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OPTIMIZATION OF THE ENERGY PRODUCTION OF DIESEL ENGINES DURING THE SCORCHING PERIOD OF A HOT CLIMATE

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ABSTRACT

The study envisaged within the framework of this project consists in evaluating the losses due to decommissioning and in proposing a solution for optimizing the production of thermal engines used by the National Electricity Company (SNE) of Chad. Indeed, most heat engines are designed for use in temperate countries, when operating during the hottest months of the year they experience energy losses. Motors installed by the National Electricity Company (SNE) at the Farcha II power plant in Chad frequently experience alarming thermal failures due to cooling system temperatures which often cause derating in hot weather.
Considering the very high air temperature in the outside during the heat wave, the cooling system can no longer cool the environment adequately with the cooling fluids. Much of the heat produced inside the combustion chamber is not released into the atmosphere, overheating the engine. The objective of this work is to ensure a punctual treatment of the cooling air in the cooling circuit to allow the engine to operate in optimal conditions during the hottest months of the year (March, April and May). Based on the derating calculation methods by the WOIS software, we found that a loss of about 300MWh and a negligible loss of diesel consumption. To recover these losses, a solution was proposed by installing a terrace fogger on the airy space of the air coolers. The installation of this ventilated surface air cooling system lowers the ambient air temperature from 41.9 to 36 ° C as well as the water in the cooling circuit. The installation of this device makes it possible to adequately cool the ambient air intended to cool the cooling water circuit so that the engine operates under normal pressure and temperature conditions during the hotter months of the year.

KEYWORDS: Energy, Optimization, Cooling, Temperature, Derating.

NOMENCLATURE

Latin letters

SNE	National Electricity Company
WOIS	WÄRTSILÄ Operator's Interface System
LT	Low Temperature
HT	Hight Temperature
ACRE	Australian Cooperative Research Center for Renewable Energy
Tmax	Maximum ambient temperature
Tr	Reference temperature,
fd	Derating factor.
P_{uX}	Power adjusted from ambient conditions
P_{uR}	Power indicated under standard reference conditions

Greek symbols

$\alpha 1$	Temperature derating
$\alpha 2$	Derating according to humidity
$\alpha 3$	Derating as a function of the altitude
α_{site}	Site altitude,
α_r	Reference altitude
α	Power adjustment factor
η_m	Mechanical efficiency of the motor
β	Fuel adjustment factor.
β_r	Fuel consumption under standard reference conditions,

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ISO	International Organization for Standardization
P_x	Power ratio indicated
P_r	Power ratio indicated
P_{vX}	Room water vapor pressure
P_{vR}	Water vapor pressure under reference conditions
TcX	Temperature of the charge air cooling water
T_{CR}	Reference temperature of the charge air water
A, M , N and S	Coefficients depend on the type of engine
Ts	Dry temperature
Th	Humid temperature
T_{r0}	Dew temperature
h	enthalpy
V	Specific volume
r	Absolute humidity
Pvsat	Saturation Pressure
Pv	Vapor pressure
β_x	Fuel consumption adjusted from ambient conditions.
φ	Relative himudity

1. INTRODUCTION

Nowadays electrical energy plays a very important role in everyday life. The National Electricity Company (SNE) is one of the largest energy producers in Chad. Most of its productivity comes from thermal oil engines.

The National Electricity Company (SNE) is the only company that produces about 90 MW of electric power, it has several power plants including that of Farcha II [1].

To meet their considerable cooling needs, thermal power plants usually use water and ambient air. Climate change is a big challenge for cooling processes because it changes surrounding conditions such as water and air temperature.

Industrial installations such as a thermal power station achieve optimum efficiency thanks to an efficient cooling system. The Farcha power plant uses Wartsila W20V32 diesel engines for power generation.
With a capacity of 60 MW, it has 7 generators each with a maximum production power of 8,777 kW.

To ensure the protection of the generating sets, there is a derating system which automatically reduces the load on the engine when the ambient temperature reaches 42 ° C or even 45 ° C. This reduction easily increases the maximum allowable power from 8,777 kW to 7,500 kW, or a power loss of approximately 1,277 kW per generator. This has a consequence on the efficiency of the engine.

This article is part of the research that may lead to a result that will optimize the productivity of a generator (G5) of the Farcha II thermal power plant during the period of great heat.

