Predictive Maintenance Through Thermographic Analysis: Case Study in a Manaus Industrial Pole Company

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Abstract

Due to the high demand for electricity in the manufacturing industry, companies to obtain greater profitability on their produced goods, seek and adopt ways to reduce energy consumption, and use predictive maintenance as a tool by applying thermography. Thus, the purpose of the research is to show the importance of thermographic analysis for assessing losses and preserving the safety of the company's physical facilities. The research is descriptive, qualitative and case study. The instrument used for data collection were direct observation and document analysis. In this context, the results obtained were the mapping in the manufacturing facilities and the identification of some failures in the company's electrical system. After this data collection process, it was possible to analyze and plan the corrective actions. In conclusion, it is possible to reduce manufacturing costs through predictive maintenance through the thermographic analysis tool, positively impacting the company's financial results.

Keywords: electrical installation; thermography; predictive maintenance.

1. Introduction

Predictive maintenance has applications in various areas, with the most diverse purposes, however in the area of electrical, the method used is thermography, a procedure that the equipment used is the thermographic camera. Predictive, thermographic maintenance is intended to perform routine inspections to correct overloaded cables, and eliminate heated connections, these two main factors dissipate heat energy, causing power losses, increasing power consumption and energy bills.

Thermographic monitoring should be planned and executed with the utmost importance so that the cost of electricity does not get out of control, and companies do not end up having low profitability due to monitoring reports made sporadically it is possible to map major causes and greater propensity, with up-to-date maintenance on electricity will be reduced, as well as fire hazards.

It is well known that industries today have a high demand for electricity so that they can produce their products, and get their revenue, however, it is not enough to have a high profit if you have to pay a high price on the electricity bill, Measures can be taken to avoid unnecessary energy consumption. Thus, the research problem seeks to answer the following question: What is the importance of predictive maintenance through thermographic analysis for an industrial center industry in Manaus?

In this context, the present research aims to discuss the importance of thermographic analysis for the evaluation of losses and preservation of building security. To achieve this objective, some specific objectives were stipulated which are: to analyze an electrical system of a company of the industrial pole and Manaus; point out the advantages of thermographic analysis for company results; compare the results with other thermographic analyzes of the Manaus industrial branch.

The choice for the theme arose from the need to solve the problem of the studied company in relation to the energy consumption that is very high, identifying these failures through thermographic analysis, to present possible solutions.

In this context, the relevance of the theme is to show that building maintenance through thermographic analysis has several benefits not only in the area of maintenance, but a thermographic analysis can point out possible flaws that can cause damage to the company's financial performance and safety. Of their collaborators, being able to avoid accidents and risk of death.

For the company, thermographic inspection in its greatest contribution is to avoid the waste of electricity, also ensure the safety of employees, and the integrity of the company building, because through inspections routinely made in the electrical circuit of a company, it is possible to detect points hot wastes that are wasting energy, and over time can even damage material parts of the company, thus contributing to the financial savings in terms of energy consumption as well as the safety of everyone in the environment.

2. Theoretical Referential

2.1 Predictive Maintenance

Maintenance has several applications. With the evolution of production processes, machines and technology in general, it has become increasingly important to maintain commercial, industrial and residential facilities, which has made the concept of “repair” very comprehensive and assumed. Greater importance than that linked to immediate problem solving [1].

Maintenance is the process that is intended for the conservation of goods (facilities or equipment), maintaining their technical, functional and safety characteristics. This is a set of technical care indispensable for the regular and permanent operation of machinery, equipment, tools and installations [2].

It is seen as the need to ensure that systems and equipment present availability and performance when required to operate and make maintenance teams come to work to positively transform work situations in a process of continuous improvement [3].

The mission of maintenance is to ensure the availability of the function of equipment and facilities to meet a production or service process, with reliability, safety, environmental preservation and appropriate costs, leading to maintenance as a strategic function in obtaining results and leveraging the company and competitive levels of quality and productivity [4]. As for strategy and how maintenance is performed, there are at least three basic types, as illustrated in the following figure.

