Analysis Fault and Effect Modes – FMEA: Failures Fire Protection System Turbine in Thermoelectric Plant

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Abstract ***— In the electrical sector, the quality of their systems is extremely important, since the electrical sector works in an interconnected way, in which the occurrence of problems in a generating unit interferes in the transmission system and, consequently, in the final customer. This work aims to use FMEA (Failure Mode Analysis and Effects), as a tool to analyze the occurrence of faults and increase the reliability of a system in a thermoelectric plant. The system chosen in the thermoelectric power plant for the execution of the FMEA is the fire protection of the Turbo-Generator. The methodology used in the development of this work is the formation of a multidepartmental team for brainstorming, mapping the causes and effects of failures; use of building tools and analytics of the FMEA, the results were efficient in the day to day being important in the cognitive aspect to the entrepreneurs and employees.***

Keywords — Turbo Generator. FMEA. Thermoelectric.

I. INTRODUCTION

The studies were developed in a Thermoelectric Plant, applying a case study in one of its systems. Electric power generation is the final product, but the availability for generation without the occurrence of failures is the main focus of the operation and integration of the power plant throughout the electrical system.

A Análise dos Modos de Falhas e Efeitos (FMEA) surgiu em meados dos anos 60 pela NASA, posteriormente, teve uma ampla divulgação nas indústrias aeronáuticas por volta dos anos 70. Esta ferramenta passou a ser utilizada na indústria automobilística na década de 80, ampliando-se para seus fornecedores na indústria de autopeças. A norma americana QS 9000, por exemplo, desenvolvida pelas grandes montadoras nos Estados Unidos, Ford, Chrysler e GM, especifica o FMEA como técnica de análise e prevenção de falhas (ALVES; COSTA, 2004).

According to Hellman and Andery (1995), FMEA efficiently assists in the search for the primary causes of the problems, aiming to eliminate the causes with the

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elaboration of action plans. Using a set of criteria to prioritize managerial actions in problem solving.

For Palady (2007) the FMEA is a technique that offers three distinct functions: it is a tool for predicting problems; is a procedure for developing and executing new or revised projects, processes or services; is a diary of the project, process or service.

The use of this tool will reduce the chances of the product or process to fail during its operation, that is, it is seeking to increase reliability, which is the probability of failure of the product / process (ALMEIDA, 1998) .

Arthur and Silva (2005) contribute by defining reliability as "the ability of a product to perform its function without failure under specified conditions for a specified period of time or minimum number of cycles or events." Carvalho (2005) adds the previously mentioned concepts and conceptualizes reliability as a related characteristic by the probability that the product performs an expected function, between a time interval and under conditions of use for which it was created. It is usually represented based on average parameters of failure numbers or the time interval between failures.

This article aims to apply a quality tool that improves the level of reliability in the fire fighting system in a gas turbine, reducing the equivalent rate of forced unavailability in the Thermoelectric Power Plant in Macaé / RJ. The following are some comments on quality management, FMEA (Fault Effect Mode) and thermoelectric. Finally, the application performed in the study company is presented, followed by the final considerations.

II. THE EVOLUTION OF QUALITY IMPROVEMENT

The quality can be observed from the beginning of the manufacturing activities, when the production was totally handmade where the masters-craftsmen used the observation as an instrument of quality control, aiming at avoiding failures in the manufacturing process (ADAM, FOSTER, 2000).

A World War II had a major influence on quality during the 1940s, as the volume of products was larger and the time available for inspection in the process was smaller, thus consolidating statistical control by sampling (GARVIN, 1992).

In the postwar period, since the mid-twentieth century, there has been a major evolution in business management, especially in Japan, motivated by the recovery of its economy. Four basic elements have been developed in the process of quality evolution: Quantification of Quality Costs, Total Quality Control, Reliability Engineering and Zero-Defect Program. Thus begins the Age of Quality Assurance. (GARVIN, 1992; IRVINE, 2000).

Still in the 50s, Armand Feigenbaum presented a more advanced concept, Total Quality Control. The quality was part of the whole productive chain, seen as a competitive strategy (Nilsson et al., 2005; Mizuno et al., 1993).

The application of quality programs gave rise to ISO certifications, which incorporate rigorous parameters of evaluation of organizational performance, evaluating the conformities determined by the organization, through internal processes such as procedures, standards and norms.