The work consists of taking stock of the energy loss and a proposal for improving production by correcting the engine cooling circuit.

2. THE FARCHA II SNE THERMAL PLANT

Thermal power plants are power plants that produce electricity from mechanical energy produced by heat engines and transformed by alternators. We will only be interested in the study of reciprocating internal combustion engines used in SNE power stations.

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Figure: 1 Exterior view of the plant

The types of motors and alternators used at the Farcha II plant as well as the powers installed and available in each sub-plant.

Figure: 2 The machine room

Table 1. Technical characteristics of FARCHA II engines

Type de moteur	**WÄRTSILÄ 20V32**
Number of machines	7
Number of cylinders	20
Rated power (MW)	9.2
Displacement	320mm
Piston stroke	400mm
Rotation speed	750 tr/mn
Sense of rotation	Horaire
Alternator type	ABK DIG 171N/8
Installed capacity (MW)	61,4
Available power (MW)	60,9

To transform the mechanical energy delivered by the motors into electrical energy, the motors are coupled to generators with characteristics given in the following table.

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Table 2. Characteristics of the generator coupled to the heat engine

Generator type	**ABB AMG 1120MR08 DES**
Apparent power	11155 KVA
Power factor	0,80
Nominal voltage	15000V
Nominal current	429A
Frequency	50Hz
Rotation speed	750tr/mn
Protection sign	IP23

Reciprocating internal combustion engines

In compression ignition engines, the fuel is diesel. It is injected under pressure into the combustion chamber containing air, previously compressed and hot, on contact with which it spontaneously ignites. These engines are called diesel engine.

Both spark-ignition and compression-ignition engines are internal combustion engines, because combustion takes place inside the engine [4]. Figure 3 shows the schematic of a reciprocating internal combustion engine.

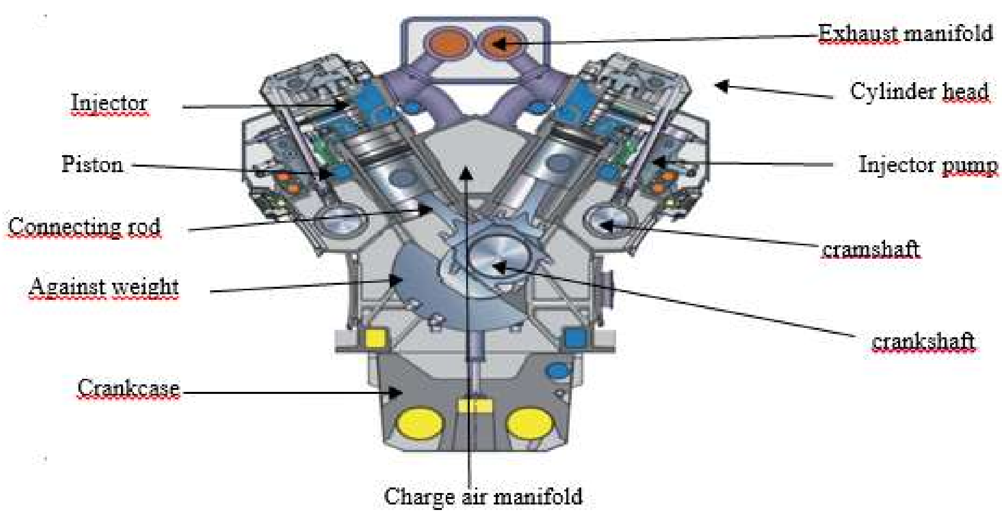

Figure 3: reciprocating internal combustion engine [2]

The cooling system of WARTSILA 20V32 diesel engine

The function of the diesel engine cooling system is:

- To dissipate the release of heat produced by combustion inside the cylinder.
- To maintain the temperatures of the various components at levels compatible with sufficient mechanical resistance.

Its role is therefore essential for the preservation of the engine. There are two cooling techniques, namely air cooling and water cooling.

- **Air circulation system.**

The charge air filter prevents water and particles from entering the engine. The charge air is filtered by a self-cleaning filter system that combines two dry filtration techniques. Before entering the filter, the air flows through the weather grille (see figure 4). Each engine must have 24 charge air filters in the weather grille.

