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**DEVELOPMENT OF A MONITORING SYSTEM FOR TEMPERATURE  
AND PRESSURE MEASUREMENT – SMTP TO BE USED IN THERMAL  
SYSTEMS**

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**Abstract.** *The thermal systems have their operation based on the variables, such as temperature and pressure, of their working fluids or refrigerants, in addition to their operational characteristics and properties. This work aims to develop a measurement tool, monitoring and diagnostics of temperature and pressure of thermal systems. First, using for example, generating diesel units (GDU) with diesel engines, as well as implementation in a HVAC system environment, specifically a split air conditioner in a test bench in Climatization and Thermal Comfort Laboratory – ClimatConT, from the Federal University of Pará – UFPA. The main goal of this work is the implement of a set of instruments and controllers that will form the Monitoring System for Temperature and Pressure Measurement, called SMTP, working with data acquisition, monitoring, measurement and analysis of operational parameters of thermal systems in operation. With SMTP is possible to perform monitoring and comparison of real-time operating conditions with the specific technical standards for the tests, in addition to identification of performance loss and possible failures, the tool should increase the availability and reliability of the system. In this first moment as a case study the SMTP was installed in internal combustion engines of diesel thermoelectric power plants – TPPs, aiming to reduce the operational and maintenance costs, besides providing the application of predictive maintenance techniques in power generation systems, furthermore, with the adaptations, the tool could work in other types of thermal systems as well.*

**Keywords:** *Power Generation, SMTP, Predictive Maintenance, Monitoring and Diagnostics, Diesel Engine.*

## 1. INTRODUCTION

Thermal systems have their evaluation based on the control and monitoring of intensive properties such as the temperatures and pressures of the working fluids.

In each type of installation of thermal systems, subject to the appropriate proportions, temperature sensors is used to obtain the conditions and limits of this magnitude of the work place, such as the ambient temperature, inlet and outlet of the fluid or gases in the system, in addition to the working pressures.

An example of the application of SMTP in a thermal system must take into account the operating regime of, for example, Thermoelectric Power Plants (TPP) with internal combustion engines (ICE), because in Brazil, one of the critical points regarding procedures of maintenance to be adopted by the energy generating companies depends on parameters to evaluate how the system is working. The ideal situation for power plants that operate with diesel engines is continuously without overload and at full load (SANTOS, 2012). However, the activation of this modal is conditioned to the availability of hydroelectric generation, which has a 60.4% share in the Brazilian Energetic Matrix (ANEEL 2020).

The scenarios of uncertainty about the moment of startup of the TPP, by the National System Operator (ONS), demand of installations that use diesel engine for electric generation with higher levels of availability and system reliability and, with a constant management system of the Generating Diesel Units (GDU).

In the first phases of Research and Development (R&D), several activities were developed for the theoretical bases of the project and the achievement of goals and objectives such as:

- Bibliographic research on standards, books, manuals,
- Technical visits to obtain technical data for the most varied thermal systems,
- Identification of operational parameters relevant to your operation; Identification of equipment for monitoring, among others.

As results achieved up to the current stage of R&D, activities were developed such as:

- Laboratory tests to check the influence of different concentrations of biodiesel on the performance of GDU,
- Obtaining operational parameters of the generator set, tested in the Climatization and Thermal Comfort laboratory – ClimatConT at UFPA, projects for temperature and pressure data acquisition modules,
- Creation of a software called "Monitoring System for Temperature and Pressure Measurement – SMTP".

What is expected in this R&D is to develop a mobile data acquisition system, which can generate assessments and actions to be taken, based on predictive management information for diesel engines, based on data acquisition, such as temperatures and pressures, read at different points in the thermal systems. In addition, it will be necessary to analyze the various operating parameters of the engines, such as: oil analysis, quality of cooling and lubrication fluids, gas emissions and basic field of operation, in order to assist in the development of a set of predictive maintenance procedures for GDU.

This paper aims to present the characteristics of the monitoring system, with the development of its components and the creation of administrative management software, called SMTP to be integrated into the monitoring system of thermal systems, where the results of the tests in a GDU of a thermal power plant.

## 2. THERMAL POWER PLANTS WITH DIESEL ENGINES

In Brazil, TPP were designed for continuous operation without overload or at full load (Santos, 2012). However, according to the level of the hydrographic basins of the hydroelectric plants, ONS determines the operation regime of the TPP, thus, some have to work intermittently and with partial load and other plants are out of operation for long periods.

Such operating regimes have advantages and disadvantages, if, on the one hand, it reduces gas emissions, the cost of operation and maintenance, on the other hand it results in the need for constant management of the operation of the GDU, especially at the moments when the plant is in continuous operation, or when it is out of operation, but available for the National Electric System – SIN.

In the studies in the bibliographic references, no monitoring systems with an open platform were found, only the programs produced by the manufacturers of the GDU that sell closed systems were found, where the user has to adapt to the conditions of the manufacturers.

In some TPPs were found software and spreadsheets made by some employees, to control specific parameters of the generation of electricity. However, this software has no standardization parameters obtained, i.e., each thermal power plant develops software for their interests with instruments and equipment operating only in its facilities, this is due to the diversity of engines found.

This fact was verified in the technical visits, carried out by the team of researchers, made in some TPPs, which operate with a diesel engine. It was also verified that there are no predictive maintenance procedures for the conservation, hibernation, reactivation and evaluation of the operational conditions of the GDU, when they are out of operation.

Given the above, the motivation to develop a tool or system, in the form of a set of mobile components, arose to monitor and diagnose the operational conditions of the GDU in a simple way with an open platform, which will aim to present solutions or actions for each condition of thermal variation and pressure identified.

### 2.1 Characteristics of TPP case study target

In the first phases of this R&D, technical visits were made to several TPP in Brazil, as shown in Table 1, with the objective of collecting data on their operational characteristics and identifying the procedures used in the monitoring and thermal diagnosis adopted.

Table 1. TPPs visited by the project researchers.

