Architecture of the Data Collecting System of Figueira da Foz Mill

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ABSTRACT

In a world that is becoming utterly technologic and innovative, the need to update traditional industries is crucial in order to minimize losses while maximizing their market value.

Being the Pulp and Paper Industry one of the largest in the world, and considering all environmental and governance issues, this work focuses on the identification of data that is being collected and stored, having as background the case study of The Navigator Company – not only using the potential of the industry 4.0 (the latest revolutionary path that involves a decentralisation of the control for a more effective production), but also taking into account their goal to achieve predictive maintenance by preventing asset failure, as it analyses production data to identify patterns and potential risks.

Considering that the Company does not have the information organized and available to the people who need it to work, a data collecting system architecture was designed, containing all subsystems that are crucial to better assess the mill's relevant data and gaps which were found throughout the production process.

Therefore, and bearing in mind the Company's familiarity with SAP PowerDesigner, this tool was used and an UML visual modeling profile was created to model the architecture of the data collecting system of the Figueira da Foz mill.

KEYWORDS

Industry 4.0; Predictive Maintenance; Pulp and Paper; Data Collecting System

1 INTRODUCTION

The pulp and paper industry is one of the largest and most important industries in the world. It supplies paper to over 5 billion people worldwide. Pulp and paper manufactures are highly complex and integrate many different process areas including wood preparation, pulping, chemical recovery, bleaching, and papermaking to convert wood to the final product [1].

In order to face the Industrial needs, the fourth industrial revolution brought the concept of decentralized control and sophisticated connectivity (Internet of Things features), which lead to the reorganization of industrial production systems, and the flexibility of mass customed production and quality enhancement. Consequently, big Industries and Enterprises felt the need to keep up with the demands of this entirely technological World, and The Navigator Company, one of the world's largest companies in the paper industry, was no exception.

The Navigator Company is an integrated producer of forest, pulp and paper, tissue and energy, and whose activity is based on modern large-scale factories with state-of-the-art technology and a benchmark of quality in the industry. The Company's business model is developed based on an excellent raw material - Eucalyptus globulus - whose intrinsic characteristics allow the development of a strategy of differentiation, based on high quality products, which are now an international reference in this sector.

Considering that both equipment conditions and production process are equally important for the good function of the mill, Predictive Maintenance (PdM) techniques were brought to attention, due to predicting future failures in assets and ultimately prescribing the most effective preventive measures by applying advanced analytic techniques on big data about technical aspects such as condition, usage, environment, or maintenance history.

This way not only appropriate maintenance is given, but also the consumption of resources and energy are optimized, leading to continuous improvement.

1.1 The Problem and Objectives

In a globalized, technological World (where the need to keep up with the latest developments is vital), big companies and industries have the need to reinvent themselves in order to correctly deliver their products in a fast, effective way. The Navigator Company is no exception, and, through this work, the goal is to conceive a way to help this Enterprise achieving predictive maintenance and thus improving the production process with reduce costs and waste of resources.

The Navigator Company plans to implement an Asset Performance Management (APM) - a system that is intended to help optimise the performance of its assets by connecting different data sources and using advanced analytics to turn data into actionable insights. This system will integrate the Company's existing plant systems to collect data but they do not have the information regarding the identification of the assets and data that was being collected, how it was being collected and where it was stored, organized and available to the people who need it to work, which not only limits it to its innovation objectives based on the potential of the Industry 4.0 vision, but can also help them change the way their maintenance works, and consequently the production and management of the mill.

Considering what was previously said, this work aims to contribute to the solution of this problem, which involves the identification of all data sources, the creation of a catalog with the different systems that collect data and what data is retrieved, and the modelling of the data collecting systems architectures', in order to understand what useful data is being collected and what other sets of data collection would be of interest for further analysis.

2 RELATED WORK

This section presents the most relevant research developed regarding Pulp and Paper Industry, Industry 4.0, Internet of Things and the Automation Pyramid.

2.1 Pulp and Paper Industry

Nowadays, the pulp and paper industries can use technical equipment and high-speed machines that are able to produce width paper rolls at a faster speed, when compared with initial times. The pulp can be produced by chemical or mechanical processes from wood which contains 50% water, 45% cellulose, 25% lignin and 5% other materials. Regarding mechanical processes, forces that pull the fibres apart from each other are used, preserving the main part of the lignin. However, they tend to have low resistance and may be discoloured, therefore being commonly used for newspapers. Chemical processes eliminate non cellulose wood components, leaving the cellulose fibres intact, offering higher strength and an easier bleaching process, being mostly used on papers that are commercially produced all over the world.

2.2 Industry 4.0

The term Industry 4.0 stands for the fourth industrial revolution [2] and its vision is that in the future, industrial businesses will build global networks to connect their machinery, factories, and warehousing facilities as cyber-physical systems, which will connect and control each other intelligently by sharing information that generates actions. These cyber-physical systems will take the shape of smart factories, smart machines, smart storage facilities, and smart supply chains [3].

Cyber-physical system (CPS) seeks the integration of computation and physical processes. This implies that computers and networks can monitor the physical process of manufacturing a certain process. On the other hand, Internet of Things (IoT) is what enables objects and machines such as mobile phones and sensors to "communicate" with each other as well as human beings to present solutions.

