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ENVIRONMENTAL MANAGEMENT AND MACHINE LEARNING: A CASE STUDY IN A THERMOELECTRIC POWER PLANT IN NORTHEASTERN BRAZIL

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ABSTRACT

Many activities can cause significant environmental impacts on the environment. A large part of the thermoelectric plants uses fossil fuels to generate energy, but they can also release greenhouse gases into the environment. Given this scenario, it is essential to have an effective environmental management system for monitoring risks within a plant. This research aimed to develop an intelligent system, based on machine learning, which allows predicting the level of risk of failure of components in the installation, in addition to predicting the level of environmental risk, in real time, of the conditions of assets and of plant events of a thermoelectric powerplant. Thus, the company has all its environmental assets implemented within a system that alerts it to deadlines, environmental conditions and historically monitors all its actions aimed at environmental preservation of the environment in which it operates.

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INTRODUCTION

Since the beginning, populations use the environment only for survival, however, with the advent of industrialization, the nature became a resource to generate products and services never done in the past, giving no time for regeneration of natural resources is not respected, which can lead to extinction.Industrial activities used to release energy and debris into the environment, that can cause some type of pollution. According to Góes (2021), the Brazilian energy matrix was largely characterized by hydroelectric generation, with the use of thermoelectric plants only in periods of water scarcity. However, there is a recent trend towards reducing the use of hydroelectric plants with the increase of thermoelectric plants, most likely due to the periods of energy rationing faced by the country (DORR *et al*., 2015). Thermoelectric powerplants can generate energy from different types of fuels (e.g., coal, nuclear, natural gas, even biomass), but fossil fuels are the most used, resulting in the production of greenhouse gases (GHG), which are responsible for global warming. According to the Ministério do MeioAmbiente (2019), Brazil has committed in the Paris Agreement to reduce its GHG emissions by 37% below levels until 2025 and by 43% below levels until 2030. Therefore, it is important that thermoelectric powerplants have an effective environmental management system so that they can anticipate the risks of any activity and/or operation that may cause a negative environmental impact. In this context, sustainability in human activities depends on prudence in relation to the use of nature, integrating a socially inclusive, environmentally supportable and economically viable development over time (VEIGA, 2005). Environmental management is considered a science that studies and helps the execution of social and economic activities considering the rational use of natural resources, whether renewable or non-renewable. This toolsare necessary in corporations and industriesallowing the use of practices that ensure the preservation and conservation of ecosystems, for the sustainability of the activities that the company performs, in this case, the generation of energy (BARSANO; BARBOSA, 2019). Furthermore, the use of tools that allow the prediction of environmental risks is a positive point within a company's environmental management,as by avoiding remediating a damage, it minimizes possible negative environmental impacts that the thermoelectric power generation system can cause in its activities. These management tools that minimize these impacts and seek to end the idea of antagonism between the environment and economic development (PETTS, 1999). Thus, this study aims to develop an intelligent system, based on machine learning, which allows the prediction of the level of risk of failure of installation components, in addition to predicting the level of environmental risk, in real time, of the conditions of the assets and events of a thermoelectric plant. This research was financed with resources from the Programa de Pesquisa e Desenvolvimento do SetorElétrico, regulated by the Agência Nacional de Energia Elétrica(ANEEL; PD-02901-0003/2019) and is being carried out by Termocabo, in partnership with a Software In Forma S.A