Figure 4 shows photos of the weather grille (left) and G5 engine filters (right). This equipment is provided by the manufacturer is AFF-DP Technologies of France.

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Weather grille

Air Filter

Figure 4 : Weather grille and air filters

The charge air system supplies the engine with clean combustion air. The overload air to the engine is taken from outside the engine room [3].

The air is drawn in through the filter and compressed through the turbocharger, this air is then cooled in two phases by a water-air exchanger (see Figure 5) to be fed into the cylinders for combustion. The air temperature at the cylinder heads must not exceed 100 ° C (the value recommended by some manufacturers is 80 ° C) [6].

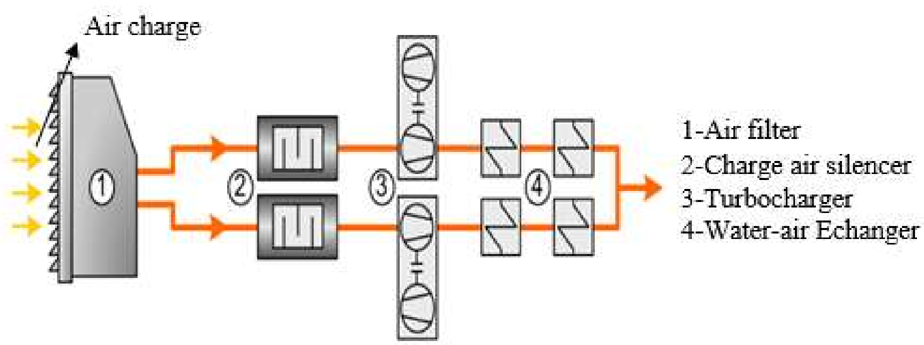

Figure 5: Charge air system [2]

- **The WÄRTSILÄ 20V32 engine cooling water system**

The cooling system of a diesel engine has conventionally been regarded as an auxiliary system of lesser importance, while necessary for his performance and its operation [8].

The cooling system is an important part of the engone, it ensure the maintenance of engine at optimum operating temperature. Its degradation can cause a disturbanceof all engine performance [9]

The engine is cooled by a closed circuit cooling water system, divided into two circuits: the LV circuit (low temperature) and the HV circuit (high temperature). In the cooling system, the water is cooled in an external cooler. Both circuits are fitted with thermostatic valves mounted on the motor or externally as presented in [3].

The role of the W20V32 engine cooling system is to maintain the engine temperature under normal operating conditions. It uses chemically treated cooled water. The system is divided into two circuits: a low temperature (LT) cooling water circuit and another at high temperature (HT).

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The temperature control valves direct water to the radiators or to the engine, depending on the water temperature [3].

Figure 6 shows the schematic of the W20V32 engine cooling system.

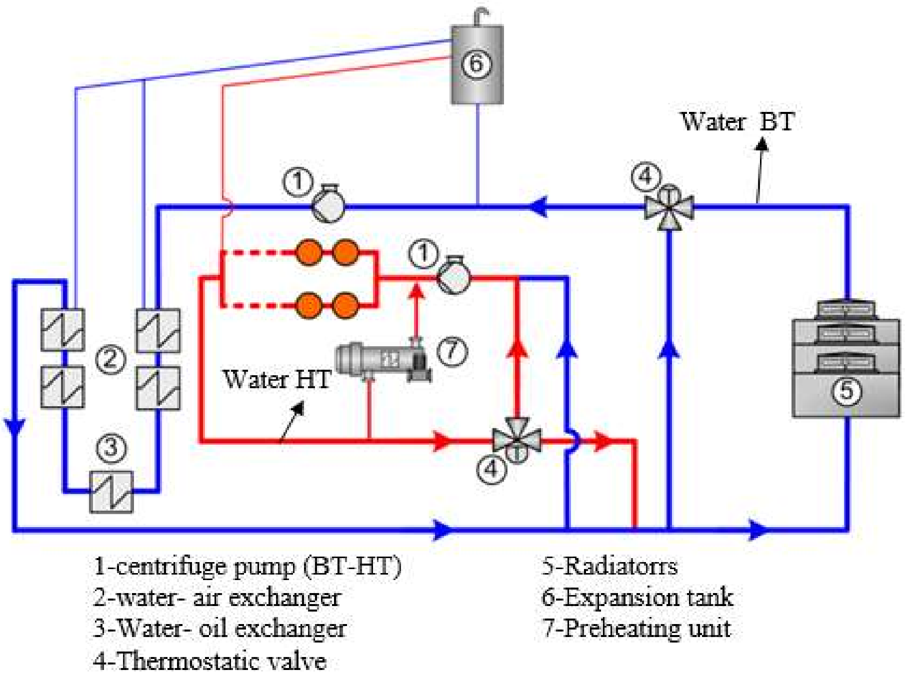

Figure 6 : Schematic of the Wärtsilä engine cooling system [3]