Thus ISO 9000 was used as a qualifying criterion in the case of supplier selection, thus eliminating the need for large contingents of auditors, using the certifications and audits of third parties accredited for this purpose. In this context several quality tools were developed among them the FMEA.

III. ANALYSIS OF FAILURE MODES AND EFFECTS (FMEA)

The national electric sector, increasingly, has been seeking availability of generation of its electric power generating units; and thus, it is necessary to use efficient tools in the minimization of failures (BRAGLIA, MAFMA, 2000).

The FMEA is an engineering technique used to define, identify and eliminate known or potential failures of systems, projects, processes and / or services (STAMATIS, 2003, CARBONE & TIPPETT, 2004).

According to Palady (2007), FMEA, when used as a tool, is a low-risk, high-efficiency technique for problem prevention and identification of the most cost-effective solutions.

This tool is very successful when its application is carried out in a team, because the best evaluations are drawn from a set of ideas. The advantages and disadvantages of each approach can be estimated by relating the cost and benefit associated with each one.

The development of the FMEA performed by a team has its higher costs if compared to one developed individually; however, the chances of better identification and prevention of failure modes when developed by a team are higher, and the quality / reliability return exceeds the FMEA development and maintenance costs (COTNAREANU, 1999; FERNANDES, 2005).

FMEA is considered a proactive tool because it analyzes potential problems before they even occur without the need to create prototypes or wait for the problem to occur during their operation; due to this subjectivity, this method requires a presumptive work in relation to possibilities and their prevention, using the practical experiences accumulated by specialists in the projects, processes or services. In this context, according to Gilchrist (1994) and Magalhães (2008), since the

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development of the FMEA in the mid-1960s, two modalities derived from this method emerged.

- Project FMEA
- Process FMEA

There are five basic elements that should compose the structure of the FMEA, the lack of any of these elements may impair its effectiveness or its success, in terms of quality / reliability, the results can be minimal or zero. The basic elements of FMEA are shown in Figure 1 (GILCHRIST, 1994):

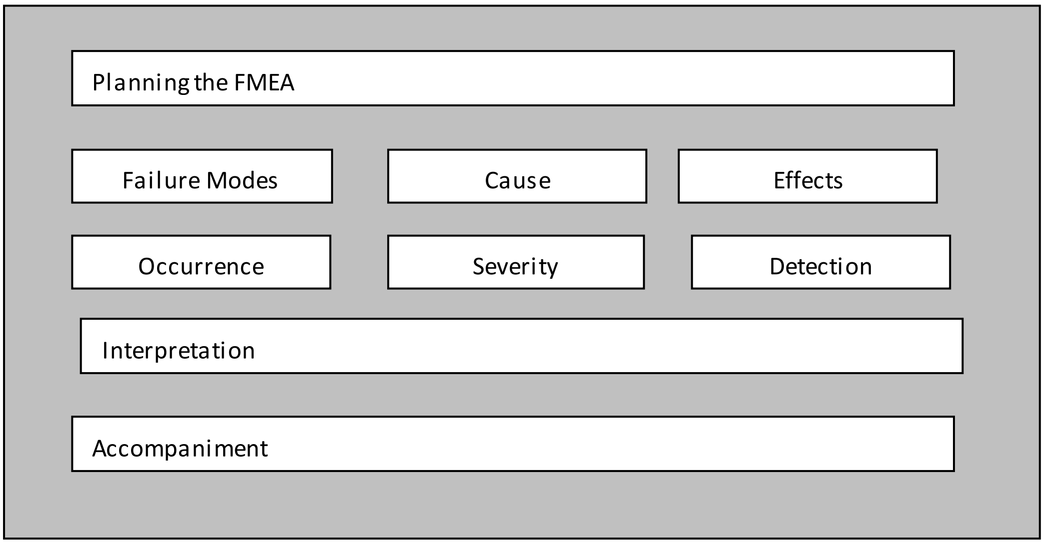

Fig. 1: Basic Elements of the FMEA. Source: Adapted from Palady, 2007

After defining the functions that produce the products / processes are classified and listed their causes and their effects (PUENTE et al., 2002). The next process is to create a scheme to identify the most important failure modes, quantifying and classifying each of the three categories, as shown in Figure 2.