The incorporation of such technology allows objects to work and solve problems independently. The Internet of Services (IoS) aims at designing a wrapper that simplifies all connected devices to make the most out of them by shortening the process. It is the customer's gateway to the manufacturer.

Identifying and structuring an architecture or model can be a long, tedious process with much negotiation to abstract from specific needs and technologies. Reference Architecture can serve as an overall generic guideline. However, not all domain applications will require each detail for real-life implementation.

RAMI4.0 is a reference architecture for smart factories which started in Germany and today is driven by all major companies and foundations in the relevant industry sectors **[4]**. This reference architecture seeks to focus on four aspects, including horizontal integration through value networks, vertical integration within a factory, lifecycle management and end-to-end engineering, and human beings orchestrating the value stream [4]. The reference architecture model RAMI4.0 is a three-dimensional layer model that shows how to approach the deployment of Industry 4.0 in a structured manner and has been put forward for standardization as DIN SPEC 91345 [5].

The first dimension consists of the hierarchy levels (the right horizontal axis of the reference architecture model that illustrates the functional classification of the various circumstances within Industry 4.0); the second the life cycle and value stream (this dimension represents the product life cycle with the value streams it contains, being displayed along the left-hand horizontal axis.); and the third and final dimension which covers the layers (used in the vertical axis to represent various perspectives, such as data maps, functional descriptions, communications behaviour, hardware/ assets or business processes. This corresponds to IT thinking where complex projects are split up into clusters of manageable parts [5]).

Predictive maintenance is a method of avoiding asset failure by analysing production data in order to detect patterns and foresee issues before they happen. By spotting deterioration earlier than it could be detected by manual means, reliability increases. This earlier detection provides the maintenance workers more time to intervene - hopefully enough to avoid failure [6]. These projections are based on the equipment's condition which is assessed based on the data gathered using numerous condition monitoring sensors and techniques.

2.3. Internet of Things (IoT)

The Internet of Things (IoT) can be defined as a kind of network technology which connects the information sensing equipment with a variety of wireless communication equipment and realizes intelligent monitoring and positioning through the exchange of information. Hence, it makes things easier to control and manage, this way keeping up the evolution of the Internet as it contains continuously smart intelligent networking equipment.

With Internet of Things (IoT), the whole process of papermaking will be revolutionized, and the complete eco-system will be driven by real-time communication. Trough sensors, the equipment will interact with its environment and it will communicate with other machines, this way triggering actions or reactions to the process of production. Therefore, it will help the company not only for easy monitoring but also to enlarge their production based on the received data. Efficiency and flexibility will also be increased. [7]

The Industrial Internet Reference Architecture (IIRA) [8] is a standard-based open architecture for IIoT systems. It optimizes its value by having a vast industry applicability to drive interoperability, map applicable technologies, and guide technology and custom development. The architecture description and representation are generic and at a high level of abstraction to support the broad industry applicability.

2.4 Automation Pyramid

Industrial automation systems are very complex due to a vast number of devices with confluence of technologies working in synchronization. In order to know the system performance, we need to understand the various parts of the system [9]. This integration of technologies is represented by using an Automation Pyramid model which includes the five technological Levels (Field, Control, Process Control, Management and Company) which can be considered in an industrial environment. The technologies interdepend both within each level and between the different levels by using industrial communications.

3 PROBLEM CONTEXT AND ANALYSIS

3.1 Maintenance at The Navigator Company

The Navigator Company wants to increase equipment's reliability and reduce maintenance costs, so they must act on maintenance management to optimize processes and equipment reliability to increase availability. Preventive Maintenance (PM) consists of frequently scheduled inspection, corrections, cleaning, lubrication, parts replacement, calibration, and restoration of components and equipment. PM schedules periodic inspection and maintenance at pre-defined intervals (time, operating hours, or cycles) in an attempt to reduce equipment failure. It is performed regardless of equipment condition. The main maintenance model of the company is PM and PdM to eliminate corrective maintenance, non-planned or emergency.

The Navigator Company uses the following PM techniques [10]:

- Autonomous Maintenance: Planned actions are essentially from a surveillance type and register detected anomalies.

- Lubrication: Consists in lubrication routines, lubricant changes and sample collect to external analysis; it includes surveillance tasks, filter cleaning and substitution and failure detection in these circuits.

- Sensory: It consists in first level maintenance routines, providing the identification of potential problems through the agent senses maintenance. When supervising the detected anomalies, the person in charge emits intervention requests to the cases that require the equipment to stop.

- Systematic (Programmed Shutdowns): Maintenance actions periodically accomplished, requiring that equipment must stop running. Most of these plans are accomplished on programmed plant shutdowns.

Moreover, the PdM techniques used are the following [10]:

- Vibration control and analysis of rotative machines: Values registered by the off-line and on-line systems and kept in Historical Record for posterior processing (by specialized technicians).

- Temperature control and registration (thermography): Allows to identify the reduction of thermal isolation areas and defective or improper electrical isolations and electrical unfastening. Periodic routine inspections are executed every six months in Paper Mill and every three months in Pulp Mill.

- Thickness control of static equipment: Allows condition analysis of equipment, being able, through obtained values, to identify failure risks. The equipment is essentially made of pipe sets (ex: pipes of auxiliary and recovery Boilers, water and steam pipes, etc).