The HT water outlet, oriented towards the tree-way thermostatics valve, circulates in the distibution piping to the radiators. The water is cooled in the radiators by the air-coolers which use the air from the airy space which is at ambient temperature..

The WÄRTSILÄ 20V32 Engine cooling water circuit

The HT water outlet, directed by the three-way thermostatic valve, circulates in the distribution piping to the radiators. The water is cooled in the radiators by cooling fans (air coolers) using the air from the ventilated surface which is at room temperature. Electrically driven The speed of the radiator fans is regulated according to the temperature of the water in the return line from the radiators, to maintain the desired outlet water temperature when the ambient temperature is below the set temperature [5].

- **Radiators**

A heat exchanger is a device for transferring thermal energy from one fluid to another without mixing them. This is the case with a radiator. The water is cooled in the radiators by electrically driven cooling fans [3]. The G5 engine radiator fields is a HV circuit water cooler device consisting of 03 radiators supplied by the manufacturer Alfa Laval Vantaa Technology in Finland. Table 3 gives the characteristics of the radiator.

- **Air coolers**

The air cooler is a heat exchanger specific to the engine cooling circuit. Its principle is to use cold air taken from outside the ventilated space to lower and control the temperature of the water in the engine cooling loop.

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In the case of the Farcha power station, it is a device for drawing cold air from the surface of the ventilated space and discharging it at high speed over the radiators to be able to cool it. The water is therefore cooled thanks to the ventilation of the air coolers.

The speed of the radiator fans is regulated according to the temperature of the water in the return line from the radiators, to maintain a desired outlet water temperature. But during hot periods, this rate is not sufficient to cool the water to the desired temperature. The air coolers are supplied by the same manufacturer as the radiators. Table 4 gives the characteristics of the air coolers.

- **Ventilated space**

The ventilated space below the air coolers is used to draw cold air through the air coolers, which cool the water in the radiator. In this space, temperatures during hot periods can reach 42 ° C, which does not allow the water to cool sufficiently. The ventilated space of the G5 engine is 11.2 m long and 7.2 m wide, ie an area of 80m2.

Figure 7 shows a photo of the ventilated space and radiators (left) and a photo of the axial centrifugal fans on the roof of the machine room (right).

Figure 7: Water cooling module

3. RESULTS AND DISCUSSION

Method assessment of derating

We have previously mentioned that non-standard environmental conditions reduce the power of generator sets. In these cases, how do you determine the new output levels?

A technique called "derating" is used to determine the power of the generator set under new ambient conditions. The derating of a generator set depends on the manufacturer of the device. Different manufacturers design generator sets using materials from different sources. Also, the design techniques are not similar. All of these can contribute to the overall efficiency of the generator set. Therefore, the derating of a generator set depends on the manufacturing process. The different brands consider different factors to estimate generator power under non-standard conditions.

Thus, knowing the manufacturer's derating ranges, ACRE (Australian Cooperative Research Center for Renewable Energy, in French Center Australien de Coopération et de Recherche sur les Energies Renouvelables) offers below methods for calculating derating according to temperature, humidity and altitude.