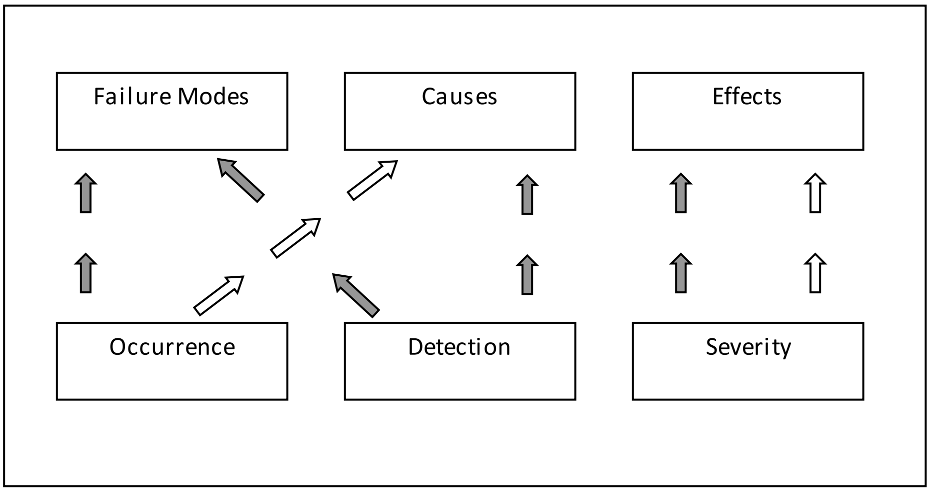

Fig.2: Approach Failure Modes. Source: Adapted from Palady, 2007

IV. THE CONTEXT OF THERMELECTRIC PLANTS IN BRAZIL

The generation of electric energy in Brazil has in its history a differentiated way in the use of its energy sources in relation to the world average. Brazil uses its large water park to generate electricity, while the world average has used its dependence on fossil energy sources (MOREIRA, 2002, ONS, 2002).

The government, anticipating the growth of electricity demand, created the Priority Thermoelectricity Program in 2000, encouraging the implementation of thermoelectric plants in the country, thus increasing the importance of thermoelectric plants in the Brazilian energy matrix (MOREIRA, 2005; SEGISMUNDO, 2008).

In 2001, at the height of the Brazilian energy crisis, thermoelectric plants were built as an emergency because it was a short-term venture compared to the construction of a hydroelectric plant. Figure 3 shows the increase in power generation in Brazil in the years 2007 and 2008, given the growth of the Brazilian productive sectors and the compensation of the levels of the reservoirs.