TPP	Place/Date of Visit	Company
Cotijuba	Belém – PA / 28/02/2020	SoEnergy
Daia	Anápolis – GO / 28/03/2020	UTEDAIA
Potiguar I e III	Macaíba – RN / 24/02/2020	CEP
Goiânia II	Aparecida de Goiânia – GO / 10/01/2020	Brentech Energia
Xavantes	Goiânia – GO / 10/01/2020	Usina Xavantes

As a result of the technical visits, it was found that the biggest problem encountered is the lack of control of the TPP's mechanical operating parameters and, consequently, the lack of automated monitoring and diagnosis systems, because, although there are some initiatives, each thermoelectric power plant makes its own control and creates its own operating standards for the components of the GDUs.

Still within the limitations of controlling the operational parameters of the TPPs, installations outside the standards required by Eletrobrás for fuel unloading activities were observed (Eletrobrás, 2006), in addition to fuel measurement procedures in storage tanks that reduce the levels of accuracy of data used or reported, for example.

To carry out this R&D with the application of the “Routine Cycle Methodology” (Santos, 2012) and the use of a tool for monitoring and thermal diagnosis of GDU, TPP Goiânia II was selected, located in the city of Aparecida de Goiânia – GO, controlled by Brentech Energia S.A, as a case study.

Among the most relevant information obtained during technical visits, the main data are highlighted, as shown in Table 2, and the topics listed on the technical and maintenance characteristics of TPP Goiânia II.

Table 2. Main data of TPP Goiânia II.

<b>TPP Goiânia II – Brentech Energia S/A</b>	
Total Installed Power	142,5 [MW]
Effective Power	140 [MW]
Number of Generating Units	116 (Diesel cycle)
Operation type	PIE (Independent Energy Producer)
System	Interconnected to the Electric Grid
Operational Situation	At the disposal of the SIN

As shown in Table 2, there are 116 GDU distributed in three sheds of sheltered engines, but the temperature and pressure analysis tests were carried out in only two diesel engines, located in shed I, this occurred, due to the availability of operation of the Goiânia II thermoelectric power plant.

The GDU selected by the engineering team of TTP Goiânia II, for the tests was 22, which is a Mitsubishi Maritime engine of 2,346 hp, coupled to a Stamford electric generator, whose electric power is 1,840 kW, both manufactured in 2008.

## 2.2 Description of measurement parameters used for diagnosing GDU

In the first moment of R&D, all activities were carried out to define the parameters that would best assist in the analysis of the operational conditions of diesel engines.

It was verified that, for the operation of a GDU, it is necessary to analyze the conditions of the fluids used, for example, the intake air, the cooling water, the fuel mass and the lubricating oil and that, during the operation, these quantities should be evaluated according to their working temperatures and pressures, with no standardized values for the maintenance condition of the engines of the thermoelectric power plant used as a case study.

Therefore, the parameters for measuring fuel flow, electrical quantities and gas emissions were obtained during commissioning tests carried out on a YANMAR generator set, model 4TNV88, with power of 21.6 kW (Yanmar, 2005), existing at the Motor Laboratory – LabMotor, from UFPA, with the objective of standardizing the actions for testing GDU on real TPP.

For the experiments, diesel fuel of types B0 (pure diesel) was used, and blends B2, B5, B7 and B10 (respective quantities of biodiesel in the diesel fuel). The mixtures were evaluated through data collections carried out in periods of 30 minutes for the loads of 25, 50, 60, 70, 80, 90 and 100% applied to the sets, obeying an interval also of 30 minutes for stabilization observed by the gas temperature data exhaustion (ABNT, 1984 and ABNT, 2014).

The measurement of the fuel flow parameter was performed at the entry and return points of the fuel line, in order to quantify the Specific Fuel Consumption ( $C_{ESP}$ ) using Equation (1) of the studied GDU, the temperature measurement was also made in order to monitor whether the fuel would reach its flash point (ABNT, 2000 and Santos, 2004).

$$C_{ESP} = \frac{\dot{m}_C}{P_{el}} \left( \frac{kg}{kWh} \right), \quad (1)$$

Where  $\dot{m}_C$  is the mass flow of fuel, in kg/h and  $P_{el}$  is the Electric Power Generated, in kW.

According to SANTOS (2004) and BRUNETTI (2012) the specific consumption of a GDU indicates how the efficient generator group is being operated, this is because it relates the mass flow of fuel consumed by the power generated, this being the relevant parameter in the evaluation of a GDU, regardless of the application, type or size of the engine.

The composition of the measurement system included: two flow meters, model LSF45, installed in the fuel and return of fuel; two PT-100 resistive thermometers and a PHI-ID controller from TechMeter for converting electrical signals into flow measurements (CONCEIÇÃO, 2018).

For the evaluation of the electrical quantities, the SAGA 4500 meter, model 1382-4B from Landys + Gyr and the software record from the same manufacturer were used. The data from the SAGA 4500 was used with the flow data to calculate the specific consumption and income of the GDU (Santos, 2012).

The thermal efficiency of the GDU was calculated using the values of the electrical powers –  $P_{el}$ , in kW, of the mass flow rates of fuels –  $\dot{m}_C$ , in kg/s, of the test time –  $t$ , in s and the lower calorific power –  $PCI$ , in kJ/kg, for each fuel blend, using Equation (2) (Santos, 2004 and Brunetti, 2012).



As shown in Figure 1, it is clear that decentralization and modularity in the monitoring process is the most viable and inexpensive solution. In this case, each variable will have a specific module for acquisition.

This architecture has several advantages, among which can be mentioned: Ease of the module calibration process: a calibration procedure will be established for each module, according to the variable to be measured by it, which reduces the possibility of gross errors, also facilitating maintenance, reduction of the influence of interfering variables: the physical quantities are translated into electrical signals.