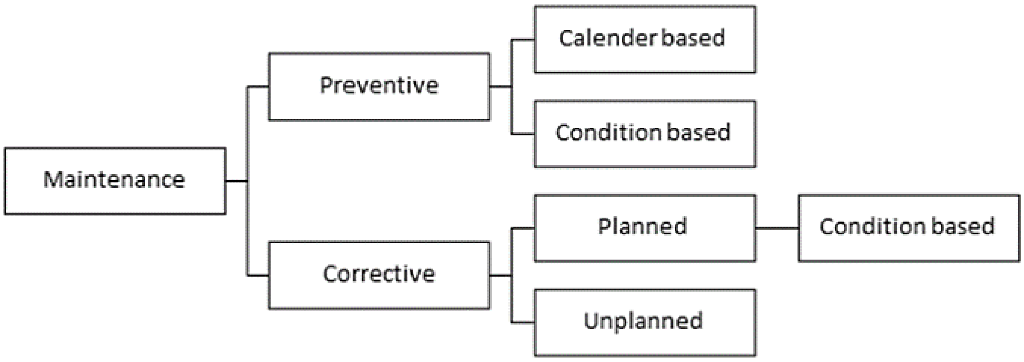

Figure 1. Types of maintenance
Source: SENAI, 2014.

For the company to achieve excellence, improvement in all areas is required and this will only be achieved by the engagement and collaboration of the entire team ensuring the availability and reliability of the facilities at an optimal cost point. To achieve this goal, it is responsible for keeping the production system equipment and facilities in perfect working order. For each machine or equipment there must be a maintenance plan that must be followed.

In this research, only preventive and predictive maintenance will be addressed. The type of predictive maintenance consists of evaluating the actual operating conditions of machines or equipment, as well as their parts, for efficient use of the useful of and planning of maintenance interventions [1].

Predictive maintenance has a wide field of application, both mechanical and electrical tracking, the differential of this maintenance is to show the actual state and performance of the equipment in its operation, thus providing data that ensures the interval between repairs, in addition, decreases occurrences of unscheduled machine shutdowns created by faults or improper operation [4].

Preventive maintenance is the maintenance modality that works based on hours worked of machines, accessories or equipment, for that is used the mean time curve for failure (CTMF) tool that generates data and graphs of problem histories presented, with Based on these data preventive maintenance is planned, it is the maintenance mode that acts before the problem becomes bigger, thus avoiding corrective maintenance action, the most important difference of this mode is the ability to program the machine shutdown, accessory or equipment, so that it has less impact on production [5].

In the case of industrial electrical installations which is the main object of study, electrical networks require inspection and cleaning routines of electrical panels to ensure the safe operation. Large installations incorporate transformer stations, which are subject to legally binding inspection and management conducted under the responsibility of a recognized professional, the so-called TRIESP (Technician responsible for private service electrical installations) [6].

In this context, thermography is the most common technique and is prominent in predictive maintenance. With a wide range of applications, it is possible to discover various production failures, preventing electrical breakdowns, mechanical and material and equipment fatigue, yet can be applied to investigate component temperatures to detect future premature machine and equipment failures, avoiding downtime. of production [7].

2.2 Thermographic Analysis

The use of tools that anticipate the verification of electrical problems in the industrial sector has been growing over the years, such as infrared radiation analysis or thermographic analysis. The use of thermography has been expanding rapidly in various sectors of civil society. The most common applications are in studies of thermal comfort, preventive and predictive maintenance, medical, mechanical and electrical component evaluation, artwork evaluations and material properties [8].The use of tools that anticipate the verification of electrical problems in the industrial sector has been growing over the years, such as infrared radiation analysis or thermographic analysis. The use of thermography has been expanding rapidly in various sectors of civil society. The most common applications are in studies of thermal comfort, preventive and predictive maintenance, medical, mechanical and electrical component evaluation, at work evaluations and material properties [8].

Thermography is considered a tool of the quality of rising predictive maintenance, as its advantages are of great importance, such as nonintervention in the operation of equipment and production processes, in addition to the relative ease of analysis and imaging and ease of operation of the thermal imagers. In the industrial sector, it is possible, through a thermographic report, to pinpoint the exact location of the problem (hot spot), in time to avoid losses of relevant magnitude [7].