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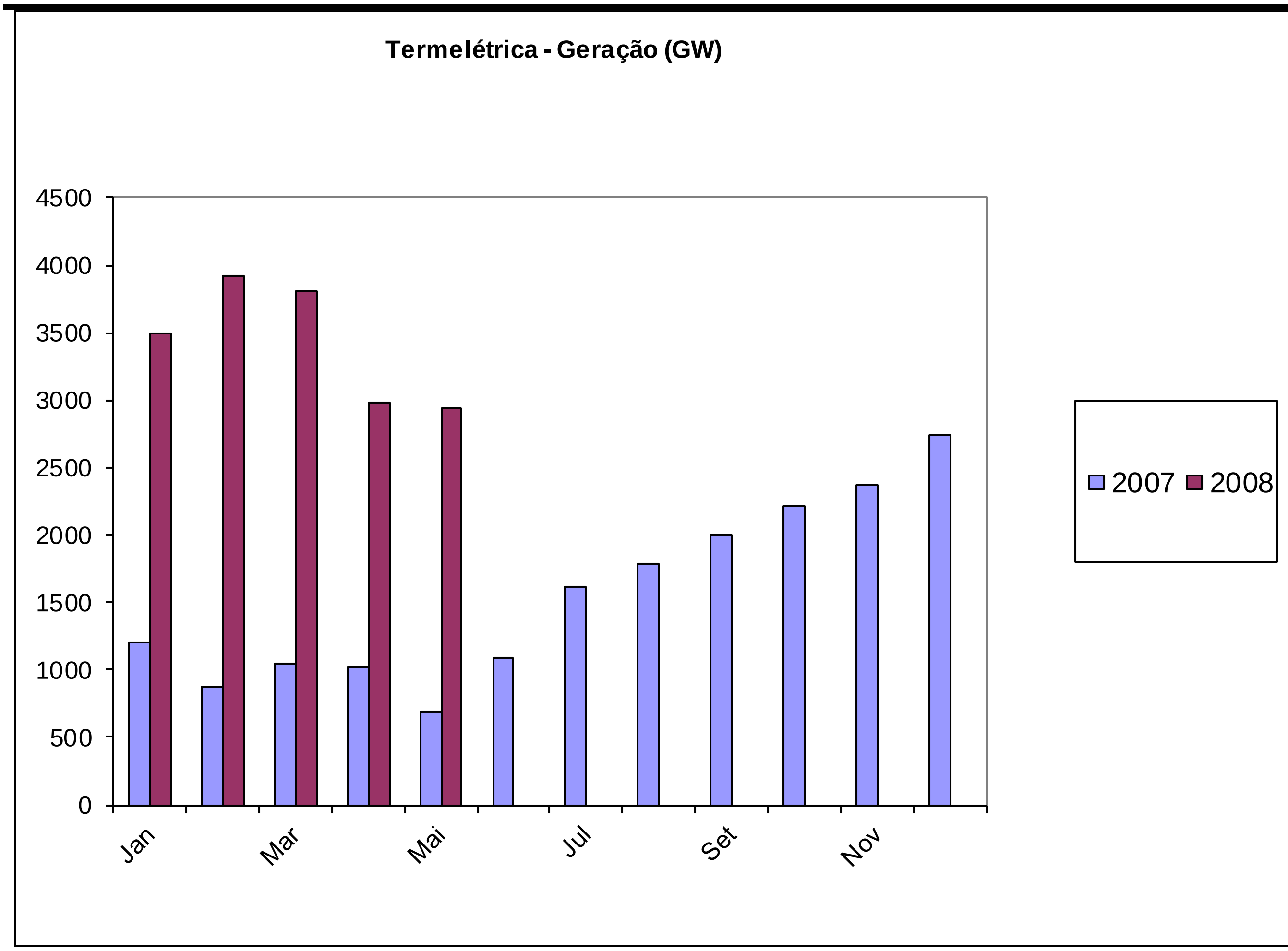

Fig. 3: Electric Generation (GW). Source: National Operator of the Electric System - ONS / 2008

In thermoelectric plants, thermal machines are used to generate electricity, transforming thermal energy into work, the fuel used comes from different sources such as natural gas, diesel oil, sugarcane bagasse, coal, etc. The machines can be grouped according to the type of combustion: internal combustion (engines and gas turbine) or external combustion (steam turbine) (MOREIRA, 2005).

Another type of turbine used in thermoelectric plants is the steam turbine, which has the function of transforming the expansion of the steam produced in the boilers and generate work, as shown in Figure 4. Below are some types of steam turbines (MOREIRA, 2005):

- Back Pressure - The steam after expanding into the turbine is destined for some other process or released into the atmosphere. It is the simplest turbine and is mainly used in cogeneration circuits.
- Extraction-Backpressure - When processes downstream of the turbine operate at more than one pressure level, turbines with steam extraction are used. There are systems with controlled extractions (control valves) and others where the extraction flow is a function of the flow conditions in the turbine and process pressures.
- Extraction-Condensation - The steam after leaving the turbine yields heat in a condenser, changing phases and being pumped again to the boiler. The turbine may have steam extraction for process. In this system, the flexibility of operation is much greater and the capacitor absorbs the variation of load either in the demand for electric energy or in the demand of steam for process.

