METHOD OF DETERMINATION OF CRITICAL COMPONENTS OF POWER GENERATION SYSTEMS

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Abstract. *This paper shows the development of a methodology for determining the most critical components in systems for generating electrical energy, such as the diesel thermoelectric power plant, identifying, analyzing, systematizing, classifying, standardizing and parameterized, each component of the systems and subsystems of generation, so that it can adjust the program of maintenance of such systems generation. This study was motivated by the need to identify critical points in existing systems to generate electricity, treated by thermoelectric power plants, especially those in the system isolated from the north and northeast Brazil and, consequently, increase the operational reliability of generating units, aiming to reduce the overall costs of operation and maintenance. This is one of the topics of a more comprehensive management approach called "Cycle Routines for Improvement of Process Systems and Power Generation", which aims at the development and implementation of a systematic management and planning of maintenance activities, operation, monitoring and diagnosis of the generating units of thermoelectric power plants. This methodology is used some tools of artificial intelligence as fuzzy logic (for correlation between the components of the system and aid in decision making), genetic algorithms (for the identification and classification of components of systems and subsystems), neural networks (for development of prognostic behavior of elements of the system), including also the calculation of uncertainty and standard deviation of the quantities, by suggestion of some indicators of efficiency of effectiveness and continuity of services for power generation, with the objective to achieve the lifting of the operating conditions of power plants, through their diagnoses and prognoses, which will provide the control, supervision and improvement of operating conditions of plants, together with the operational reliability of the system.*

Key words: *generation of energy; maintenance and operation; managerial tools; logic Fuzzy; artificial intelligence;*

1. INTRODUCTION

The State of Pará, located in northern Brazil, is currently composed of 143 municipalities. Of these 38 villages are served by thermoelectric power plants to diesel – UTEs in isolated systems. Existing municipalities with their head offices linked to the national electricity system; however there are still places without care for electric power. The concessionaire of the state is responsible for the generation of energy, with a total of 165 generating units – UDGs.

In UTEs that meet in public service places is necessary to reduce the costs of the generation of electricity, making power plants more efficient. This involves the effective control of all operating parameters of power generation, as the fuel consumption of UDGs, prevention and investigation of failures in system and equipment, etc.., until the planning of maintenance in UDGs. That task must be performed considering that the degradation of the performance of those components is causing an increase in the consumption of parts necessary to keep a plant operating, such as fuel, the filters, lubricant oil, among others, to produce the same amount of electricity than a system in perfect condition. Moreover, maintenance is a cost, due to the intervention, which according Jelen, (1983), in thermoelectric power plants on average close to 5% of the investment cost of the system per year.

A diagnosis of an effective system in a generation should allow the installation of individual management of the causes of failure of operation, so the reduction in performance can be detected and located and corrected the anomalies. Thus, any intervention is more precise, thus avoiding the practice of corrective maintenance not scheduled.

The control of information from the generation of energy leads to significant economic, because it facilitates the assessment of the costs of possible corrective actions not planned, or emergency in thermoelectric power plants, allowing the identification of components and/or systems responsible for loss of income or causing of failures in UDGs. As a result of the control, the UTEs now have an economy with the reduction of fuel consumption of plants. Besides the knowledge of actual operating conditions of the generating sets, together with the cost of maintenance, will be defined the parameters to decide when to intervene in a generating unit.

This study proposes a methodology for the detection of anomalies or deficiencies of group responsible for the loss of efficiency of a generation, or will be exposed a methodology for determining the criticality of a system of generation, than the method in UDGs UTEs of using diesel or biodiesel as fuel.

2. CYCLE ROUTINE FOR IMPROVEMENT OF SYSTEMS OF ELECTRICAL POWER GENERATION

The cycle of routines was developed a methodology for obtaining of the database for the application in systems of electric power generation being used some tools of artificial intelligence, besides managerial and administrative elements, as Reliability Centred – RCM, the methods of administration of systems and processes, as 5S, TPM, six sigma, etc., besides the reliability engineering. (Santos, E. C., 2006)

The basic functionality of the cycle is the identification, attendance, control, evaluation and treatment of the: tasks and planned activities; of operations and maintenance of the systems and processes and use of the resources (personal, materials and financial), inside of the objectives and goals defined by the company.