MATERIALS AND METHODS

EquipMaint (EqM) is a tool that meets the demands of operation and maintenance (O&M) management, in addition to other activities, in organizations that deal with complex installations, high-value equipment, standards and regulations. EqM has several functionalities that guarantee the realization of integrations between systems (e.g., SCADA2, GIS3, EMS4) in an uncoupled way and without causing dependency in the processing between the systems. EqM also works as a manager of these integrations, keeping all the records of data sent and received, monitoring failures and allowing the configuration of integration parameters. The urgent maintenance cost is 20 to 100 times bigger than a scheduled maintenance. In relation to environmental management, there are costs that cannot be repaired within an ecosystem. Depending on the magnitude and scope of an environmental impact, a degraded area may no longer be recovered, causing a large-scale environmental liability. The CRISP-DM methodology (Cross-Industry Standard Process for Data Mining) was used to develop a solution that will automate the predictive maintenance process in environmental management. CRISP-DM provides organizations, regardless of industry and data mining tool, with the necessary structure to obtain faster, simpler, cheaper and easier-to-manage results (SHEARER, 2000). The stages (III to VIII) of the project are related to the phases of the CRISP-DM methodology, as can be seen in Table 1.

Table 1. R&D Project Stages versus CRISP-DM Stages

PROJECT STAGES	CRISP-DM STAGES
StepIII – Identification of Relevant Data and ETL	Business Understanding, Data Understanding and Data Preparation
Step IV – Creating a Data Mart	Data Preparation
Step V – Recognition of Failure Patterns	Data Preparation
Step VI – Creation of a Real-Time Failure Risk Level Prediction Model	ModelingandEvaluation
Step VII – Dashboard Development	Implantation
StepVIII – Pilotproject	Implantation

Step I - State-of-the-art survey: Conducting literature research on machine learning techniques applied to predict the level of risk of failure in real time, of each component, of the installation from data meters, assets and plant events. For this survey, the plant's Operating License (OL), the Simplified Environmental Report (SER) and the Solid Waste Management Plan (SWMP) were also used.

Step II – Implementation of the EqM tool (Maintenance and Operation): Process for (i) management of intervention requests (local and systemic) and (ii) management of occurrences and execution of interventions. This phase also aims to implement an environmental management process and maintenance activities with the support of the EqM software, covering the normative and executive areas, corrective, preventive and predictive maintenance.

Step III – Identification of relevant data and ETL: The results of machine learning solutions depend on the data used, so it was necessary to analyze the available databases and identify the relevant data to solve the problem. After identifying the necessary data, the ETL (Extraction, Transformation and Load) flow was performed. Data selected in different databases will be stored in a unified location in the desired format.

Step IV – Creation of a Data Mart: Construction of a data repository focused on the specific purpose of the project, which is to predict the level of risk of failure in real time, based on meter data, asset conditions and events of the plant.

Step V – Recognition of failure patterns: Preparation of data for identification and labeling of event patterns associated with evidence of equipment failures.

Step VI – Creation of the failure risk level prediction model in real time: Construction of the equipment failure prediction model in real time, from the extraction of useful knowledge previously hidden in the data. This phase consists of creating models and carrying out experiments to find the best results. The model selection will be performed based on performance evaluation metrics to validate the achieved results.

Step VII - Dashboard Development: Implementation of a dashboard to visualize the model in production. The dashboard will include some views to support decision making. The main feature is to indicate the equipment risk level (score) in real time. Furthermore, it will allow the measurement of KPIs according to the decisions taken.

RESULTS E DISCUSSION

Collection and analysis of primary data was done by reviewing the documentation of all activities related to environmental management within the thermoelectric plant. All current and past data from these activities were collected for insertion in the tool Equipmaint. The aspects shown in Figure 1 were monitored within the powerplant and comprise the research that minimize environmental risks, in addition to carrying out a predictive analysis.