- Spectrographic and ferrographic control of lubricant oils: Very small concentrations of metallic wear products suspended in lubricating oil can be identified and therefore allows to detect failure evidences. It is possible to set corrective action through contamination elimination source, filter improvement, or the use of another type of lubricating oil.

3.2 Data Catalog

The data catalog is divided into six columns: Equipment, Data System, Data, Periodicity, Data Structure and Data Storage.

Although the catalog identifies the equipment being monitor, the identification of the data system and the data storage, regarding the data itself it is a initial version because it does not entirely answer to what relevant data is being collected or how.

3.3 Visual Modelling Profile

In order to understand what useful data is being collected and how, a structure of all the data systems is required, therefore an architecture of the data collecting system of Figueira da Foz mill was modelled.

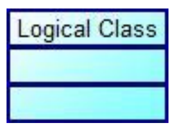
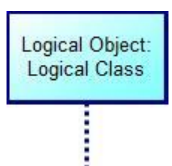
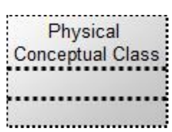
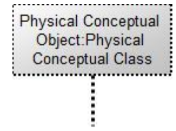
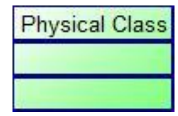
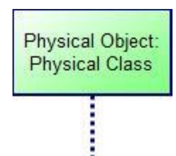
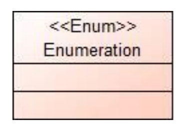
Considering the numerous physical devices and machines that all systems of the Company are made of, the best solution to modelling the problem would be Systems

Modeling Language (SysML) which is specialized in these systems. However, considering that The Navigator Company was not aware of this modelling language and was already familiar with the SAP PowerDesigner tool, although it does not have SysML, it included Unified Modelling Language (UML).

Since UML focuses more on modelling logical systems and being rather software and information specific, an UML visual modelling profile was created to model the data architecture of the Figueira da Foz Mill using SAP PowerDesigner tool.

Table 1 shows the visual modelling profile in use in this document. It is ordered by the name of the element, its definition, and the notation. The profile also identifies the logical, physical, and physical conceptual components, classes, or objects that are used.

Table 1: Visual Modelling Profile

Element	Definition	Notation
Logical Component	Represents a logical modular part and gives structure to a system. It communicates with other components through the use of interfaces.	
Logical Class	Describes logical objects that share the same attributes and relationships to give structure to a system. The first compartment is relative to the class's name and the second to its attributes name and type.	
Lifeline of a Logical Class and Object	Exposes an interacting logical object in the first partition and a logical class in the second. Time is illustrated along the vertical axis.	
Physical Conceptual Component	Represents a physical conceptual modular part and gives structure to a system. It communicates with other components over the use of interfaces.	
Physical Conceptual Class	Describes physical conceptual objects that share the same attributes and relationships to give structure to a system. The first compartment is relative to the class's name and the second to its attributes name and type.	
Lifeline of a Physical Conceptual Class and Object	Exposes an interacting physical conceptual object in the first partition and a physical conceptual class in the second. Time is illustrated along the vertical axis.	
Physical Component	Represents a physical modular part and gives structure to a system. It communicates with other components through the use of interfaces.	
Physical Class	Describes physical objects that share the same attributes and relationships to give structure to a system. The first compartment is relative to the class's name and the second to its attributes name and type.	
Lifeline of a Physical Class and Object	Exposes an interacting physical object in the first partition and a physical class in the second. Time is illustrated along the vertical axis.	
Enumeration Class	An element that represents a data type which contains fixed values, also known as literals. The first partition includes the classifier «Enum» and the enumeration's name while the second contains literals.	
Actor	An individual or entity that performs behaviour in the system.	
Interface	A point of access of a component to other components.	
Report	A report included in a component to represent data generated by another component.	

3.4 System Overview

The architecture of the data collecting system of Figueira da Foz mill includes six different data collecting subsystems from different sectors of the factory, those being: a Process Data System (PDS), a Quality Data System (QDS), a Maintenance Data System (MDS), a Vibration Data System (VDS), an Inspection Data System (IDS) and lastly, a Lubrication Data System (LDS).

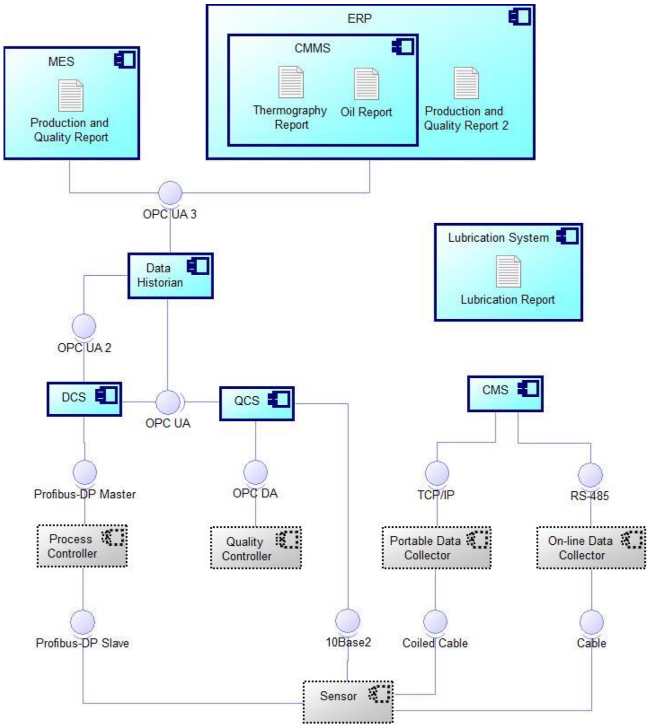


Figure 1: System Overview

To model the architecture of the data collecting system of Figueira da Foz mill, a global architecture with the integration of all subsystems is needed to provide a view of how the system (as a whole) had to be structured as displayed in Figure 1.