All of the elements of the cycle seek objectives and general goals of the organization as:

- Definition of the operational goals of the process found in the objectives and purposes of the company;
- Monitoring and reduction of rates or operating parameters identified and stipulated in the systems or processes;
- Reduction of operational costs and of maintenance of each system and subsystem;
- Increased operational reliability;
- Adoption of indexes and parameters to monitor and optimization of the processes or systems of the organization;

The Figure 1 shows a schematic drawing of the cycle, with their respective tasks and activities:

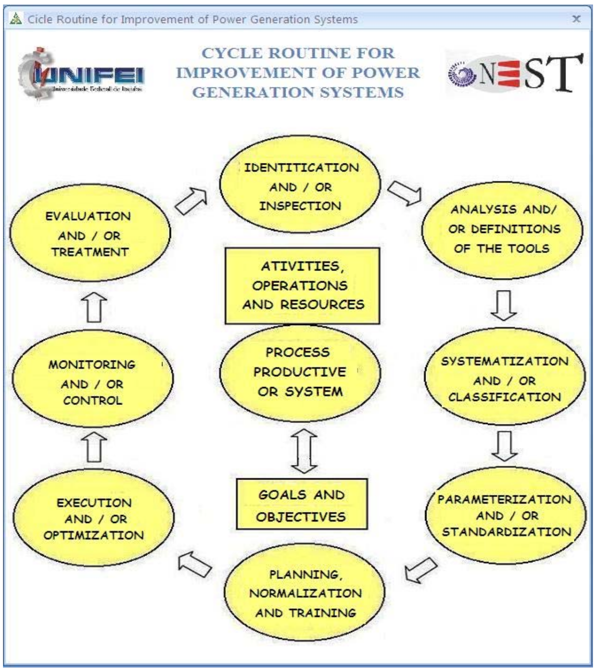

Figure 1. Initial Screen of the application Cycle of Routines.

Besides the general objectives the cycle has specific objectives, to know:

- To supply the full knowledge of the productive process or systems to be gotten better;
- Monitoring the development of processes and systems for providing the company:
  - Identify current and future needs and the criticality of the process in existing firms and new needs;
  - To determine of indicators and comparison parameters and analysis;
  - To promote a change of the administration culture, maintenance and operation with the mentality formation for-active of the employees with the use of the maintenance engineering;
  - Systematize and sort of systems and subsystems of the organization and equipment, with its peripheral;
  - To define the operational parameters and their procedures and norms of the process indicating, after tests, the great conditions of operation of the systems;
  - To standardize of the activities and elements in the development of the tasks gone back to the maintenance of equipments and consequent reduction of costs of the process;
  - Plan interventions (inspections and reviews) in machinery and equipment by reducing operating costs;
  - Promote continuous training of officials of the company by increasing the operational reliability of the process;
  - To optimize the productive process of the organization or system;
  - To know the critical points of the systems and processes so that it is possible treat them;

2.1. General Characteristics of the Cycle of Routines

It can be noticed in Figure 1, for all involved those in the processes, the general objectives and goals of the productive process or of the system, for each task and/or activity, where they will be defined the activities, the operations, the resources and the evaluation forms for the development of the cycle;

The cycle should have his beginning in the second semester of every year, with the first four tasks, in order to serve as reference and base of data, to facilitate the elaboration and to participate in the financial planning of the organization for the following year. That is an important moment in the formatting of the database to be created;

The beginning of the tasks raisin for the registrations means of communication of the company (internal newspapers, bulletin boards, e-mails, etc.), of the period implantation of the cycle and the names of the team of the members of the implantation teams and development of the activities of the method; (Moraes, P. H. A., 2004)

2.2. Activities of the Cycle of Routines

According to Figure 1, Table 1 shows a summary of tasks and activities of the cycle of routines:

Table 1. Tasks and activities of the cycle of routines.

Tasks / Activities	Description
Identification and/or inspection	To identify the needs, deficiencies and/or occurrences in the process, in a continuous way for projects in operation and new projects, problems to be corrected, frequent types of flaws, components of the subsystems that present critical levels of wear and tear, of improvement of procedures, environmental conditions, etc. In this activity it should be looked for to know all of the internal and external processes to the company for the development of the current process.
Analysis and/or definition of the tools	Make the analysis of needs to verify all aspects involved in the same solution, defining the management tools (software) to be used in each subsystem of the process.
Systemization and/or classification	Using the principles of business and administrative systems and takes place in the division of the enterprise systems and subsystems. Deploy to operational coding and classification of all components in order to identify them as items of maintenance. (Santos, E. C., 2007).
Parameterization and/or standardization	The analysis of the operation conditions and the obtaining of the operational parameters of the equipments that it composes a system, through reception tests, they are objects of that task, following by the study of standardization of components and consumable elements of the same ones, seeking the reduction of the costs and standardization of the maintenance.
Planning, normalization and training	This step is made the settings and details of activities to be implemented to achieve the objectives and goals of the company. Plans are drawn up in the activities, the physical and financial schedules, standards and operational procedures.
Execution and/or optimization	These activities have the goal of processing the plan developed and studied in fact, running it with efficiency and effectiveness, when evaluating all canonicals which can contribute to the evaluation or improvement of the process.
Monitoring and/or control	This phase must have its beginning before the end of the previous phase of the cycle and having as objective to verify if the implementation/optimization is done efficiently and effectively in the planning, or if the activities are making in developing the objectives and established goals.
Evaluation and/or treatment	Along with the assessments of the productive process and the efficiency of the cycle of routines is made of the risks of the treatment process, to form ballast information about the potential loss of generating units and damage likely to occur in the system of generation. Facilitating celebrção of contract of insurance of the equipment. (Brindest, A., 2004).