In fact, compatibilization reduces the influence of parasitic capacitances and inductances, largely generated by the mixture of disparate electrical signals; increase in reliability: the system can be programmed to alert the central supervision of the loss of any monitoring module, whether due to an electrical surge or other accident, and, even so, to continue monitoring the other quantities; cost reduction: modularization leads to cost reduction, as a possible loss or exchange of some module represents a lower cost than in the case of a centralized system.

Finally, evaluating the advantages and disadvantages of each studied architecture, the most suitable was the (SCD-Md), because it fits more in the operational requirements, because it is of low cost and for facilitating the control of the modifications of the elements of the SMTP by the team of researchers.

### 3.2 Computational platforms

Two computational platforms for SMTP were analyzed, which would use as a requirement for processing large amounts of data. These were:

- RaspBerry Pi, from the RaspBerry PI Foundation, which appeared on the market for educational purposes;
- Texas Instruments' BeagleBone, developed as a way to test the applicability of an OMAP3530 open source image processor.

Considering the initial R&D proposal, the RaspBerry PI platform proved to be suitable for use in several scenarios, as it presents reasonable computational power and low cost.

### 3.3 SMTP – MT Acquisition Thermocouple

Analyzing the thermal systems where the SMTP can be used, a large amount of materials was verified, which made it necessary to design and develop a sensor that would fit in most types of thermal systems.

During the research of the various thermal systems, especially the types of engines, where the SMTP could be used, it was found that in the inspection windows the materials used are: carbon steel and aluminum. Therefore, there is a need to use a magnetic base to fix the thermocouple to the engine block using carbon steel windows.

For the acquisition of temperatures in several points of an engine, such as in the inspection windows of the engine block, a K-type thermocouple was developed by the team of this R&D, with a magnetic base and an extension rod. With the thermocouple completely isolated, as shown in Figure 3.

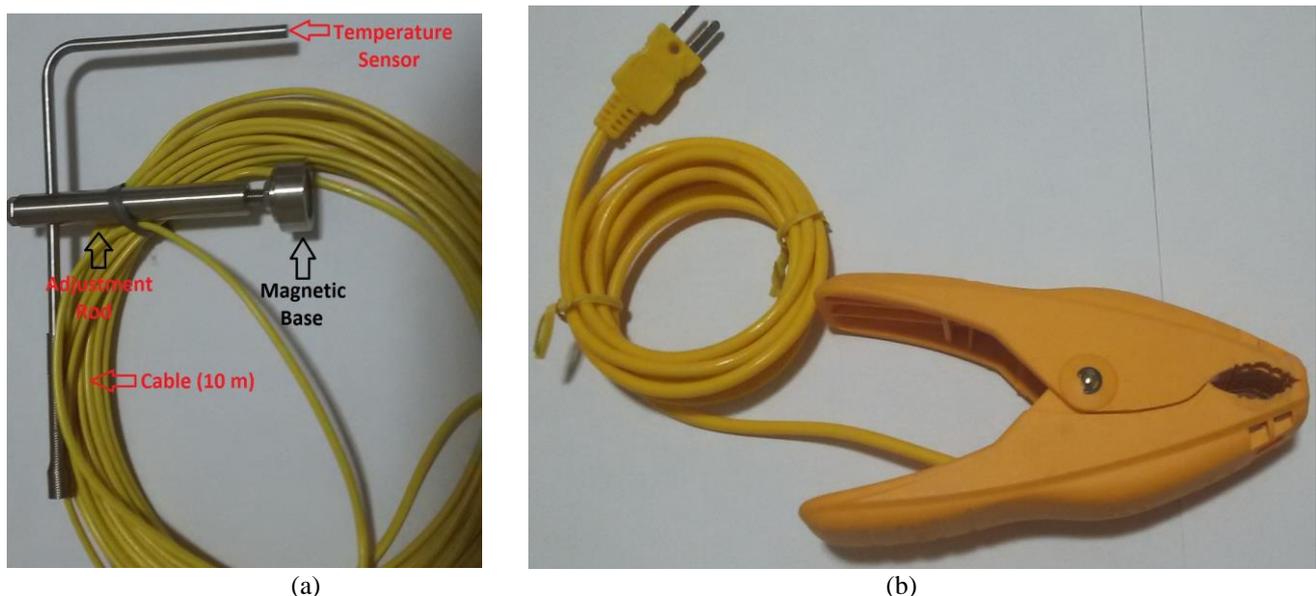


Figure 3. Temperature sensor developed for the SMTP: (a) With magnetic base and (b) Claw-type.

In the case of engines with aluminum inspection windows, in addition to the magnetic base, an extension rod, Figure 3(a), is required, where the thermocouple can be positioned closer to the center of the inspection window. In both cases, the engine temperature can be assessed, informing which engine sector has some type of anomaly (ANALOGICA, 2013).

The temperature sensor developed for R&D, have the following measurement principles:

- Adequate dynamic response: the transducer had to have an adequate convergence time;
- Range: 800 ° C;
- High precision; Working range: - 30 to 800 ° C;
- Linearity: the transducer must exhibit linear behavior, within the measurement range of interest.

The development of temperature sensors was due to the need to find a sensor that could withstand high temperatures, that had good linearity and accuracy.

According to Santos *et. all.*, (2020) in some thermal systems, such as air conditioning, it is necessary to install a clamp-type transmitter, which will supply the temperature of a gas in a pipe, as shown in Figure 3 (b).

The temperature module should have fifteen measurement points, one for each engine window, totaling eight points, one for the ambient temperature, two for collecting the exhaust temperature, two for fuel oil supply and return temperature and, finally, two more points to read the engine water temperature.

### 3.4 SMTP – MT Acquisition Board

Based on the information mentioned above, an acquisition board for the SMTP – MT was designed, with an ADS1118 CI, with two channels and an internal temperature sensor (Texas, 2015).

Figure 4 shows the final design of the acquisition board for electrical parameters.