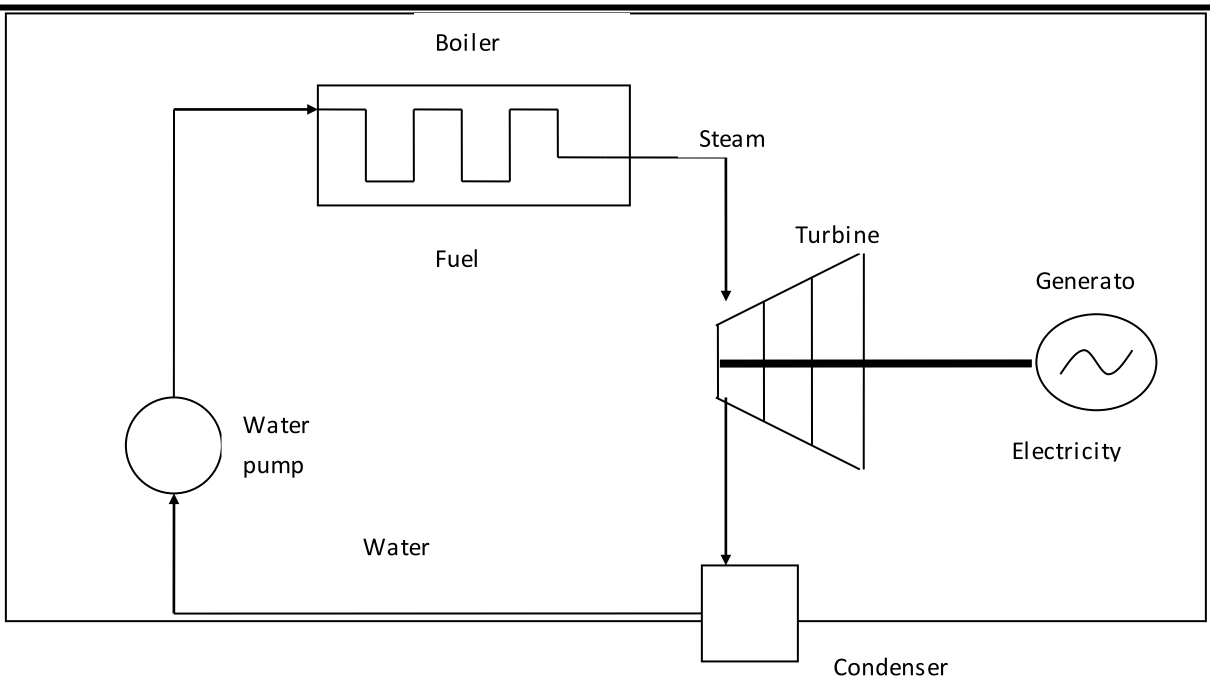

Fig. 4: Simplified scheme - Steam turbine. Source: MONTICELLI, A. & GARCIA, 2003

The turbo-generator's fire protection system is also composed of a combustible gas detection system. This system has three sensor / transmitter assemblies, the sensors being located inside the turbine compartment, while the transmitters are on the outside. There are two levels of gas detection alarm, one with 20% LEL (Lower Explosive Limit) and another 60% LEL, the lowest level (20%) is responsible for alerting the existence of gas and the performance of 60% presence of gas is responsible for the automatic stop of the turbo-generator, with the activation of the exhaust fans to remove the gases.

The existing protection systems in the plant have been designed and calculated according to National Fire Protection Association (NFPA) standards and codes.

Figure 5 illustrates the location and number of sensors that make up the turbine and generator fire protection system

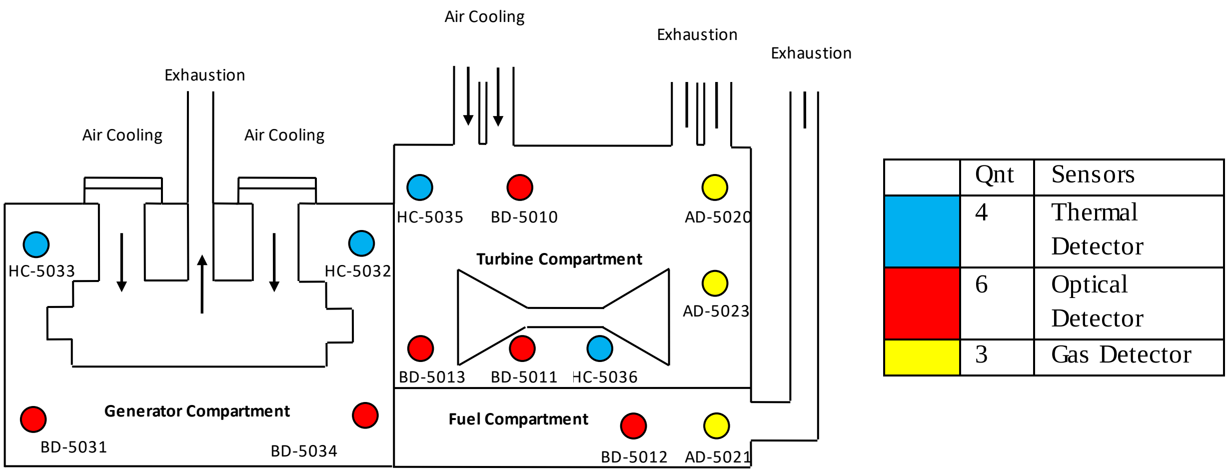

Fig. 5: Sensor distribution in the Turbo-Generator compartments. Source: MONTICELLI, A. & GARCIA, 2003.