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If the maximum ambient temperature during operation is higher than the reference temperature, the temperature derating (α1) is calculated using the equation [7, 10]:

$$\alpha_1 = 1 - (T_{max} - T_r) \times f_d \qquad \text{(i)}$$

If the maximum ambient humidity is greater than the reference humidity, the derating according to humidity (α2), is calculated using the equation:

$$\alpha_2 = 1 - (h_{max} - h_r) \times f_d/10 \qquad \text{(ii)}$$

If the altitude of the site is greater than the reference altitude, the derating as a function of the altitude (α3), is calculated using the equation.

$$\alpha_3 = 1 - (\alpha_{msite} - \alpha_r) \times f_d \;/\; 100 \qquad \text{(iii)}$$

According to ACRE, if the derating rates are given by the manufacturer (value of the derating factor), the formula of equation (3.5) makes it possible to calculate the adjusted power, from the ambient conditions.

$$P_{UX} = \alpha_1 \times \alpha_3 \times \alpha_3 \times P_{UR} \qquad \text{(iv)}$$

The norm ISO 3046-1: 2002, provides procedures for calculating adjusted power (equation v) and specific fuel consumption for ambient site temperature conditions from known values of standard reference conditions [10]. It should also be checked whether the power and fuel consumption values achieved under ambient engine the test conditions correspond to the declared values.

$$P_{UX} = \alpha \times P_{UR} \qquad \text{(v)}$$

With α: power adjustment factor. The power adjustment factor α is given by the formula of the equation.

$$\alpha = k - 07(1-k)(\frac{1}{\eta_m} - 1) \qquad \text{(vi)}$$

With ηm: mechanical efficiency of the motor and k: power ratio indicated. The value of 0.8 is taken by default for the mechanical efficiency in the absence of manufacturer specifications.
The indicated power ratio is given by the formula:

$$k = (\frac{P_x - \alpha \times P_{UX}}{P_y - \alpha \times P_{UR}})^m \times \left(\frac{\tau_y}{\tau_x}\right)^n \times \left(\frac{\tau_{cy}}{\tau_{cx}}\right)^s \qquad \text{(vii)}$$

Calculation of adjusted fuel consumption from ambient conditions
The fuel consumption adjusted from ambient conditions can be determined by the equation:

$$\beta_x = \beta * \beta_r \qquad \text{(viii)}$$

$$\beta = \frac{k}{\alpha} \qquad \text{(ix)}$$

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Specific power and consumption of fuel from February to August

Our study focuses on the G5 engine currently in service. The G5 has an alarming anomaly on the BT water and charge air temperatures caused by the adverse environmental conditions of the hot period.

In table 3, we have summarized the values of the parameters influenced (active power, specific fuel consumption, etc.) by the derating, for the months of February to August 2019. These parameters were recorded in the interval of hour from 11h00 to 16h00 mn with the software WOIS.

Table 3. Derating parameters [1]

Physical quantities	February	March	April	May	July	August
Tamb (°C)	22	41	41,9	41	37	26,10
Habs (g/kg)	2,2	1.4	1,5	8,3	18,9	20,20
T eau BT (°C)	39	53	59	53	49	41
Tairsur.adm (°C)	53,2	70,5	70,9	70,7	63,1	56,4
Pact (kW)	8522	7462	7483	7394	8196	8350
CScarb (g/kWh)	205,6	205,3	205,4	205,3	205,5	205,6
Qf (kg/h)	1660	1683	1674	1679	1612	1617

Compared to the derating the available active power drops at least from 8522kW to 7483kW a difference of 1039kW during the 5h per day during the heat wave month, a loss of 467 MWh is observed.

Fuel loss

The income of the business also depends on the cost of the engine's fuel consumption. The figure below shows the evolution of the specific consumption of diesel fuel according to the active power.

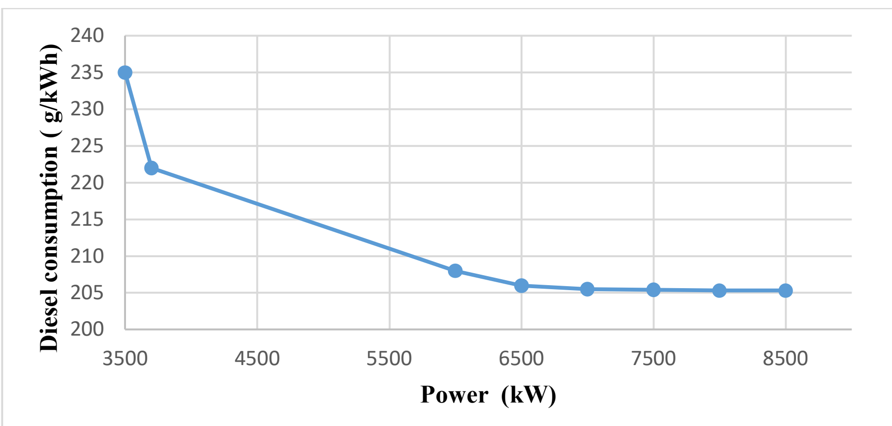

Figure 8: variation of specific consumption as a function of active power

From 7 MW the specific consumption is more or less constant. It has been shown that during the months of March, April and May, it has a loss of power and in contrast a constant specific fuel consumption during the period of decommissioning.