Source: System Cycle, (2008).

3. APPLICATION OF THE CYCLE IN THE NORTH AREA OF BRAZIL

The use of the cycle of routines in 15 UTEs the concessionaire Pará started the second half of 2002 with the participation of the team's maintenance CELPA. The other power plants are the state is the control is outsourced to other companies. The initial work was the removal of the operating conditions of UDGs and records of the information distributed in the following technical tasks and activities:

3.1. Identification and/or Inspection

Considering that the generation of power plants in the CELPA, is a public service by 24:00 hours, one of the events identified as critical, and should be treated, was the total number of outage in UTEs.

For outages of energy monitoring began in 2003, which were recorded all kinds of interruptions of the system, may be all or part of the mill, lasting more than three minutes, including the reclosers on feeders and the plants, the planned maintenance, weather, among others. This period was an initial target of up to three outages per year at each UTE.

Requirement by the National Agency of Electric Energy - ANEEL was created a system that all outages that occur in plants of the state should have passed your information on a daily basis for the operation department of the concessionaire, which sector is responsible for data processing and transfer of information to regulatory agencies. Thus it was possible to follow up the causes of anomalies and the creation of the knowledge base of the cycle of routines. The Figure 2 shows the monitoring of the outage occurred in UTEs system alone in the period 2003 to 2008 emphasizing the participation of companies generating.

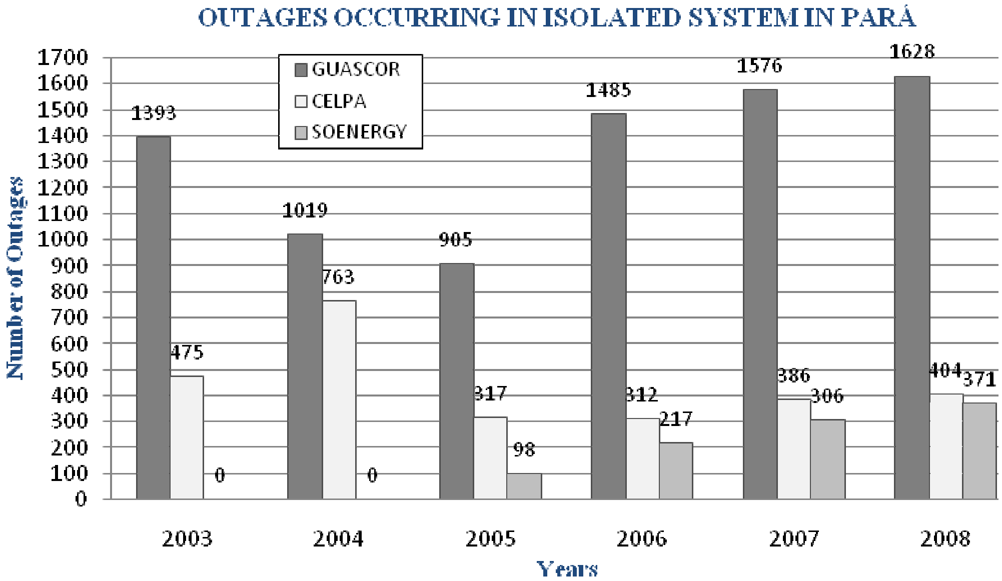

Figure 2. Outages occurred in the isolated system of the State of Pará in the period 2003 to 2008.

Apart from issues relating to disconnections, the use of the cycle in UTEs also identified other problems, such as:

- High specific consumption of UDGs;
- Diversity of consumable elements;
- Lack of training of the operators and of the maintenance team;

3.2. Analysis and/or definition of the tools

The adopted managerial tool was the Integrated System of Maintenance - SIM, application of maintenance administration used by CELPA for control service orders (opening and closing) and as database of the maintenance items; however there were the adaptation need and configuration of the information gotten up so that the application could be used for the electric power generation.