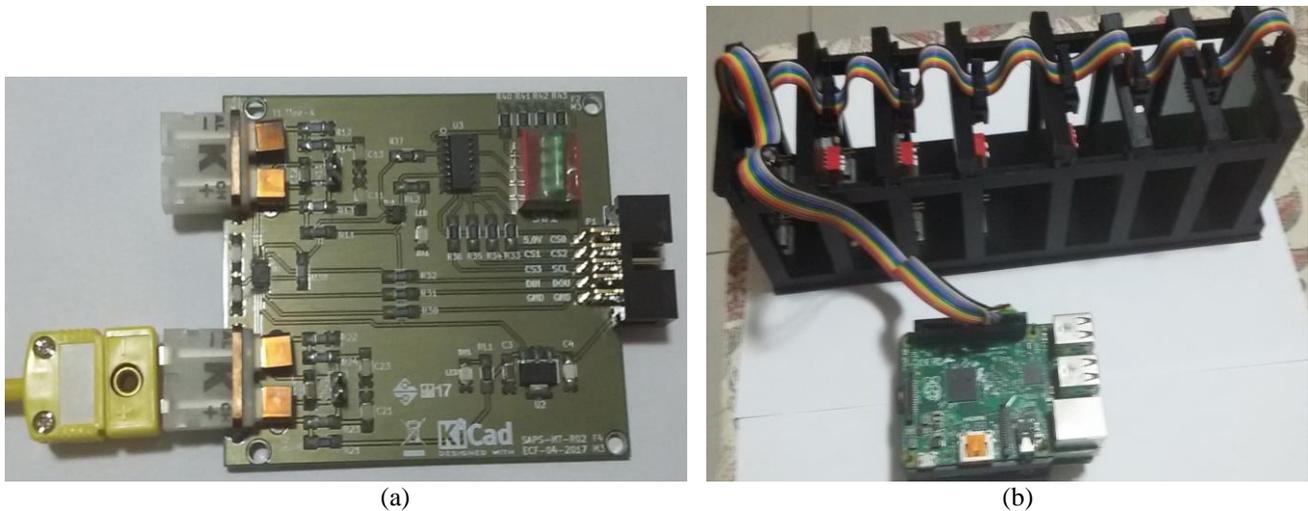


Figure 4. SMTP temperature acquisition system boards: (a) Thermal parameter data acquisition board and (b) Raspberry cards connected to eight developed temperature data acquisition cards.

The SMTP – MT module is used for the acquisition and processing of temperature signals from the diesel engine aiming at the supervision and diagnosis of failures correlated to the temperature magnitude.

On each temperature acquisition board developed in R&D, it is possible to install two sensors.

This module provides fifteen measurement points, one for each engine window, totaling eight points, one for ambient temperature, two for collecting exhaust temperature, two for fuel oil supply and return temperature and, finally, two more points to monitor the engine water temperature.

### 3.5 Monitoring system for temperature and pressure measurement – SMTP

The STPM software comprises the drivers for the temperature and pressure modules, as well as an easy-to-handle Human-Machine Interface (HMI).

This platform aims to integrate the software through a local network with the help of two network protocols: Security Shell (SSH) and File Transfer Protocol (FTP), the first has the purpose of creating servers in the modules that accept the command entry in the operating system through a remote terminal, the second concentrates a storage server and transmits files in the HMI, so that it centralizes the test data.

### 3.6 Human - Machine Interphase (IHM)

The IHM was developed aiming at agility and versatility with respect to the existing operating systems, prioritizing a language that would provide rich documentation and understandable syntax, so that the code would be easy to build and manipulate even to less experienced programmers. by the Python language.

The Python language was created in 1991 by Guido Van Rossum and has the characteristic of being oriented to high-level objects providing a very high degree of abstraction, being very close to human language, contrasting low-level languages, consequently facilitating the learning and construction of the project as a whole. In addition, its great versatility allows communication with other languages such as C++ (language on which the driver was built), possibility of integration with languages directed to the Web, libraries for building interfaces and manipulating the system.

For the development of a Graphical User Interface – GUI, one of the standard Python graphical interface packages, Tkinter, was chosen. Because it is an old package with a large amount of information, it is “lighter” than similar GUI - not requiring too much graphics hardware, yet it presents an archaic design, without much possibility of variation.

The choice of the \*.txt extension is due to the amount of RAM and reduced processing power of the Raspberry Pi. In modes, there was a need for direct manipulation of some elements, for which it would be necessary to use a low-level language. In this context, the medium level language was chosen (it has both elements at the machine level and elements similar to human communication) C.

It is the most used programming language in the world, being a powerful language with consolidated documentation and active community and for having known Python integration techniques.

The SMTP was developed in acquisition and analysis modules so that a user can access the system, it is necessary to have the software and the set of acquisition cards. After installing the program, is necessary that the people involved in the preparation of the engine's operational diagnostics are registered in the application's database.

After accessing the system, the main menu window is shown, as shown in Figure 5 (a).



(a) (b)  
Figure 5. SMTP software: a) Main menu window and b) Registration window.

To facilitate operations, a set of guidelines was developed to assist in the tasks. These tasks are presented in each window in the “green” color, as can be seen in Figure 5 (a). It is also possible to observe that SMTP activities are divided into (Santos, 2012): Registration; Analysis of occurrences; History of occurrences; Monitoring; and About.

After the user clicks on the registration button, in the main menu window, he is taken to the window shown in Figure 5(b), which is the software registration window that has the following features:

Right after registering all the installation information, it is possible for the user to make the selection of the GDU and proceed with the installation of the sensors, which with the magnetic bases facilitate the operation.

With the sensors installed, both from the GDU and in the SMTP case, and with the analysis and history of occurrences, it is possible to monitor the operational parameters of the GDU.

Figure 6 shows the SMTP monitoring window, where you can see the image movement buttons, so that it is possible to view the various positions of the engine (front position, right side, left side and rear position).