Proposals for improve the WÄRTSILÄ 20V32 engine cooling system

During the hot period, a decrease in energy productivity causing a loss of profitability for the company, this handicap was entrusted to us to emerge from the avenues of optimization solutions. According to the observations, the temperature of the ambient air used for cooling the water at the level of the radiator fields reaches a very high temperature during the hot period (41.9 ° C), which does not allow cooling. the water in the LV circuit because the set point temperature is 45 ° C for the motor. To cool this water during the hot period, additional cooling is

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required. As part of this work we are proposing the cooling of the air in the ventilated space under the aero-coolers, that is to say the ambient temperature of the air used to cool the water in the cooling circuit.

- **Installation of a terrace fogger**

The fogger is a device for spraying water in very fine droplets to moisten the outside air (house, terrace, etc.). The mist produced by the high-pressure fogger evaporates almost instantly into the air, so it is a system that involves projecting very fine drops of water into the air. The fogger has two main functions: to refresh the ambient air or to water. Thanks to the propulsion of micro-droplets of water, the air appears cooler. It can reduce the air temperature by about 5-10 ° C. The fogger does not wet surfaces so there is no risk of corrosion.

A control box is usually installed outside the roof of the generator room (this box contains a pump, a solenoid valve, and sometimes sensors to measure the humidity of the air. There is also a timer programmable). The box is connected to the electrical network and to the water supply pipe.Nozzle ramps are installed above the roof, near the space under the radiators, it is also possible to install these nozzles at the level of the gutters and then activate the system.

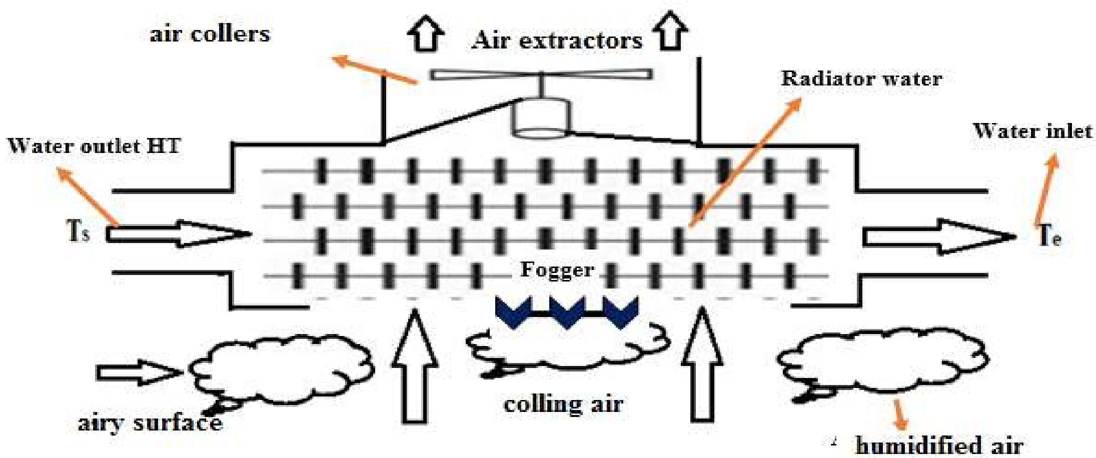

Figure 9 : installation of a terrace fogger

The RENSON type high pressure mist sprayer is chosen for the installation. The RENSON fogger kits with 15 nozzles create an insect barrier and a comfortable environment by lowering the temperature under the radiators. Microdroplets propagate and evaporate instantly on contact with air. Table 2 below shows the characteristics of the RENSON fogger to be installed under the radiators of the surface of the ventilated space.