The goal line to the deployment cycle CELPA was in the reduction and control of outages occurred in UTEs the concessionaire, and, in absolute numbers, interventions to average below three monthly outages per plant in 2007 because it is a dynamic system interruptions may occur with outages scheduled for maintenance, etc.

3.3. Systemization and/or classification

Each element that composes UDGs received an operational genetic code so that it was possible identifies it in the system in a faster and efficient way and without duplicities. Those codes had as example: 01.11.02.01.03.02.100, that it represents the type of generation of energy 01, the generation place codified with the number 11, a generating unit in the base 02, a component of the generation system codified as 01, a generation system codified as 03, a subsystem generation codified as 02 and an element of a subsystem of code 100.

As each element of the coding system received a value of the classification of initial criticality – $\boldsymbol{C_{EQ}}$ to facilitate its monitoring when in operation. This value was adjusted as to obtain the history of the operation of generating sets, with its value ranging between 01 and 10, as Table 2.

Based on all the historical causes of anomalies were grouped into major categories and/or representative, such as: Fuel system; Power system; Cooling system; System of admission of air; Lubrication system, Ventilation system air; System of departure or electric; System protection; System of regulation of speed, damage to the generator; The system framework of controls or panel of control – QCM; Processing system (the plant substation); Unavailability of generation; Failed operation (operations and timing); Storms / animals at the substation; Scheduled maintenance; Ignored and cause; Failure in the stability/failure urban distribution network;

Table 2. Classification of the critical elements of the system.

C_{EQ}	Description
10	Very critical element, the system **stops** for a long time (more than one month) if he is not working properly and rely on scheduled or corrective maintenance to restore its;
9	Very critical element, the system **stops** for a long time (more than two weeks) if he is not working properly and rely on scheduled or corrective maintenance to restore its;
8	Very critical element, the system **stops** for a long time (more than a week) if he is not working properly and maintenance is scheduled for its restoration;
7	Very critical element, the system **stops** for a long time (more than three days) it is not working properly and corrective maintenance is scheduled for its restoration;
6	Very critical element, the system **stops** for a mean time (more than one day) it is not working properly and corrective maintenance is not scheduled for its restoration;
5	Critical element, the system **stops** for a mean time (more than twelve hours) it is not working properly and corrective maintenance is not scheduled for its restoration;
4	Critical element, the system **stops** for a time average (over four hours) it is not working properly and corrective maintenance is not scheduled for its restoration;
3	Necessary, the system **stops** for a short time (more than an hour) it is not working properly and corrective maintenance is not scheduled for its restoration;
2	Necessary, the system **does not stops**, or is operating with restrictions, for a few days until the scheduled corrective maintenance performed with replacement component;
1	Necessary, the system **does not stop**, or is operating with restrictions, for a few hours until it is held on scheduled or corrective maintenance that there is a shutdown for the replacement component;

Source: Santos, E. C., (2004).

3.4. Parameterization and/or Standardization

In function of the characteristics of the generating groups of the plants and of their operational conditions and of the regional distances of the state, tests of reception of machines were accomplished where parameters were created and defined the operational strips of each UDG and the frequency limits, of potency factor, of tension and of generation current and of distribution.

In this same accomplished task the standardization of the following items:

- In the communication ways and of the types of information and documents to be reviewed for the team of maintenance of the generation;
- Plans of maintenance of UDG's, defining the accomplishment of the maintenance per hours for types of same manufacturer's machines and load classification;
- It was created the plan of maintenance of electric generators, picture of commands and transformers, with their respective procedures of inspections; Periodicity of change of the consumable elements;
- Basic listings for revisions of generating groups;

With the increase of period of use and standardization of the periodicities of changes of the consumable elements, was possible to the reduction of the operational costs, as shown in the Table 3, that it shows the reduction of costs with several filters, addictive for radiator and lubricating oil and being compared the periodicities and costs of the elements in the year of 2007.

Table 3. Reduction of cost of the consumable elements of the plants.

Elements	2002		2007		Difference X R$ 1000
	Unit (*)	Cost Annual R$ X 1000	Unit (*)	Cost Annual R$ X 1000	
Filters	7827	2.978,71	4390	1.006,66	1.972,05
Addictive for radiator (l) (**)	1521	29,70	254	1,392	28,308
Lubricating oil (drums)	658	614,70	278	312,42	302,28

(*) The units are the numbers of filters used in the motors and of drums of 200 liters of lubricating oil.
(* *) The addictive for radiator was used in the system of cooling of the motors in substitution to the filters of water, which were eliminated of UDG's;
Source: System Cycle, (2008).