4 PROCESS AND QUALITY DATA SUBSYSTEMS

This section aims to describe each one of these subsystems, which are vital to the Pulp and Paper production.

4.1 Process Data Subsystem (PDS)

A PDS is end-to-end, meaning it starts from the beginning to the end of the whole process of making paper. It focuses on the control of industrial procedures in order to guarantee the efficiency and quality of the automated production line and to be able to optimize it.

The control of these processes is carried out by controllers which receive values of several measured variables through sensors, processing the given values and determining the correction signal to be carried out by actuators.

Regarding sensors that measure variables, two main types can be established: an analog sensor, which measures various variables with values between 0% and 100%, and a digital sensor which develops a binary signal, identifying two possible status: ON or OFF.

Actuators are accountable for moving and controlling a mechanism, and consist of two types: an ON/OFF valve which receives a digital signal from a controller and either opens or closes the valve in order to allow or inhibit the flow to circulate; and a control valve that receives values from 0 to 100%, indicating the desired opening for the valve. This valve contains a position sensor, which is used to accurately control the desired position.

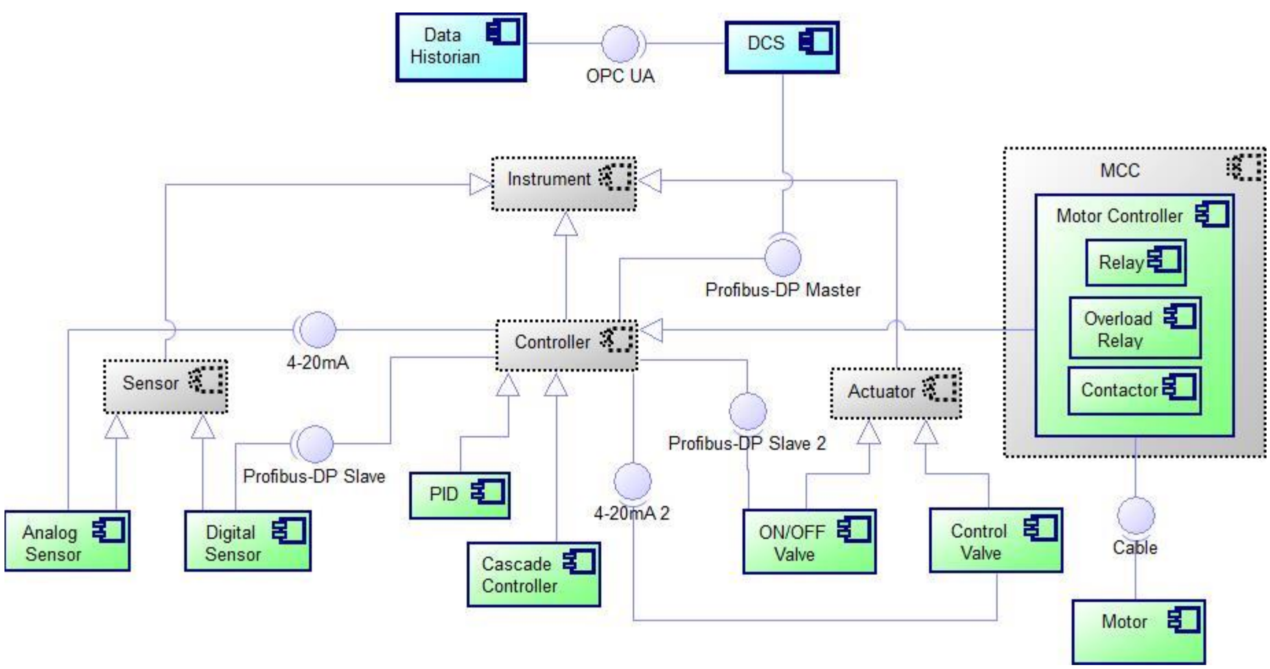


Figure 2: Process Data Component Model

In the model illustrated in Figure 2 there is also a Distributed Control Sensor and a Data Historian which records and retrieves process data in a time series database.

4.2 Quality Data Subsystem (QDS)

A QDS is based on a Quality Control System (QCS) which is installed at the final part of the paper machine, allowing to control the final product online. It measures and controls the quality characteristics of the paper, for instance weight, humidity, thickness or colour, and provides uniform quality during the production process.

The QCS consists of sensors installed inside scanners at the end of the machine, a system capable of executing complex control chains, and actuators capable of optimizing paper profiles.

The subsystem requires to represent not only the QCS, but also all other components, how they are connected to it, and where the quality data is stored at the end.

Figure 3 shows the QCS Component Model.