Figure 2 shows the evolution of display term technology: Liquid nitrogen-cooled detector, optical/ mechanical scanning system, total weight of 37 kg used in the 1970s. Electrically cooled detector, optical/ mechanical scanning system, weight 6, 1 kg used in the 80's. Uncooled, FPA (Focal Plane Array) detector, weight 2.0 kg widespread in the mid-2000 year. Flir E30 detector, weight 825g used since 2012.

Figure 2. Evolution of display term technology

a) Liquid nitrogen cooled detector; b) Electrically cooled detector; C) Uncooled detector, FPA (Focal Plane Array); d) Flir E30 detector.

Source: Cardoso; Fernandes; Valentine, 2015.

In this context, thermographic analysis is a noninvasive inspection technique, i.e., it does not interfere with machine production or equipment operation based on the detection of infrared radiation emitted by bodies having an intensity proportional to their temperature [9].

Today the instruments used to perform thermographic analysis are: infrared camera, data collector, radiometer, analysis program and conveyor belt. As illustrated in the following figure.

Figure 3. Thermographic analysis equipment
Source: Schekiera, 2011.

Regarding non-contact thermography, the infrared technique is the capture of thermal radiation emitted naturally by the bodies, allows the formation of thermal images and the temperature measurement in real time. It is made with mobile thermal imagers to detect and convert infrared radiation into visible images facilitating temperature measurement [10].

The thermographic technique can be classified as qualitative and quantitative. Qualitative using thermal standards to assess anomaly identified during inspection and quantitative in priority and seriousness analyzes for maintenance scheduling and planning [11].

The qualitative information is related to what is captured by the infrared inspection device and the quantitative is related to the graphics that will point out possible equipment and machinery failures, as illustrated in the following figure.

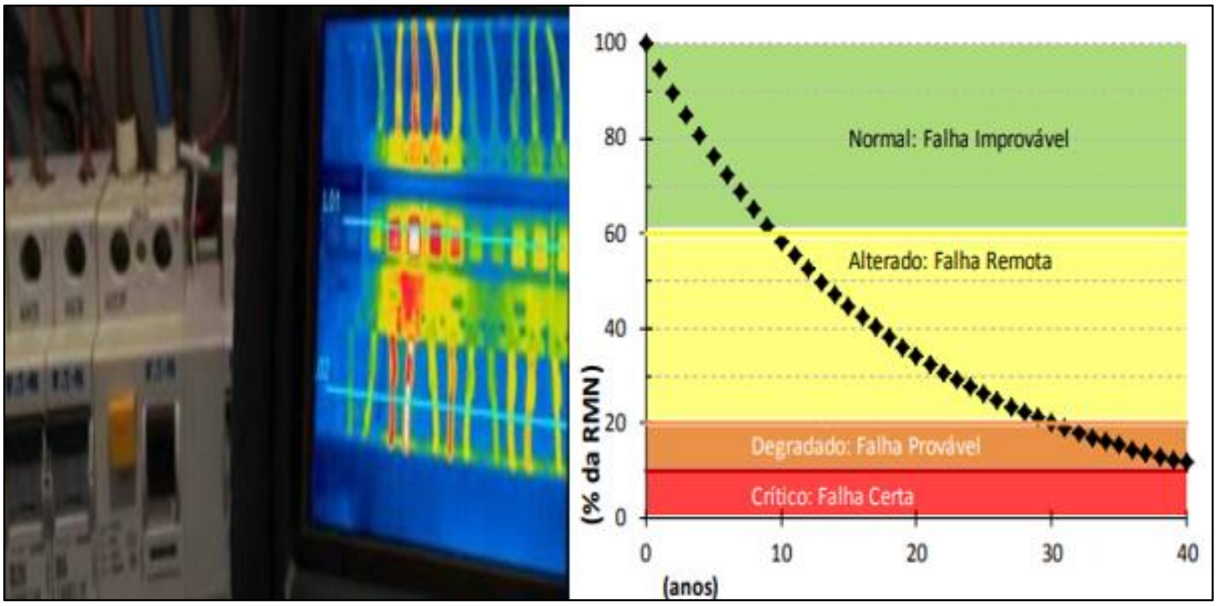

Figure 4. Qualitative and quantitative information of an inspection
Source: Amarante, Bridges, Michaloski, 2016.