In the Table 3 a comparison was accomplished being adopted the unitary current values, in 2007 of each consumable element, and, a medium operation of 8:00 hours daily rates was considered for the motors of small load of 12:00 hours for the one of medium load and 16:00 hours for the one of great load.

As a result of the process of determination of parameters and standardization was had significant reduction of the maintenance cost in elapsing of the years from 2002 to 2007, according to the Table 4.

Table 4. Cost medium of the maintenance of UDGs.

COST MEDIUM OF THE MAINTENANCE OF GENERATING UNITS R$ X 1.000,00						
UDGs	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Small Load	78,5	65,0	53,0	46,8	45,0	39,5
Medium Load	210,	150,	130,0	120,0	105,0	91,8

Source: System Cycle, (2007).

The reduction is due the standardization of the listings of materials used in the inspections and maintenances, general and partial and the use of specialized companies in the recovery of the components of the motors in the services accomplished in the general and partial revisions of the elements of UDG.

With the determination of the parameters and standardization was possible the development of study aids, norms and procedures, for training of plant operators and of technicians of the maintenance, as teaching form, popularization and the people's technical formation involved with the generation of energy.

3.5. Planning, normalization and training

In the period from 2002 to 2004 trainings were accomplished destined to personnel's formation to work with the operation of the thermoelectric power plants. Parallel they were developed and approved for the technical management CELPA some norms and procedures for the maintenance and operation of the UTEs, especially of the norms regarding the preservation of the environment, developed together with the accessory of environment of CELPA.

3.6. Execution and/or optimization

The implementation of the planning cycle occurred in the years 2004 to 2005 when it was actually possible to complete the first turn of the method. In 2006 activities were concentrated on the actions of the system monitoring and optimization of the elements of the system generation.

Despite all efforts to reduce the outrages, including the use of SIM in UTEs, the great difficulty in obtaining accurate information on the causes of outages was the major problem to be solved, because the lack of communication or the deficiency in communication between the engineering and maintenance of the operators was a major barrier to be overcome, because in many cases the operators had no knowledge to the causes of deficiencies identified and are dependent on the technical maintenance for identification. To remedy this deficiency were developed and implemented several operational procedures which were part of the handouts for the training of power plant operators.

3.7. Monitoring and/or Control

For monitoring and control of outages occurred in the isolated in Pará were certain critical components of each system of generation - C_{COMP}, through the composition of the criticality of each individual element, consisting of:

- Operational criticality of the equipment – C_{EQ};
- Criticality equivalent period of time – $C_{QETEMPO}$;
- Criticality of the element in the system – C_{ES};

The criticality of the operational equipment is intended to relate the possible deviations from the operating condition of the equipment in the generator set, considering and quantifying the importance of the element in the system which he is part. The criticality of the second term relates the level of use of the element within the stipulated schedule of maintenance for the system, emphasizing the life of the component and the third item of criticality search show the influence of the malfunction of the element in the system, building on the indicators of productivity system generation.

According to Lora (2004), Santos (2004) and Conde (2007), as well as in the case of steam turbines, the engines of the diesel thermoelectric plants, the specific consumption of fuel expressed in performance or efficiency of a UTE and may be individual or aggregate the plant. The specific consumption of a generating unit – $\boldsymbol{C_{ESP}}$ is calculated by the relationship between the consumption of fuel daily or monthly – $\boldsymbol{C_C}$, obtained by the difference of levels in the tank and/or storage of the plant or by flow meters installed on the lines of feeding and return of fuel oil, the average energy generated by the group generator – $\boldsymbol{E_G}$, as shown in Equations (1).

$$C_{ESP} = \frac{C_C}{E_G} \text{ and } C_{ESPO} = \frac{C_{CO}}{P_N \cdot t_A} \qquad (1)$$

To compare the operating performance is used to operating conditions the value of the specific good – $\boldsymbol{C_{ESPO}}$, which is the ratio between the quantity of fuel to the conditions of maximum efficiency, i.e. fuel consumption great – $\boldsymbol{C_{CO}}$, the power nominal equipment – P_N, multiplied by the time of evaluation – t_A for the optimum conditions of temperature, humidity and pressure.

The specific consumption of a generating unit shows how the performance is the same when in operation, there is need to investigate the causes of failures or malfunctions, to minimize this problem.