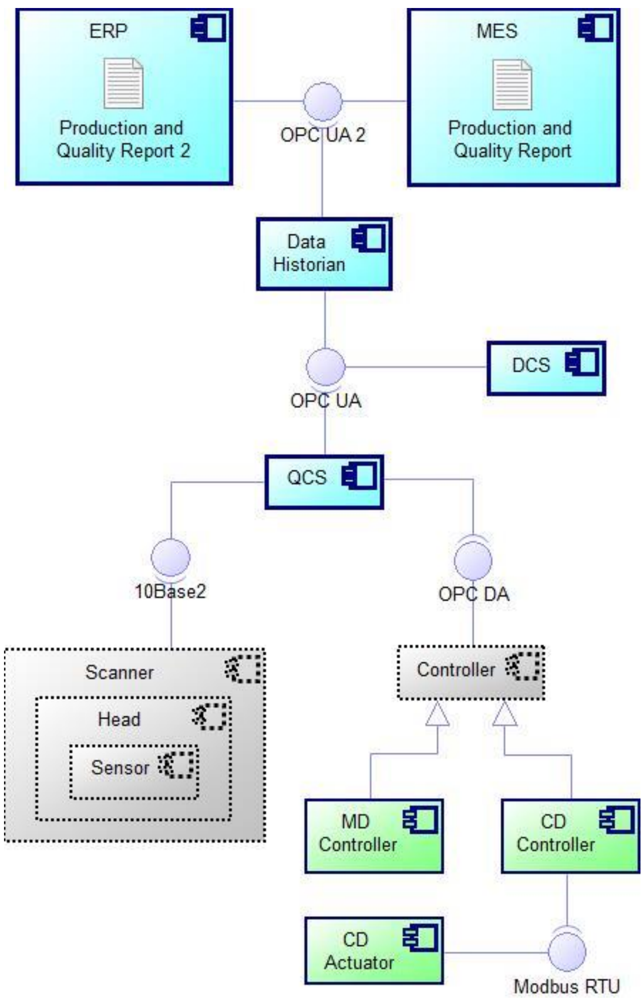


Figure 3: Quality Control System Component Model

5 SPECIALIZED SUBSYSTEMS

This Section aims to briefly describe each one of these specific subsystems.

5.1 Vibration Data Subsystem (VDS)

The VDS is based on SKF @ptitude Analyst which provides storage, analysis, and retrieval of asset information, making it accessible throughout the organization. It is a software that manages asset condition data from portable and on-line devices.

SKF @ptitude Analyst not only integrates SKF Microlog for portable data and SKF Multilog for on-line data, but also SKF Microlog Inspector for the use in Operator Driven Reliability (ODR) which is a framework for establishing an operator's activities that allows their own operation members to make their rounds, collect machine condition, and make inspections more easily.

Figure 4 describes de Vibration Condition Monitoring Component Model.

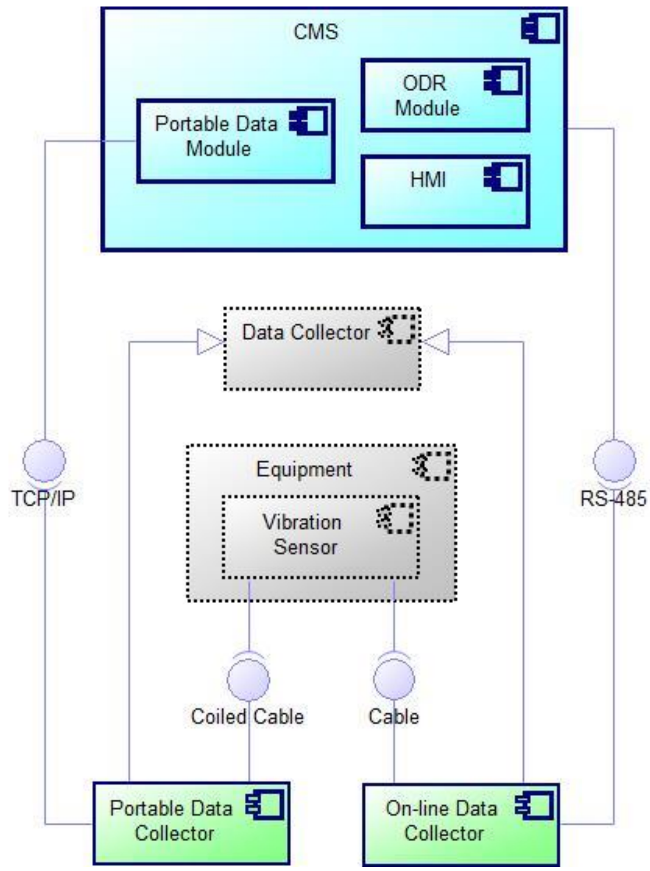


Figure 4: Vibration Condition Monitoring Component Model

5.2 Maintenance Data Subsystem (MDS)

The MDS is based on SAP Plant Maintenance (SAP PM) which is a software product that manages all maintenance activities in an organization. SAP PM module consists of key activities to include inspection, notifications, corrective and preventive maintenance, repairs, and other measurements to maintain an ideal technical system.

In this subsystem there are notifications and work orders used for equipment repairments when a breakdown occurs or for preventive maintenance, maintaining a current condition by discovering weak spots in all equipment and providing regular inspection with minor repairs.

Figure 5 represents the all the equipment that are part of maintenance and how they are identified.