V. FMEA ANALYSIS AND APPLICATION IN THERMOELECTRIC

The FMEA construction team from the block diagram, as shown in Figure 6, can separate the protection system into three parts, so the understanding becomes standardized.

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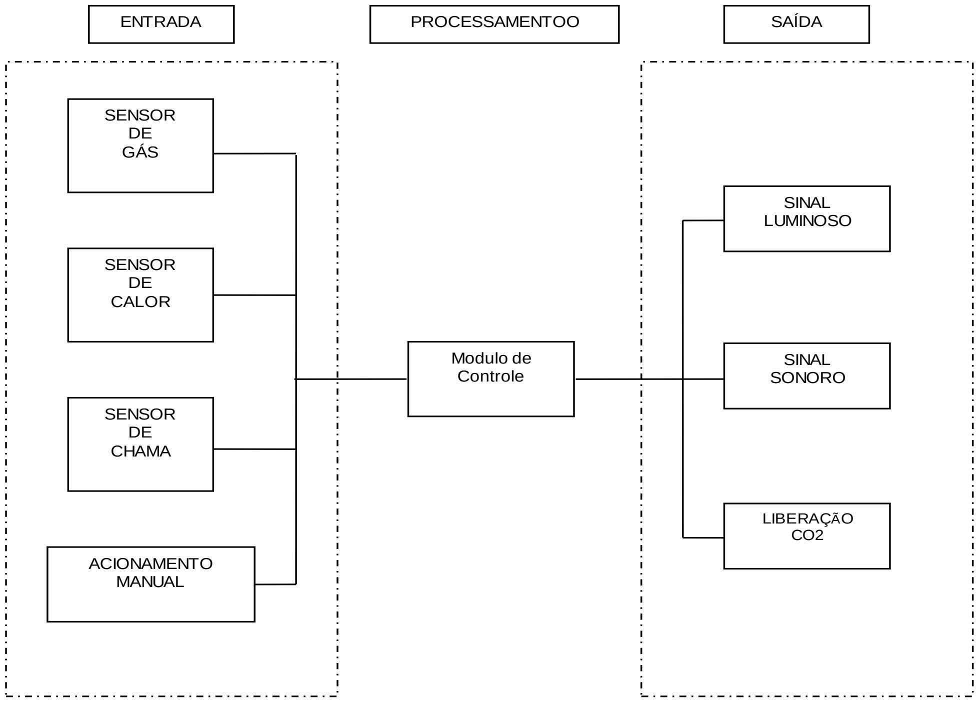

Fig. 6: Block diagram of the fire protection system. Source: MONTICELLI, A. & GARCIA, 2003.

The first brainstorm is performed according to input components, classifying their failure modes and their effects, evaluating severity and detection. The cause of the fault is identified using another tool: Ishikwa Diagram. As for the occurrence, the team uses historical data related to the amounts of failures that occurred in that system. As results of this work, they follow the FMEA frameworks of each component of the fire protection system.

The team chosen to develop this FMEA, is composed of four members, in order to obtain maximum use with the exchange of experience of these professionals. The team was formed by (Stashevskiy, Elizur, 2000):

- 01 Electrical Engineer
- 01 Production Engineer
- 01 Operator
- 02 Maintenance Technicians

When surveying the documentation of the fire protection system, it was defined that the system would be divided into subsystems and its components would be treated in FMEA for their functionality. For a better understanding of the functionality of the subsystems and their components, a block diagram was constructed, as shown in Figure 7 (FMEA-Sensor) and 8 (FMEA-Strobe Light):