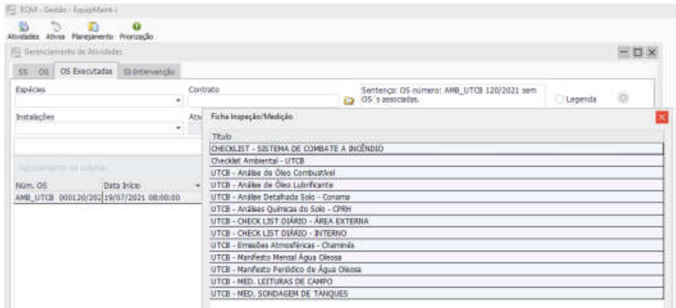

Figure 1. Aspects monitored by the tool *Equipmaint.*

At this context, environmental management is an important tool for the modernization and competitiveness of organizations (CAMPOS; MELO, 2008). A company that is concerned with the impacts that its activities can cause to the environment demonstrates a differential, as it is focused not only on providing a service to society, but also on the sustainable development of its activities. These companies seek to meet the requirements defined by customers or even proactively adopt the certification of their management systems, because they believe there are benefits for the organization of the company's routines (PEDRIALI *et al*., 2020). All variables listed in Figure 1 can be viewed in spreadsheets and graphics, providing a better strategy for analyzing the results of monitoring carried out within the powerplant. The results are analyzed in accordance with the resolutions of the Conselho Nacional do MeioAmbiente (CONAMA), such as: No. 491/2018 (provides for air quality standards), No. 01/90 (provides for noise levels), No. 357 /2005 (provides for the classification of water bodies and conditions and standards for the release of effluents), in addition to the Política Nacional de Resíduos Sólidos (PNRS, 2010) which deals with the separation and disposal of solid waste produced in the enterprise and other relevant legislation.Fulfilling these resolutions increases the organization's success, as well as increasing its competitive advantage over other companies, generating tangible (operational efficiency) and intangible (reputation and brand value) results (OLIVEIRA *et al*., 2012).

In its indicator panel, where indexes and targets are listed, risks are mapped to structure preventive measures, in case any of the listed indicators disagrees with the legislation in force. This information has a high analytical value, which allows the structuring of reports that meet any demand of the company with its customers and their maintenance. According to Francisco *et al*. (2020), with all the data projected on a panel screen, the idea of generating reports on the environmental gains of the projects monitored in their research became more noticeable, as it made it easier to obtain the associated historical data. All monitored environmental indicators are the result of the operating license and environmental management of the powerplant and through predictive analysis, can be inferred if any chosen indicator within the monitoring, could present results in disagreement with legislation and thus proceed with the mitigation or reduction of damage, corroborating what Dorr *et al*. (2015), that highlights the use indicators as essential management tools.This system allows all these variables to be registered, because if any situation happens again, it already has a database with the information to be followed by the company. With this, alert data were configured in the system that indicate the dates of performance of environmental management activities, eliminating risks of environmental accidents as well as environmental fines. The organization of these data was an important step for the future prediction of the level of failures, acting to prevent negative environmental impacts (Figures 2 and 3).

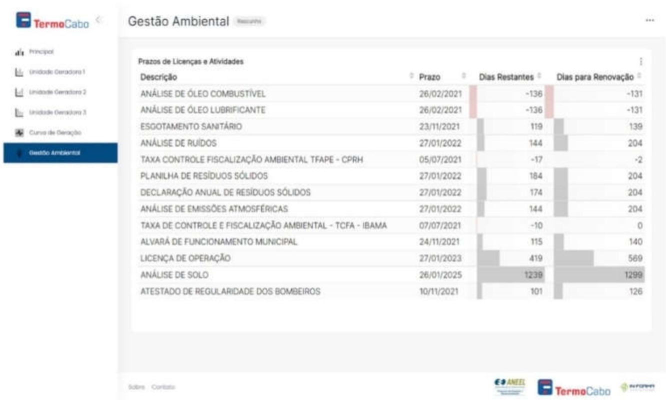

Figure 2. Image of the developed dashboard showing measured indicators

Figure 3. Dashboard image highlighting activity deadlines

Therefore, both the top leadership and the operational level of the plant have access to the dashboard screens and follow in real time all the nuances related to its environmental management system. These use of the dashboard as a support tool in decision making was also pointed out by Bissacot and Oliveira (2016), Carvalho *et al*. (2021) and Francisco *et al*. (2020), helping to define the availability of resources and the actions to be implemented as well as the associated risks, considering the strategies outlined by the powerplants. According to Francisco *et al*. (2020), this instrument enables continuous data management and not just an annual static photograph, which makes the indicators become performance management indicators.

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