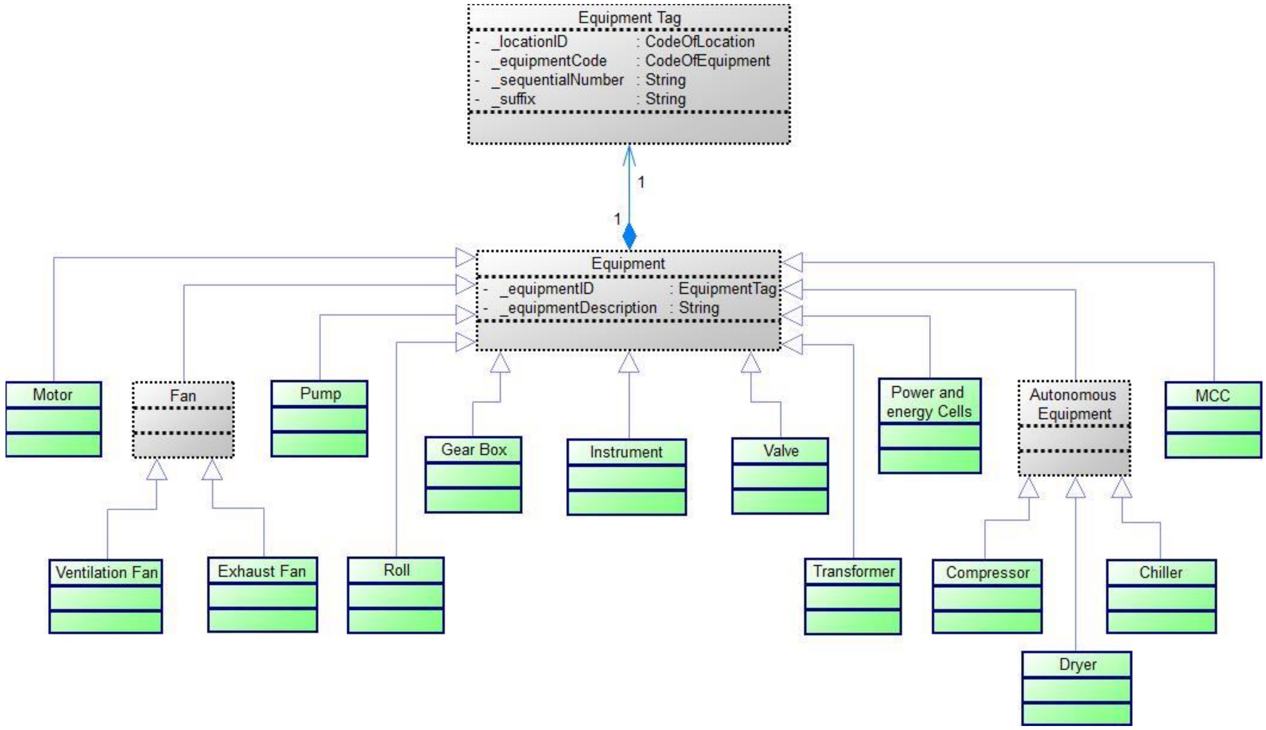


Figure 5: Maintenance Management Equipment Domain Model

5.3 Lubrication Data Subsystem

The LDS is based on a Lubrication System provided by BP, Lubgest, that integrates all standard equipment planification of several types of equipment, with its lubrication points and lubricant to use. Afterwards, Lubgest will create regular reports with the tasks to be performed in each equipment.

The Lubrication System Domain Model is displayed in Figure 6.

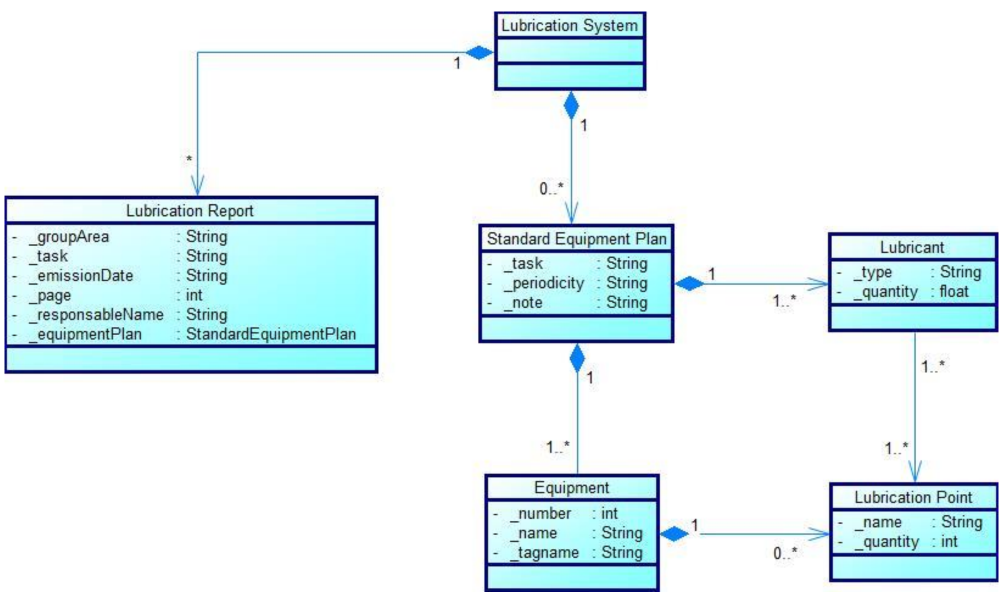


Figure 6: Lubrication System Domain Model

5.4 Inspection Data Subsystem (IDS)

The IDS collects thermography and oil measurements and analysis through requested services which are provided by external companies.