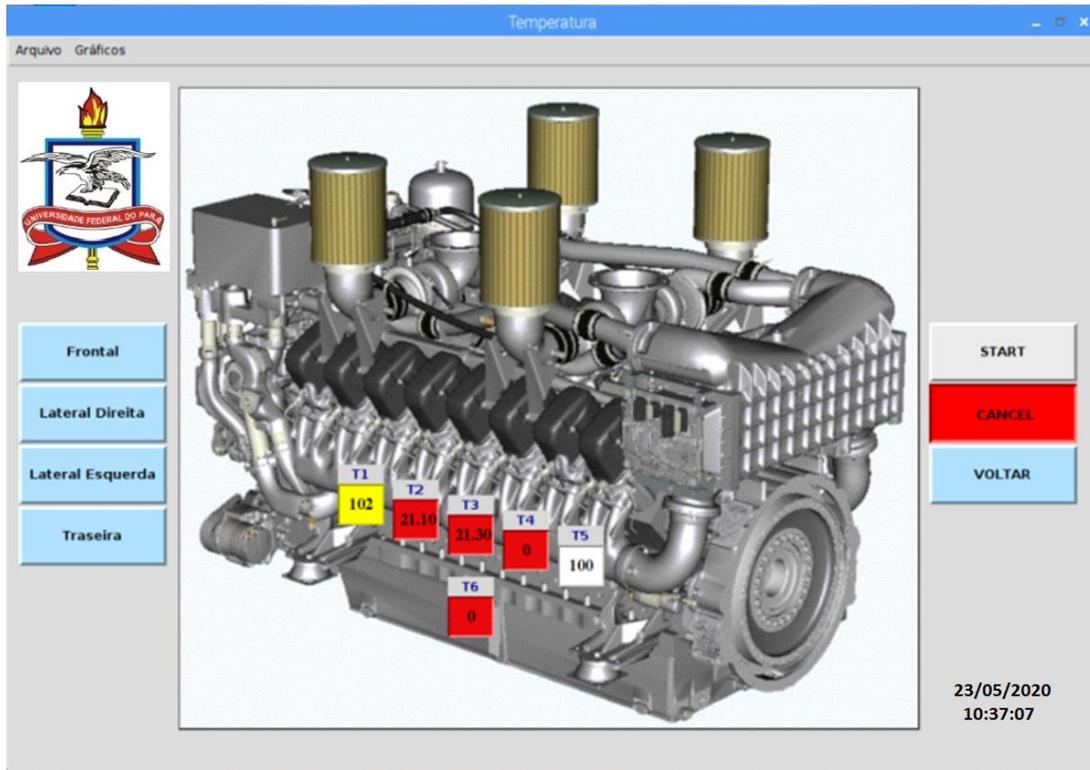


Figure 6. SMTP software monitoring window - Right side of the engine.

In each monitoring screen the motors are shown, in their respective positions, the values of the quantities and parameters being acquired, as can be seen in Figures 6, 7(a) and 7(b).

For each displayed quantity, the operational limits that are part of the program's database and that use the color standard for their exposure were researched, with the “white” color used for the normal operating range, the “yellow” color, for the conditions of attention and alert and the color “red” for the conditions of minimum values and danger.

The screenshots shown the “START” button to initiate the data acquisition at any time, also the user can click in “CANCEL” button to cancel the operation and can return to the main menu, by clicking on the “BACK” button.

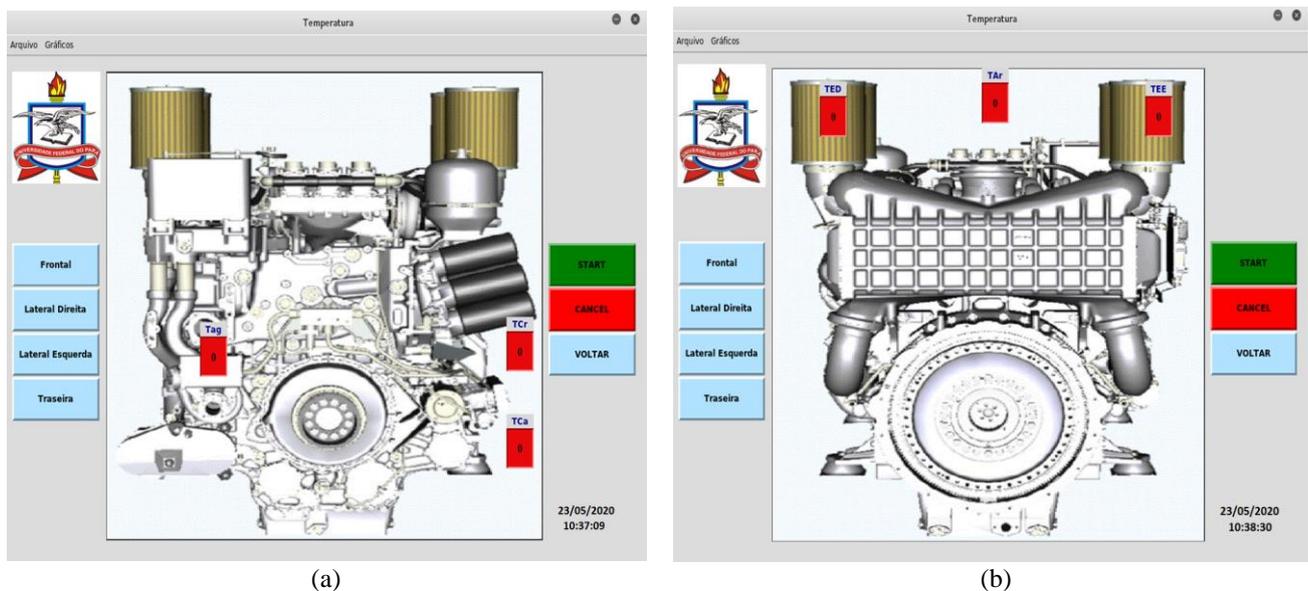


Figure 7. SMTP software monitoring window: a) Front view of the engine and b) Engine rear view.

SMTP was programmed to record data every five seconds or when there is a tendency to increase the parameters being monitored, or when they fall below the minimum limits required for the operation of the engine. In these circumstances' files are saved in \*.txt format, which can be post-processed in the investigation of anomalies in the GDU.