Another parameter for evaluating the performance, depending on the use of equipment in plants is the load factor or average use and average load factor of great UDGs that can be calculated by Equations (2), as: (Santos, E. C., 2004)

$$F_{UTIL_{(i,j)}} = \sum_{j=1}^{m}\left(\frac{P_{EF_{(i,j)}}}{P_{N_{(i)}}}\right), \qquad F_{UTILO_{(i,j)}} = \sum_{j=1}^{m}\left(\frac{P_{EFL_{(i,j)}}}{P_{N_{(i)}}}\right) \tag{2}$$

where: F_{UTIL}, the load factor or the use of group generator i, in the time interval j; P_{EF} is the effective power of UDG i, j in the time interval, in kW and the rated power of the P_N group generator i in kW; F_{UTILO}, the optimal load factor, or use of the group generator i, in the time interval j and P_{EFL} is the effective power of UDG released, in kW;

In search of a parameter for evaluating the components of a generating unit is estimated to be the critical value equivalent – V_{CE} of each component using equation (3):

$$V_{CE} = C_E^2 \cdot \sum_{i=1}^{m} C_{Si}^2 \Big/ \sum_{j=1}^{n} N_j \ , \tag{3}$$

where, N_j is the sum of all indices of criticality assigned to each of the elements of the system, C_E is the number of criticality of each element and C_{Si} is the sum of the critical elements of the system to which the component part;

Bringing together the equations (1), (2) and (3) so that it can have global parameter for the calculation of the criticality of equipment C_{EQ}, Equation (4), determine which equipment to a plant or a set of plants with higher criticality, depending on their performance:

$$C_{EQ} = \frac{\left(2 \cdot V_{CE}^{1/2} + N_O^2\right) \cdot C_{ESP}}{C_C \cdot F_{UTIL}}, \tag{4}$$

where: N_O is the total number of events (outages, rationing, stops the generating unit, etc.) caused by the same elements of the system, jeopardizing the continuity of care for thermoelectric power plant, with longer duration of three minutes;

Another parameter used in the composition of the criticality of the components of a system is the critical equivalent in time – $C_{EQTEMPO}$, which is obtained according to the percentage of use of the element in the system – P_{UE}. This percentage is calculated by the relationship between the accumulated hours of operation of the equipment – h_{AO}, since its commissioning last in hours, the estimated useful life of equipment – V_{UE}, in hours, as seen in equation (5). :

$$P_{UE} = \frac{h_{AO}}{V_{UE}}, \tag{5}$$

Thus the criticality of time is calculated by Equation (6):

$$C_{QTEMPO} = \frac{P_{UE}^2 + RMDO^2}{T_{OPA}}, \tag{6}$$

Since the ***RMDO*** is the record of average daily operation of a generating unit in hours and T_{OPA} is the time for annual operation of the equipment in hours.

The third installment of the composition of criticality, i.e., the criticality of the elements of the system – C_{ES}, is calculated by equation (7)

$$C_{ES} = N_{OS} \cdot \left(\frac{C_{ESP} \cdot F_{UTILO(i,j)} \cdot C_{CO}}{C_{ESPO} \cdot F_{UTIL(i,j)} \cdot C_C}\right), \tag{7}$$

Where: N_{OS} is the number of occurrences for all the subsystems of the system of generation, in absolute numbers.

Using the method of RCM was possible if it calculates the readiness of the equipments in terms of percentile being used the Equation (8), together with the standard deviation of the critical measures – σ_S:

$$D(\%) = \frac{MTBF}{MTBF + MTTR} \cdot 100, \tag{8}$$

where, ***D (%)*** it is the percentile readiness of the equipment, ***MTBF*** is the medium time among flaws, ***MTTR*** is the medium time for repair.

Getting the composition of the criticality of the components calculated by Equation (9):

$$C_{COMP} = C_{EQ} + C_{QTEMPO} + C_{ES} + D(\%) \pm \sigma_S \ , \tag{9}$$

Whereas there are currently in the Brazilian legislation indicators for power generation, it is suggested the adoption of indicators based on the philosophy of DEF and FEC, Equations (10), established by resolution 024/2000 and ANEEL, both for distribution and transmission of energy.

$$DEC = \frac{\sum_{i=1}^{k} Ca(i) \cdot t(i)}{Cc} \text{ and } FEC = \frac{\sum_{i=1}^{k} Ca(i)}{Cc}, \tag{10}$$

where, ***DEC*** is the equivalent duration of interruption per consumer unit – **UC**, expressed in hours and hundredths of hours, ***FEC*** is the equivalent frequency of interruption by UC, in number of interruptions and hundredths in the number of interruptions, ***Ca(i)*** is the number of UCs interrupted by an event ***(i)*** in the period of investigation, ***t(i)*** is the duration of each event ***(i)*** in the period of investigation, ***i*** is the index of events that cause interruptions in the system in one or more UCs ***k*** is the maximum number of events in the period considered and **Cc** is the UCs total number of all considered at the end of the period of investigation.