The thermography inspection service is performed by the *Instituto de Soldadura e Qualidade* (ISQ), that with the *Laboratório de Ensaios de Termodinâmica e Aeroespaciais* (LABET), one of the ISQ laboratories, carries out numerous types of tests and elaborates a very detailed thermography technical reports in accordance with criteria and international standardization.

Figure 7 illustrates the structure of thermography inspection.

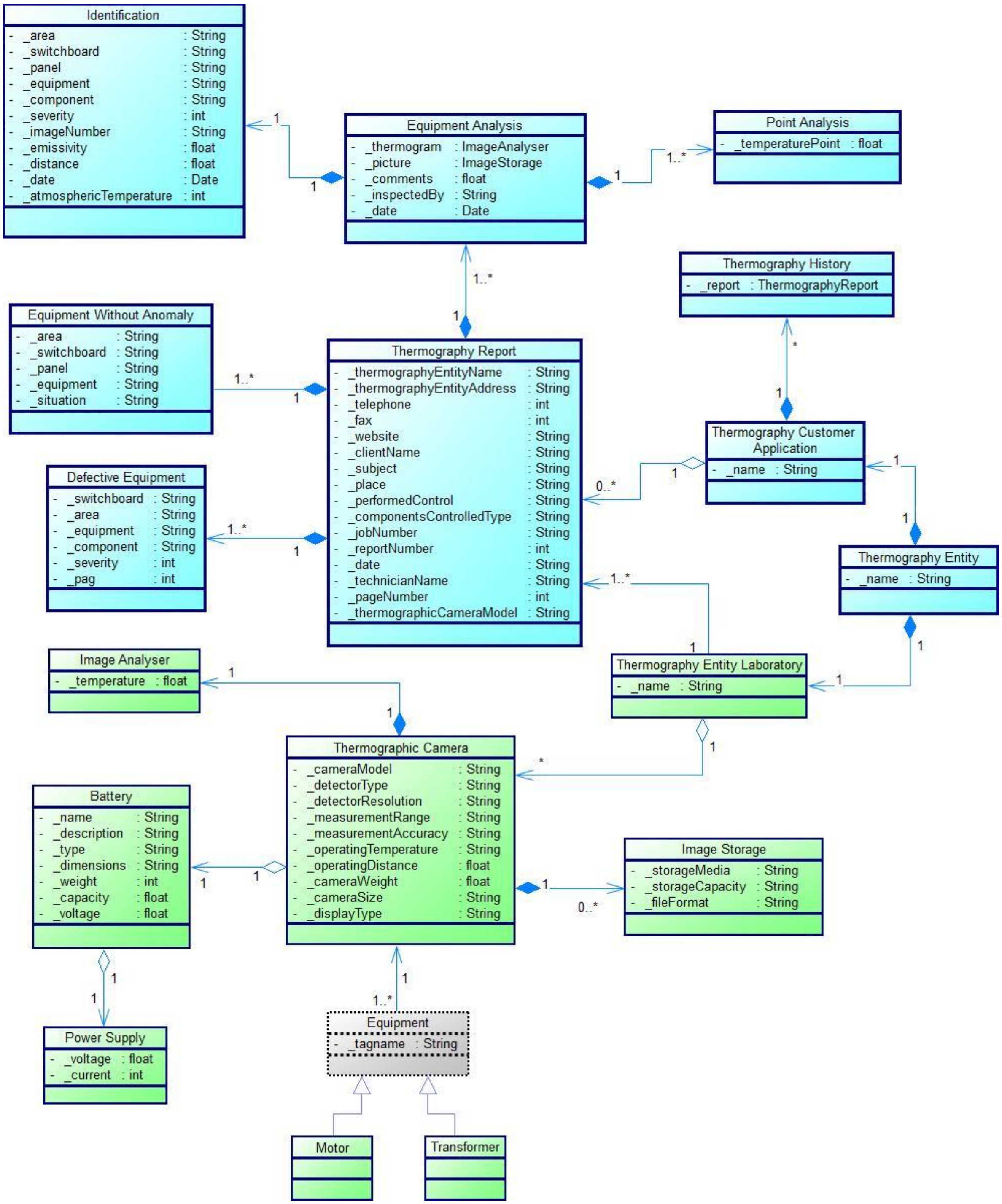


Figure 7: Thermography Inspection Domain Model

The oil inspection service is executed by BP (British Petroleum) which is the oil supplier of Figueira da Foz mill, that receives an oil sample and elaborates a result and analysis report is also made by their laboratory.

Figure 8 shows the oil inspection domain model.