Because temperature is the main detectable variable in the failure process of an electrical installation, this is where the largest application of thermography in the industrial area is concentrated. A thermographic inspection of electrical installations will identify problems caused by current / resistance ratios, usually caused by loose, corroded, oxidized connections, or component failure itself. In addition, design errors, assembly failures and even excessive and / or lack of preventative maintenance can cause overheating in electrical systems.

2.2 Standard Temperature of an Electrical System

One of the most important variables in predictive maintenance of electrical panels is the Maximum Allowable Temperature (MTA) of its components, i.e. the maximum temperature under which the component is allowed to operate. This standard is based on ABNT (Brazilian Association of Technical Standards) standards, NBR 5410, manufacturer tables, International Electrical Commission (IEC) references [12].

The main components of a power grid and their respective temperatures are detailed in tables 1 and 2.

Table 1. Maximum Allowable Temperature (MTA)

COMPONENTES ELÉTRICOS	MTA
Contactors Coil	100 à 140 ºC
Fuses (Body)	90 à 110 ºC
NH Fuses (Claw)	90 ºC
NH Fuses (Claw)	70 à 110 ºC
Metal Connections - BT Cable	70 à 90 ºC
Metal Connections - Metal and BT Buses	90 ºC
AT Disconnect Switches	50 ºC
AT connections	60 ºC

Source: Adapted Brito, Filho, Alves, 2010.

Table 2. Temperature classification of electrical components

<table>
<tr><th>ELECTRICAL COMPONENTS</th><th>Normal Temperature (ºC)</th><th>Light Temperature (° C)</th><th>Moderate Temperature (ºC)</th><th>Severe Temperature (ºC)</th><th>Temperature Extreme (ºC)</th></tr>
<tr><td>Contactor coil</td><td rowspan="10">T<35</td><td rowspan="10">35≤T< 40</td><td rowspan="5">40≤T<60</td><td>60≤T<100</td><td>T≥100</td></tr>
<tr><td>Fuse (Body)</td><td rowspan="4">60≤T<90</td><td rowspan="4">T≥90</td></tr>
<tr><td>NH fuse (claw)</td></tr>
<tr><td>Metal connections</td></tr>
<tr><td>Metal and Buses</td></tr>
<tr><td>Hooded wires</td><td rowspan="2">40≤T<55</td><td rowspan="2">55≤T<70</td><td rowspan="2">T≥70</td></tr>
<tr><td>Metal Connections - BT Cable</td></tr>
<tr><td>AT Disconnect Switches</td><td>40≤T<45</td><td>45≤T<50</td><td>T≥50</td></tr>
<tr><td>AT connections</td><td>41≤T<50</td><td>50≤T<60</td><td>T≥60</td></tr>
<tr><td>High voltage</td><td>10≤T≤20</td><td>20≤T<30</td><td>T≥30</td></tr>
</table>

Source: Adapted Brito, Filho, Alves, 2010.

3. Methodology

The study area is located east of the city of Manaus - AM, in an industrial center company that receives incentives from Suframa. This is an industry of plastic injection industry, possui duas fábricas na cidade de Manaus, uma na Bahia e outra em João Pessoa. The case study will be carried out at the headquarters of the city of Manaus, which has a manufacturing area of 7500 m2 of built area, 83 injection molding machines and about 850 employees who during 3 work shifts industrialize more than 650 production items, It currently has about 43 customers in the most diverse segments including: electronics, mechanical, two wheels, entertainment, personal hygiene, watchmaker, computer and disposable products.

The company adheres to strict quality standards including ISO 9001 which specifies requirements for the quality management system, with a focus on sustainability, risk prevention and continuous improvement of the organization's QMS performance, also ISO 14001. which deals with specifying requirements for the environmental management system, with a focus on improving environmental performance, meeting legal and other requirements and achieving environmental objectives.

IATF 16949 specifies requirements for the automotive quality management system, with a focus on sustainability, risk prevention and continuous improvement of the organization's QMS performance.

4. Analysis and Discussion of Results

Based on the standard equipment temperature table (Tables 1 and 2), a third table was used to scale the priority level of each equipment according to colors ranging from lowest priority (good) to highest priority (black), which shows that the correction on that circuit, machine / equipment must be done immediately, as shown in the following table.