Companies generating power can be monitored through an index called here the control of duration and frequency of interruption of the system by the absolute number of occurrences – DIN and FIN, suitable for power generation, which are seen in Equations (11):

$$DIN = DEC \cdot \left(F_{UTIL} \cdot D(\%)\right) \cdot C_{ESP} \text{ and } FIN = FEC \cdot \left(F_{UTIL} \cdot D(\%)\right) \cdot C_{ESP} \ , \tag{11}$$

Thus it was possible to evaluate separately the groups of power generators determining the critical points of each, and what actions should be taken to remedy these problems

All of the occurrences of interruption of the electric power supply happened at the power plants were registered in the application “Cycle”, as well as the interruptions of the years from 2003 to 2008, as it can be seen in the graph of the Figure 3, that show the outages in isolated system in 2008.

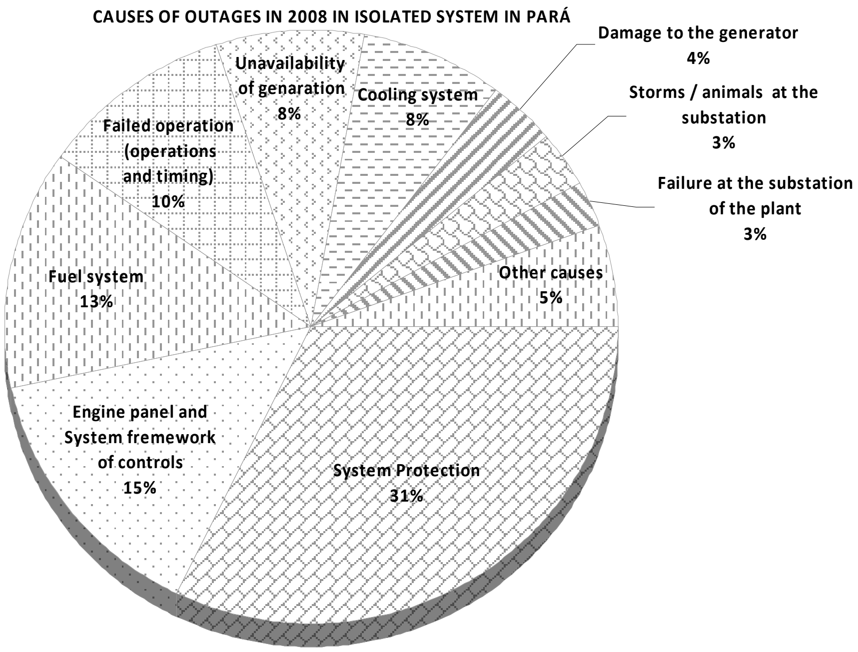

Figure 3. Outages occurred in the isolated system of the State of Pará in 2008.

The periods of outages occurred in studies of the plants were a year and had regular meeting between the engineering and maintenance of mechanical and electrical coordination to address the causes of deficiencies.

3.8. Evaluation and/or treatment

In 2002 the average availability of the plants CELPA varied from 40 to 80%. In 2007 these figures vary from 75 to 98% that due to the philosophy of maintaining plants in the so-called "cold reserve", i.e. the installed power of the mill machinery to keep itself more to that, if the losing UTE's largest machine possible to keep the generation that carried the recovery of damaged machinery. Those actions were only possible for the standardizations of the medium times of the accomplishment of the maintenance services and of recovery of the machines.

The utilization rates of DIN and FIN was effective with regard to monitoring and comparing performance of UTEs the same size and operating on similar terms. Thus, it was found that for each plant of CELPA that extrapolated the target set by ANEEL for disconnections 12 UTEs outsourced were the same in 2007.

The standardization together with the rising of the operational data of the elements of the power plants it propitiated the determination of the equipments, instruments and patrimony to have their appraised insurances.