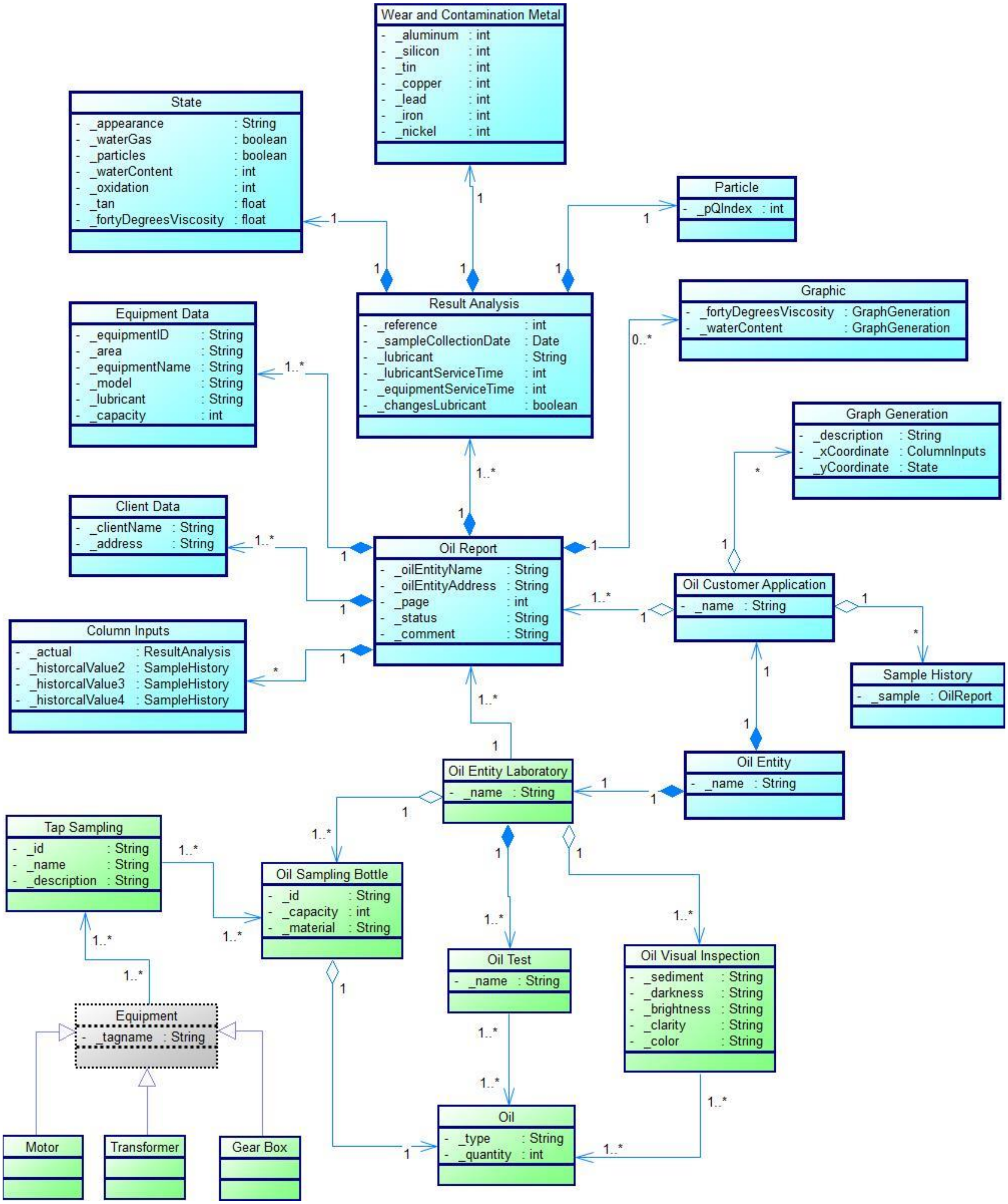


Figure 8: Oil Inspection Domain Model

6 CONCLUSION AND FUTURE WORK

Throughout this Dissertation, an architecture of the data collecting system of Figueira da Foz mill was conceived.

Considering the architecture - through the identification of the subsystems and its interfaces - it was identified how data is being collected. Furthermore, it was also described in each subsystem every asset that is subject to monitorization.

Regarding the collected data being collected and where it is stored, it can be concluded that in the data historian there are process trends analysis, production and quality reports generated by the QCS, and through the data historian tag name, a history of most of the measurements that are being collected and generated alarms from the DCS and QCS.

The CMMS reveals relevant equipment data and their locations, maintenance plans integrated, and notifications and work orders which present work history and failure dates and its causes. Beside the data being retrieved by the MDS, CMMS also stores thermography and oil reports history which include the detailed analysis made by the laboratories described in IDS.

Concerning the CMS, it includes lists of surveillance equipment, causes of anomalies, vibration alarms, reports, and analysis and graph display that can be generated.

In the lubrication system, there are equipment plans with information about the assets, their lubrication points and lubricants to apply, and also lubrication task reports executed in the lubrication system.

Considering the whole system of the mill, and with the purpose of centralizing data managing, The Navigator Company would benefit by integrating the lubrication reports in CMMS. This way the APM will only collect data through the data historian, the CMMS and the CDS.

Regarding future work, there are three interesting routes that can be explored: taking into account the Company's goal of decreasing pollution and energy consumption, it would be interesting to model the responsible systems for energy management and electricity production of the mill, which connect to the electrical distribution systems, allowing the sectioning of each energy generation and distribution zone; after the implementation of APM in the Figueira da Foz mill, the architectures of Setubal and Aveiro mills of the Navigator Company could also be created for more uniform, effective production systems; and lastly, a proposal for the future architecture of the work done.

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