Quadro 1. Priority level escalation

Severity	Temperature Condition	Corrective action
Good	Normal temperature	Do thermography conf. programming
Light	Temperatures lightly above normal	Do thermography conf. programming
Moderate	Above normal temperature	Make intervention schedule
Moderate	Temperature far above normal	Make intervention schedule
Extreme	Extreme temperature above normal	Make urgent / immediate intervention

Source: Adapted Brito, Filho, Alves, 2010.

After performing the thermographic mapping on the facilities and machines and equipment, and based on the tables detailing the working temperature and maximum allowable temperature, it was possible to generate a table and graph with number of cases detailing, the number of mild cases, moderate, normal, severe, extreme, and the maintenance field where the equipment was undergoing preventive maintenance, and the stopped field where the equipment that was stopped due to lack of production demand as shown in figure 5.

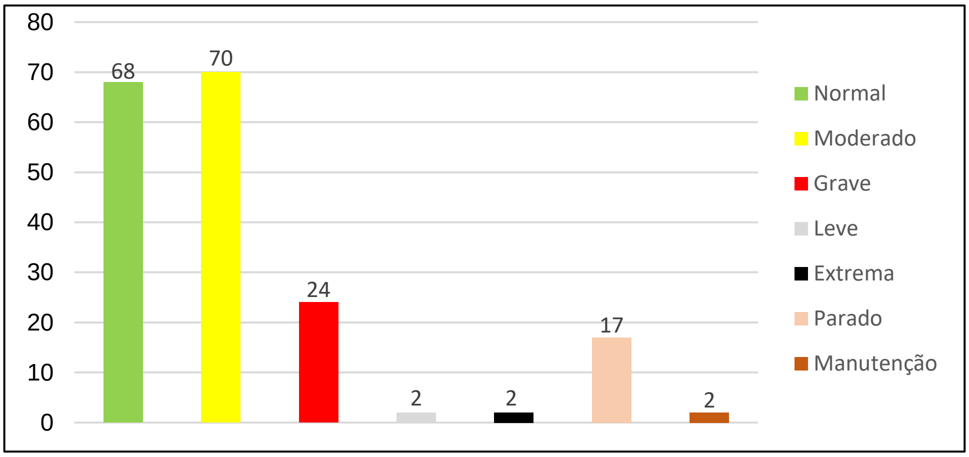

Figure 5. Number of cases detailed by level

Source: Own author, 2019.

According to the above data, 70 inspected equipment operating moderately; 68 equipment work at normal temperature; 24 devices work critically; 17 devices are stationary and the other 6 are under maintenance or are running lightly.

Further stratifying the results it is possible to list the equipment with the highest rate of problems presented, in this case the highest rate of overheating was detected in the cables, which were not badly sized, but cables that over time suffered a higher current demand causing thus overloading the circuit in general, ranging from cables to protective equipment (circuit breakers and fuses), busbars and connections integrated to the same circuits also suffer from heating, as shown in figure 6.