Planilha: Análise de Falhas - FMEA	**Processo**: Proteção contra incêndio do turbo-gerador – UG01 **Sistema:** Detecção de Gás. **Equipamento:** Sensor de Gás							**Planilha N°:** 01 **Revisão:** 0		**Coordenador:** Gilson **Equipe:**		**Data:** 28/10/08 **Folha:** 1/1
Descrição do Item: O sistema de detecção de gás é composto por três sensores, sendo dois sensores localizados no compartimento da turbina e um no compartimento de combustível. O sinal dos sensores é enviado aos transmissores, que são responsáveis por transmitir os sinais ao controlador. Ao se detectar a presença de gás ao nível maior que 60% de concentração, o controlador envia um sinal de desligamento da UG (unidade geradora).												
Ítem	**Função**	**Modo de Falha**	**Efeito da Falha**	**Causa da Falha**	**SEV**	**OCO**	**DET**	**RPN**	**Ações Recomendadas**	**RESP**	**FREQ. DA TAREFA**	**PRAZO**
AD-5020 - Sensor de Gás	Medir a concentração de gás a nível de 0% a 100%	Saturação do elemento sensor	1-Falha no sistema 2-Erro na medição	1- Vapor de óleo 2- Poeira 3-Perda de sensibilidade natural	6 6 6	4 2 5	5 5 5	120 60 150	• Limpeza do compartimento, sempre que houver vazamento de óleo. • Calibração do sensor.	Operação Manutenção	Ocasional 45 dias	Imediato 30 dias
		Queima da unidade eletrônica	1-Falha no sistema 2- Indisponibiliza a UG.	1- Baixa isolação. a) vapor de óleo	7	3	5	105	• Limpeza do compartimento, sempre que houver vazamento de óleo.	Operação	Ocasional	Imediato

Fig. 7: FMEA – Gas Sensor

Planilha: Análise de Falhas - FMEA	**Processo**: Proteção contra incêndio do turbo-gerador – UG01 **Sistema:** Sinalização luminosa. **Equipamento:** Strobe Light.							**Planilha N°:** 06 **Revisão:** 0		**Coordenador:** Gilson **Equipe:**		**Data:** 28/10/08 **Folha:** 1/1
Descrição do Item: Quando existe uma condição de alarme no sistema de proteção contra incêndio, é acionado um aviso luminoso, onde a strobe emite luz da cor vermelha, indicando uma emergência no local.												
Ítem	**Função**	**Modo de Falha**	**Efeito da Falha**	**Causa da Falha**	**SEV**	**OCO**	**DET**	**RPN**	**Ações Recomendadas**	**RESP**	**FREQ. DA TAREFA**	**PRAZO**
XL-5128 – Strobe Light	Sinal luminoso quando se há presença de alarme no sistema de incêndio.	Queima da lâmpada	1- perda da sinalização luminosa durante uma condição de alarme. 2- Sinal de alarme no módulo de controle, indisponibilizando o sistema.	1- Baixa isolação. a) alta umidade 2- Vida útil da lâmpada.	4 7	2 3	5 5	40 105	Desenvolver plano de manutenção preventiva.	Manutenção	180 dias	30 dias

Fig. 8: FMEA – Strobe Light.

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Legend figures 7 and 8:

SEV:	Severity
OCO:	Occurrence
DET:	Detection
RPN:	Risk Priority Index

The analysis of Figures 7 and 8 demonstrates the need for implementation of new safety systems and critical improvements in the plant system.

VI. FINAL CONSIDERATIONS

The electric sector is composed of several systems such as generation, transmission and distribution. The study focused on the generation system and presented a case study to a specific system, which was the fire protection system of a turbine. For electricity generation companies, the work is contributing to reduce their costs, mapping the failures of their systems making them more reliable, thus avoiding fines for high forced unavailability rate - TEIF, index used by the National Agency of Electric Energy - ANEEL, which measures the reliability of Generating Plants. For academic training, the work has immeasurable contributions, as it is a result of evolving knowledge, is the use of Production Engineering to the common welfare, contributing to the improvement of electric energy generation and not only the reduction of costs and maximization of profits. The recommendations documented in the FMEA are in the process of being implemented, so a comparative evaluation with historical data is impossible. The results do not depend only on a comparative assessment, since some benefits can be perceived immediately. The faults were mapped, and the treatments were presented; factors that positively influence the increase in reliability.

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