The Cycle still supplied the individual diagnoses of the power plants and of the generating units for the groups of interruptions of supply of energy happened in the generation system so that it was possible to intervene of form proactive in the generation systems and to reduce such effects the results of that of the analyses can be seen in the graphs of the Figures 2 and 3:

Considering the many outages in the system of thermoelectric generation in the period of study, it was possible to identify all the causes of anomalies, obtaining, through the cycle of routines, the most critical components of each UTE, allowing the performance of diagnostic and prognostic operational through the use of techniques such as genetic algorithms for identification of genotype anomalies of the UDG, Fuzzy logic as a tool to aid in decision making, i.e., providing parameters for the definition of when to intervene in UDGs of power plants, advance or delay maintenance, and neural networks for simulation of possible failures that could occur in the system, as seen in Table 5.

4. CONCLUSIONS AND RECOMMENDATIONS

The methodology “cycle of Routines” implanting in the thermoelectric power plants to diesel of CELPA came efficient as for their objectives, because in spite of four turns they have been accomplished were possible to be reduced the largest problem identified by the team of implantation of DMS, as it was the case of the interruptions of the supply of electric power of UTEs, where it was possible to maintain the company with fall tendency in this index, Figure 2, where a graph of attendance of the “cycle” is observed.

In Figure 2 there are the absolute numbers of disconnections with their medium, for company, percentage of participation, along with their trends.

However, the need of a managerial change of the activities exists, that is, according to the method six sigma, is necessary to reformulate the goals in order to maintain the reached results and to get better, continually the acting of the electric power generation in the State of Pará, in other words, it is necessary to "rotate the cycle" again.

As a result of the cycle the annual economy was verified of more of R$ 2.302.000,00 in consumable elements, even with investments in standardizations of elements of the systems, however still adaptations exist to be processed in the system of CELPA, Table 3.

It is stood out that the developed method looked for to supply tools for the socket of managerial decisions, because with the “cycle of Routines” it was possible to evaluate and to optimize the generation of energy of CELPA starting from diagnoses of the elements more critics of the system, as seen in Table 5.

The introduction of a system of intelligence artificial hybrid in the method application “cycle of routines” turned the tool still more powerful in the development of all their tasks, doing with that the socket of decision, in the operation and in the maintenance it is still more he/she needs and efficient.

The next steps of this work is the implementation of other sources of generation in the cycle of routines, such as thermoelectric power plants Steam and/or gas, together with the thermoeconomic evaluation of the productive structure of plants and the training of neural networks to simulate the behavior of fault systems of generation, so that she can get the technical parameters for performing maintenance on the various elements of the system.

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6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.

Table 5. Some causes of outages occurred in the period 2005 to 2008 of the UTEs in the isolated system in Pará.

	Power Plant	**Element of Genetic Code**	**Component System**	**Diagnosis of the problem**	**Prognosis / actions taken**
2005	Jacareacanga	01.08.01.01.03.060	Solenoid Valve	Burning of the solenoid valve engine	Burning in the disability system current. Conducting preventive maintenance on the bank of batteries.
	Bagre	01.03.01.01.01.002	Radiator of the engine	Water quality in poor cooling (use of water from the river).	Outages by overheating of the engine by clogging the galleries of the radiator. A study of filters and replacement water per radiator fluid.
2006	Bagre	01.03.03.04.13.198	Exciter	Burning fuse of the exciter of the table of commands	Current existence of above and / or below the nominal range of the exciter table of commands. Development of studies to extend the protections and electrical amperage range of equipment
	Melgaço	01.09.03.01.03.050	Fuel Oil Pipe	By dirt clogging the pipes, and water contamination by microorganisms	Occurrence of outages due to lack of fuel and damage to components of the supply system of the engine. Research on the quality of fuel delivered and stored in plants (laboratory test)
2007	Cotijuba	01.07.04.08.14.259	Failure Operation	Difficulties in performing the operations of the plant operations and synchronization	Need for training to new entrants and operators of recycling the old plant. Conducting training and monitoring of the coordinators of the electrical and mechanical maintenance
	Bagre	01.03.02.04.13.198	Exciter	Loss of excitation of UDG	Operational error was recorded during the operation and timing of UDGs. It was suggested the implementation of training and retraining for the operators, and made the overhaul of the QCM.
2008	Jacareacanga	01.08.03.01.03.060	Solenoid Valve	Improper operation of the solenoid valve	Operators of the plant's equipment withdrew the automatic and the UDGs operated, or operated UDGs unprotected. Change of procedures.
	Vila Mandi	01.14.01.04.13.221	Oil Pressure Sensor	By overload shutdown	Unexpected load growth of the town. With the need to operate with the three UDGs at certain times of the day
	Bagre	01.03.01.04.13.198	Exciter	Burning of the exciter of the table of commands	Deficiency in the current system of plant remains. Realization of maintenance with replacement of the batteries of the bank of batteries.

Source: System Cycle, (2008).