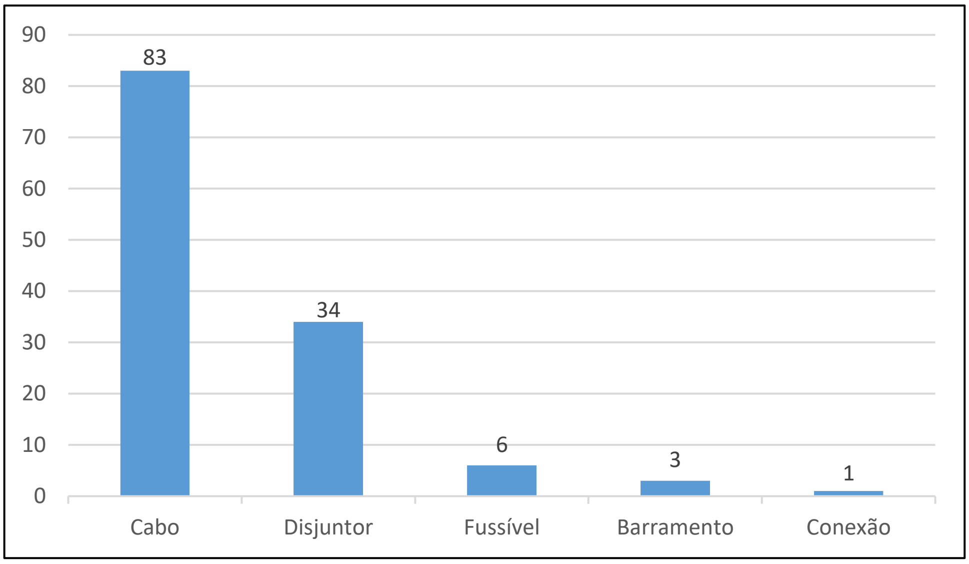

Figure 6. Equipment Issues
Source: Own author, 2019.

The data in the graph above show that 83 cases come from the mains cables; 34 cases in relation to circuit breakers; 6 fuse cases; 3 busbar cases and only 1 connection case.

Heating of the inspected mains cables and wires works at a high temperature due to the Joule Effect. Which is directly proportional to the size of the electrical current conducted by the conductors of the electrical installation, i.e. the greater the electrical current in the wiring, the greater the amount of heat generated in the conductors. When a current flow through it, a conductor heats up, releasing thermal energy due to the dissipated electrical power in its ohmic resistance. In other words, heat is released into the environment due to the meeting of moving electrons with the conductor atoms.

Other research related to the industrial thermographic analysis had similar results, in the analysis made in an electronics industry of Manaus city, in its analysis were evaluated 260 panels of low and medium voltages, with the result of the analysis were detected a higher index of heating in cables, safety devices (circuit breakers), terminals and connections [8].

In a thermographic inspection made in a company of the plastic injection branch of the Manaus industrial pole, it was concluded that the cables operate at a moderate temperature and that it requires more attention at the time of the periodic thermographic inspection [13].

Comparing these three thermographic inspections using a table we have results shown in table 3:

Table 3. Comparison of thermographic inspections

	Equipments	**Amount**
Main inspection	Cables	83
	Circuit breaker	34
	Fuse	6
	Bus	3

	Connections	1
	Total	**127**
Farias e Silva Inspection (2019)	**Equipments**	**Amount**
	Termination	15
	Cables	7
	Connections	6
	Circuit breaker	5
	Counter	1
	Total	**34**
Medeiros Inspection (2019)	**Equipments**	**Amount**
	Cables	83
	Circuit breaker	34
	Fuse	6
	Bus	3
	Connections	1
	Total	**127**

Source: Own author, 2019.

According to table 3, comparing the three thermographic inspections we have as main equipment that operate in moderate or severe temperature the cables, circuit breakers and fuses.

5. Conclusion

Maintenance types are indispensable within the industry, each operating in a different scope and with different goals, but for one goal to be achieved.

Putting a predictive maintenance system in a company requires analysis and preparation of it. Which means that once installed, the company will no longer be subjected to unnecessary downtime due to equipment and machinery breakdown. Since preventive maintenance keeps track of what is happening on each piece of equipment in real time, thus preventing it from stopping indefinitely.

According to what has been presented, predictive maintenance using the thermography technique has a greater benefit and profitability compared to other maintenance.

Therefore, the thermographic analysis, is within the predictive maintenance, is the type of maintenance in which the equipment is analyzed in its operating state, basically is the maintenance made through image analysis with the use of thermal imagers, where a standard is adopted. of temperature variation for a given equipment, in that when the temperature varies outside the working standards, that equipment becomes obsolete, thus losing yield, and generating heat due to these losses, and for this reason the thermographic analysis should be done routinely. In order to monitor the equipment, to avoid the highest energy consumption for a given activity, the analysis is done over a period of six months, thus generating reports and history of higher incidence rate.

Finally, the thermographic analysis is not only linked to the performance of the equipment, it also covers the safety field, because through constant monitoring, it is possible to avoid circuits overloading the short circuit point, electrical panels, fuses, disconnect switches, cables between others, avoiding fire principles. Finally, the thermographic analysis is not only linked to the performance of the equipment, it also covers the safety field, because through constant monitoring, it is possible to avoid circuits overloading the short circuit point, electrical panels, fuses, disconnect switches, cables between others, avoiding fire principles.

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