sup>	N E	OO	UA
		4 Maintenance management	4.4 Spares, special tools and assembly devices policy <sup>(1)</sup>	N E	OO	UA
		4.0 Industry <sup>(2)</sup>	Communication and Digitization <sup>(2)</sup>	N E	OO	UA

Notes: NE - Non-existent; OO - Outdated or Obsolete; NA - Needs Adjustments; UA - Updated and Applied; (1) Computed in more than one criterion, but the sum was taken into account only once; (2) Additional item included to assess the alignment of the Plant's O&M System with 4.0 Industry technologies. Not provided in DARDO; (3) Refers to main items 5.16.2, 5.17.2 e 5.18.2; (4) Refers to main items 5.4.3 to 5.21.6 (except 5.16.2,5.17.2 e 5.18.2); (5) Only when this item is applicable.

Source: Own authorship.

### 3.3 MCMMH maturity assessment questionnaire

For each of these criteria, according to the existing questions in DARDO, a questionnaire will be applied and answered by the person in charge of the plant. From the answers, based on the weights for each item of evaluation, the system's maturity level will be obtained as a whole or for each criterion individually.

In the Table 6 presents how many DARDO questions are used and how many additional questions should be answered to define the maturity level of the maintenance management system for each of the proposed criteria.

Table 6. Criteria evaluated by MCMMH and Number of relevant questions.

Criteria	Number of DARDO form questions	Number of additional questions
Failure Assessment and Handling	2	1
Goals and indicator management	16	2
Workshops and Tools	2	1
Functional and maintenance team organization	18	1
Maintenance planning	5	1
Maintenance Policy	16	1
MPC routines and maintenance execution	90	2
Total	149	9

Source: Own authorship.

In the structure of the MCMMH, in addition to the issues dealt with by the DARDO, nine additional questions pertinent to aspects of industry 4.0 were inserted. With this complement, the aim was to verify whether the level of computerization (digitalization) of the maintenance management system is in accordance with the most modern policies and structures applied to the contemporary industrial sector.

It is important to highlight that, in this article, the term “computerized” is used instead of “digitized”, since the first term is used by the DARDO form and the second term is most common when talking about industry 4.0. The Figure 02 illustrates the survey questions and evaluation of maturity. Question (a) comes from the DARDO form and Question (b) was added to evaluate the alignment of the plant maintenance system of technologies of industry 4.0.

<div style="border: 1px solid black; padding: 5px; text-align: center; margin-bottom: 10px;">                 DARDO Form Transcript                  The answer must be equal informations sent to ANEEL (DARDO form last annual report )             </div> <div style="border: 1px solid black; padding: 10px;"> <p style="text-align: center;"><b>Sub-item DARDO 4.1.3 – Control and analysis about occurrence maintenance tasks human errors during maintenance tasks execution</b></p> <p>Item definition: (i) Human errors control and analysis; (ii) Evaluation, treatment, disclosure and control of process disturbances; (iii) Disturbances evaluation that impact or no impact the energy process, which can caused directly or indirectly by human errors.</p> <p> <input type="radio"/> Inexistent  <input type="radio"/> Outdated or Obsolete  <input type="radio"/> Updated and applied                 </p> <p style="text-align: right;"><b>(a)</b></p> </div>	<div style="border: 1px solid black; padding: 5px; text-align: center; margin-bottom: 10px;">                 DARDO Form – Additional item                  The answer must be in relation to current situation             </div> <div style="border: 1px solid black; padding: 10px;"> <p style="text-align: center;"><b>DARDO additional item – Machine learning and online monitoring performance</b></p> <p>Item definition: (i) Maintenance analytics applied to maintenance management and making decision about corrective and or preventive actions execution;(ii) Analysis of the machine learning and online monitoring techniques performance applied to machine failure prediction</p> <p> <input type="radio"/> Inexistent  <input type="radio"/> Outdated or Obsolete  <input type="radio"/> Updated and applied                 </p> <p style="text-align: right;"><b>(b)</b></p> </div>
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Figure 2. Questionnaire example. (a) Form transcript and (b) Additional item (b).  
Source: Own authorship.

### 3.4 Probable results to the maturity levels

Finally, from the terms recognized in the literature for maturity analysis and the works cited, the following possible levels were defined: Innocent, Conscious, Developed, Competent and Outstanding. The maturity level will be given by the percentage value reached according to Table 7 below. The results obtained through this score can be expressed graphically, making its visualization and understanding easier.

Table 7. Possible Maturity Levels by the Proposed Method.

Method levels	% Points
Outstanding	Punctuation > 90%
Competent	70% < Punctuation ≤ 90%
Developed	50% < Punctuation ≤ 70%
Conscious	30% < Punctuation ≤ 50%
Innocent	Punctuation ≤ 30%

Source: Own authorship.

It is important to highlight that the last level of each criterion intends to evaluate the “Maintenance in Industry 4.0” through the applicability of the nine technologies of Industry 4.0 (BCG, 2018) in the maintenance processes. The nine technologies are Big Data, Systems Integration, Industrial Internet of Things, Augmented Reality, Robotization, Additive Manufacturing, Simulation, Cloud Computing and Cybersecurity (Gressler, 2020). If such applications are implemented, the outstanding level will be reached.

### 3.5 Conclusions

At the end of a period of application of the MCMMH, an improvement of the existing Maintenance Management System is expected to contribute to: i) the reduction of repetitive failures and non-conformities; ii) the optimization of operation and maintenance processes; iii) better design of maintenance strategies and plans; iv) minimization of the interventions and the maintenance costs; v) improvement of the spare parts policy and the planning and execution of major shutdowns.

The case study hydropower plant has one of the highest performances in the assessment by the ANEEL. With the proposed method application (using DARDO form as information support), aims to contribute gain in maintenance management system performance. Thus, contributing to this HPP plant keep its ranking current position among the best plants in the country in terms of O&M, or even improves its position in referred Brazilian ranking (classification HPPs according to production efficiency).

## 4. ACKNOWLEDGEMENTS

The authors thank COPEL (Energy Company of Paraná State) and MEC (Brazil's Ministry of Education) for the

financial support.

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