#### 4. RESULTS

Within the methodology used by SMTP, the operation of a generator set should have as reference the operational limits, as shown in Table 3, where the main operating limits of a GDU can be seen for some quantities to be evaluated (Santos, 2004 and Duff, 2010).

Table 3. Main operating limits of a GDU for TPP Goiânia II.

Parameter	Minimum Value	Attention Value	Normal Operation Range	Alert Value	Attention Value	Stop Value
Lubricating oil temperature, in °C	70	< 75	75 – 99	> 100	> 106	> 115
Cooling water temperature, in °C	70	< 75	75 – 90	> 91	> 96	> 105
Engine block temperature, in °C	80	< 85	85 – 100	> 100	> 105	> 120
Exhaust gas temperature, in °C	350	< 380	450 – 600	> 605	> 640	> 720
Turbocharger operating temperature, in °C	480	< 490	490 – 650	> 640	> 690	> 760
Air intake temperature, in °C	25	< 25	25 – 50	> 55	> 59	> 65
Fuel temperature in the supply line, in °C	35	< 40	35 – 55	> 65	> 70	> 75
Fuel temperature on return to the tank, in °C	70	< 75	75 – 90	> 95	> 100	> 105
C <sub>ESP</sub> for small engine, in l/kWh	0,290	< 0,295	0,295 – 0,350	> 0,350	> 0,355	> 0,360
C <sub>ESP</sub> for medium-sized engine, in l/kWh	0,260	< 0,265	0,265 – 0,300	> 0,305	> 0,310	> 0,315
C <sub>ESP</sub> for large engine, in l/kWh	0,240	< 0,245	0,245 – 0,270	> 0,275	> 0,280	> 0,290

The SMTP should have as an evaluation parameter the values shown in Table 3, where from the database one should compare the normal functioning of the operational conditions of the GDU under analysis through a commissioning test.

For each quantity to be analyzed, alerts were programmed with the following characteristics: minimum values; attention values; normal operating range; alert values; attention values and cut-off or stop values (in this case, the SMTP will act, when possible, on the GDU's protection system, removing it from operation).

During the post-processing for each quantity, accompanying graphs will be created, with correction of the values, so that it is possible to compare the results with similar engines in operation.

In all graphs resulting from the commissioning tests, the minimum values for the operation, minimum attention value, values for parameter readings, maximum alert values, maximum attention values and the motor stop value were used, according to the values shown in Table 3. Color patterns were used to indicate the conditions and alarms for alerting the trend of behavior.

Figures 8(a) and 8(b) show the monitoring, with SMTP, of the water temperatures of the cooling system and the lubricating oil of the lubrication system.

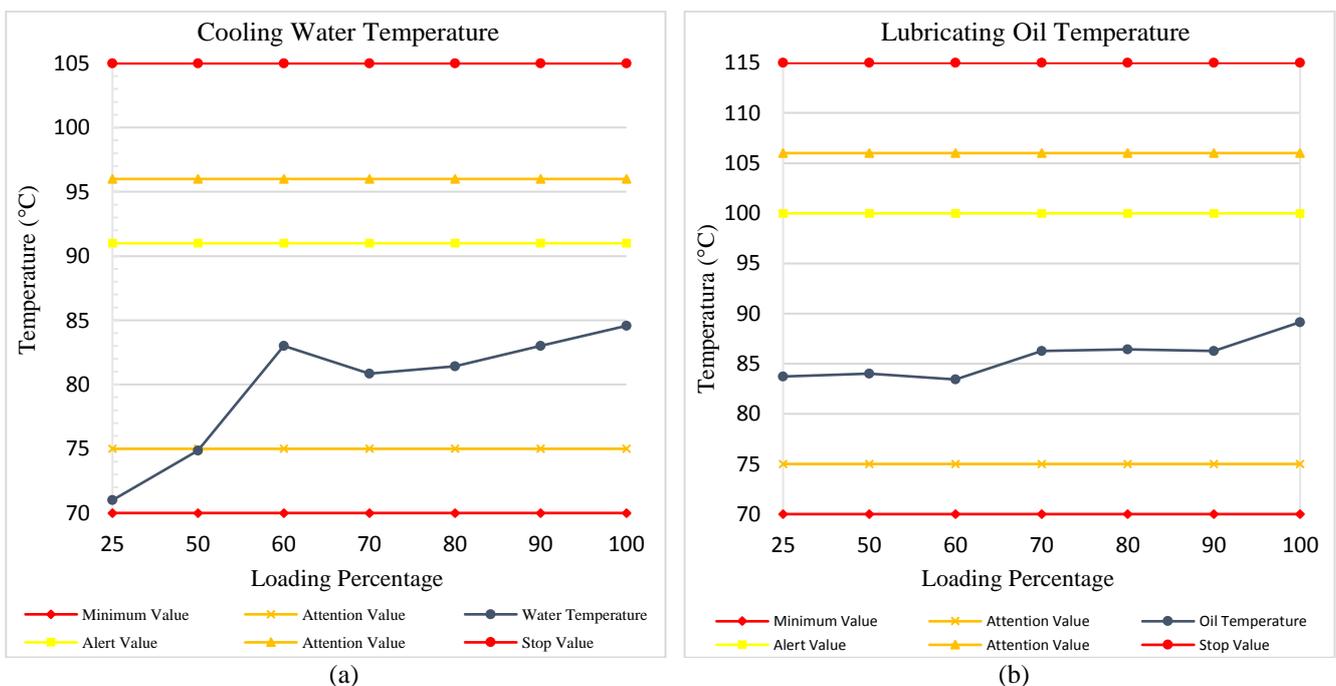


Figure 8. SMTP software: a) Cooling water temperature and b) Lubricating oil temperature.

It is possible to see in Figure 8(a) and 8(b) that, in spite of their increasing behaviors, the water and the lubricating oil temperatures remained within the acceptably minimum and maximum parameters.

The graphs in Figures 9(a) and 9(b) show the behavior of the exhaust gas temperatures, the right and left sides of the engine and the temperatures of the inspection windows on both sides of the engine, respectively.

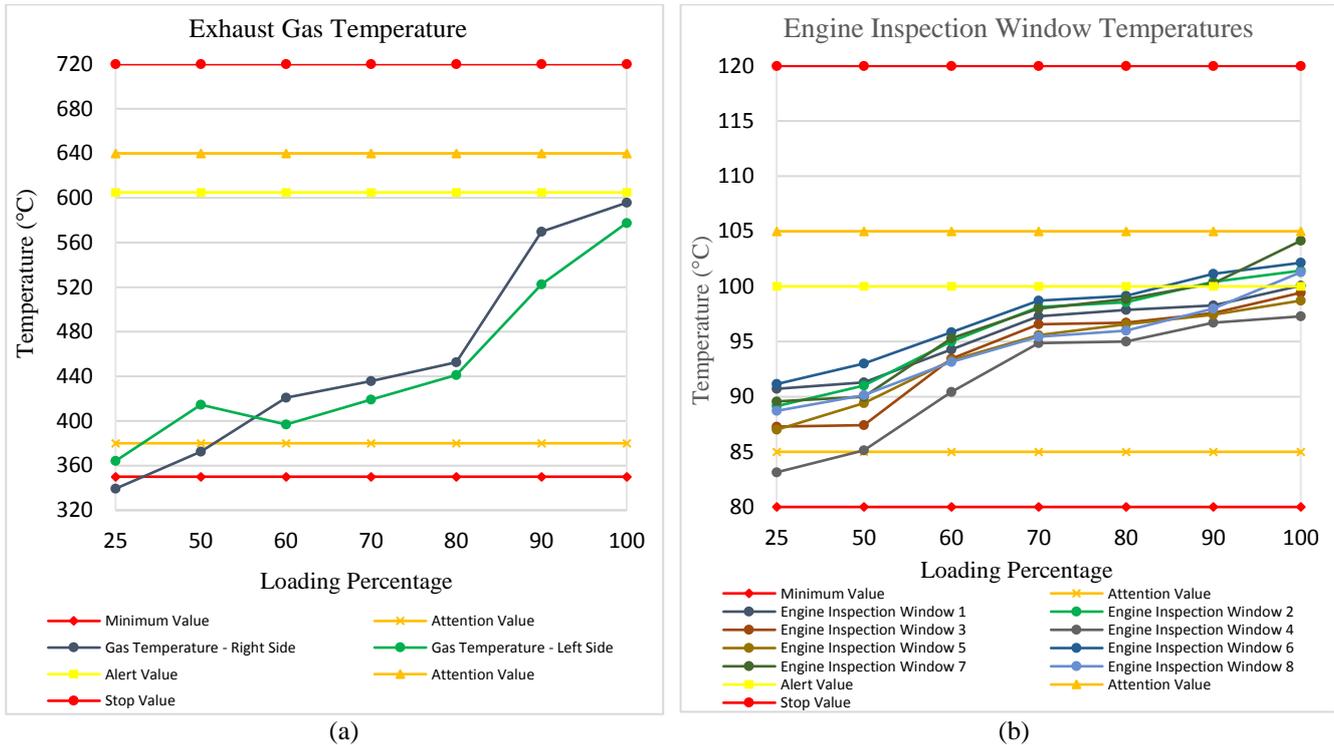


Figure 9. SMTP software: a) Exhaust Gas Temperature and b) Engine Inspection Window Temperatures

The exhaust gas temperature, on the left and right side of the engine, have different values, indicating a fuel-rich burning behavior (Right side) or lack of lubrication on the crankshaft, as shown in Figure 9 (a). In these conditions, it is necessary to stop the engine for inspection and maintenance (ABNT, 1994 and ABNT, 2000).

In Figure 9 (b) the temperatures of the inspection windows are shown, both on the right and on the left side of the engine. It is noticed that the temperatures of the inspection windows 1, 2, 6, 7 and 8, tend to increase the temperature, exceeding the maximum alert level, determined for the normal operation of the engine. This condition indicates a deficiency in the lubrication of the engine side benches. In these conditions, it is necessary to stop the engine for inspection and maintenance (ABNT, 1994 and Santos, 2004).

Table 4 shows the results of the GDU 22 test of TPP Goiânia II with SMTP.

Table 4. Report with the results of the GDU 22 test of TPP Goiânia II.

<b>SMTP TEST RESULTS</b>	<ul style="list-style-type: none"> <li>✓ The engine of the diesel generating unit – GDU 22 is a marine engine adapted for stationary application.</li> <li>✓ In the tests it was found that GDU 22 operates with mechanical losses of approximately 25%, distributed in losses of the coupling, air restriction in the intake system, the cooling system and due to the poor quality of the fuel used, which reduces the effective power of the GDU from 1,840 to 1,300 kW.</li> <li>✓ The reception curve obtained in the GDU 22 test, with SMTP, shows an increase in specific fuel consumption of 8.64%, which represents an increase in fuel consumption per hour of 29.40 (l/h)</li> <li>✓ The GDU 22 utilization factor is 0.7133.</li> </ul>
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Figure 10 shows the specific consumption curve of the GDU, comparing the values of the manufacturer's reception test, with the normalized value and the value of the test with the SMTP, according to the standardized test by ABNT NBR - 8422 (1984) and ABNT NBR ISO – 8528 – 9 (2014).

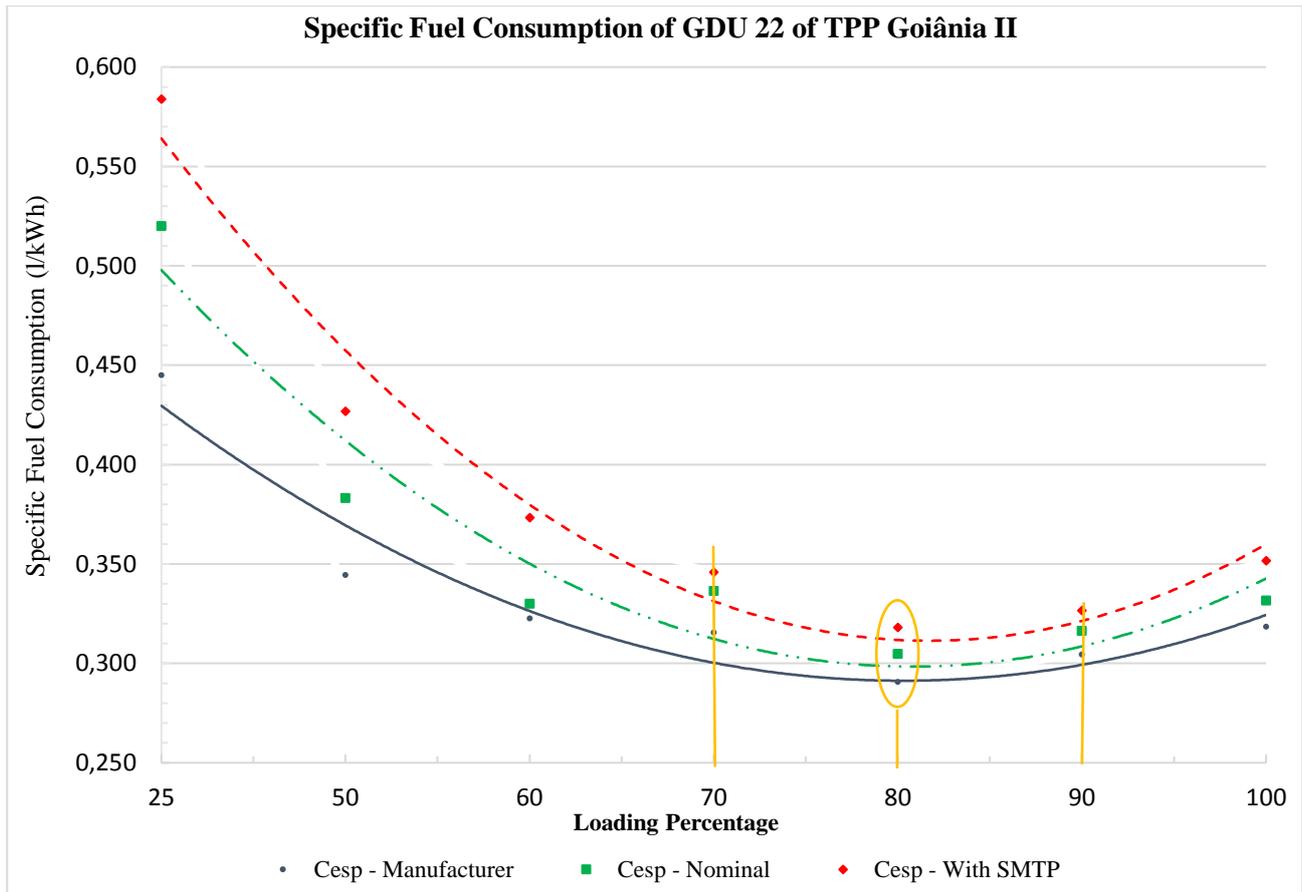


Figure 10. Curve of the reception test obtained with the SMTP for GDU 22 of TPP Goiânia II.

In the reception curves of Figure 10, it is possible to perceive the basic field of operation for GDU 22, highlighted, which varies between 70 to 90% and that the ideal load percentage is 80% of the electric power, that is, a value of 1,000 kW. In this condition, according to SANTOS (2004) and SANTOS (2012), the GDU will be able to operate for a long period without damage to the engine components.

It is also observed in Figure 10 that there is an increase in the specific consumption of the engine during the test with the SMTP, in relation to the manufacturer and nominal values. Comparing the values above with those recommended by the standard of ABNT NBR ISO – 8528 – 9 (2014), which indicates that the variation of the specific consumption of the GDU must be between 4 to 7% of the manufacturer's value, therefore, it is recommended to execution of inspection and preventive maintenance for this GDU (ABNT, 1994 and Santos, 2004).

## 5. CONCLUSIONS

As described throughout this article, the decisions made to develop a system for monitoring the temperature and pressure of internal combustion engines in thermoelectric plants have become effective, with general and specific objectives being gradually achieved.

The novelty of R&D lies in the development of an architecture with topologies mounted in modules, where data acquisition plates were designed for the thermal and mechanical parameters. Specific drivers were developed for each module so that there was independence between the quantities to be acquired. To integrate all modules, a technical administrative management software was created by the research team to perform predictive maintenance, which presents the interconnection between the module drivers and a very friendly man / machine interface.

Procedures for data acquisition were created and operational limits and diagnostic reports were defined for the most diverse types of engines, registered in the application's database.

In the first phase of R&D, commissioning tests were carried out, using conventional equipment, such as meters, analyzers and commercial sensors, which sought to identify the basic field of operation of diesel engines. These tests were done on a diesel engine installed at UFPA's LabMotor. The standardized procedures for the acquisition of each of the quantities, which were applied, both in the laboratory and in an installation with diesel engines operating in real TPP, showing that the R&D results are being satisfactory.

The next steps were to carry out commissioning tests on the LabMotor diesel engine, using the SMTP case, in order to compare the results and adjust and/or calibrate the sensors for the quantities to identify the operating conditions of the GDU.

Then tests were performed on TPP in operation, in order to form a database of occurrences and anomalies. At the end of this task, diagnostic standards were created to be used in the reports and preparation of the partial R&D report for this case study.

The use of the SMTP in TPP with a large number of GDU can significantly reduce the costs of operation and maintenance of the power plants, since a single system can be programmed to perform for periodic diagnosis and several GDU in operation, in addition to serving to realization the commissioning tests of GDU, after carrying out general reviews.

The SMTP should be used to carry out tests on other types of thermal systems, in order to form new databases and develop new actions for making managerial decisions on the operation, control and maintenance of equipment.

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