Tableau 4 : Characteristics of the high pressure fogger

Fogger type (kit nozzles 15) RENSON	Debit (m3/h)	Pressure (bar)	Power (kW)	Covered area (m2)	Rotation speed (tr/mn)	voltage (V)	Misting scope (m)
RN160028EC	0,06	70	0,22	80 à100	1450	220	4

The air cooling of the ventilated surface allows cooling by humidifying the air during the scorching period and between 11 am and 4 pm of the day and which in turn is cooled by water from the cooling circuit. The ventilated surface of the G5 engine is 80m2.

Micro-misting uses the concept of adiabatic cooling, which involves spraying fine water droplets into the air to cool it. This technique transforms sensitive heat into latent heat, the enthalpy of the air remains constant. The energy in the air is transmitted to the water vapor, which increases the relative humidity of the air and decreases the temperature of the air [10]. The droplets are usually smaller than ten microns, to stay suspended in the air.

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- Diagram of humid air of the cooling the airy surface

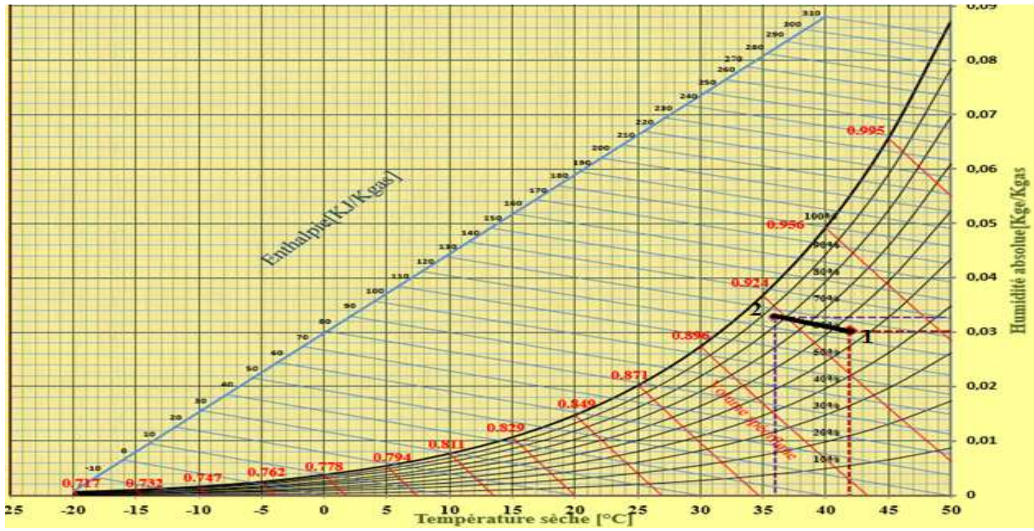

Figure 10 : Diagram of humid air

Table 5. Caractéristiques thermodynamiques de l'air humide

Data	Point 1	Data	Point 2	
T_{s1} [°C]	41.90	T_{s2} [°C]	36.00	
T_{h1} [°C]	33.73	T_{h2} [°C]	33.72	
T_{ro1} [°C]	31.32	T_{ro2} [°C]	33.8	
h_1 [kJ/kgas]	121.3	h_2 [kJ/kgas]	121.3	
V_1 [m^3/kgas]	0.94	V_2 [m^3/kgas]	0.92	
r_1 [kge/kgas]	0.0307	r_2 [kge/kgas]	0.0331	
φ_1 [%]kge/kgas	56	φ_2 [%]	85	
P_{vsat1} [Pa]	8215.61	P_{vsat2} [Pa]	5977.68	
P_{v1} [Pa]	4600.74	P_{v2}[Pa]	5081.03	

For an ambient temperature of 42 ° C, 1.5 g of water / kg.as of state 1, the air is cooled with the increase in humidity to state 2 which has an ambient temperature 37 ° C, 18.2g water / kg.as. We notice that we had a drop in temperature from 42 ° C to 37 ° C but we gained water from 1.5 g / kgas to 18.2 g / kgas in the form of vapor. This explains why we injected water in liquid form which vaporizes and vaporizes has captured energy in the air passing through it, so this is a humidifier by water injection.

4. CONCLUSION

Improving the G5 BT water cooling system by installing a patio mist sprayer on the ventilated surface helps lower the engine operating temperature during heat waves.

In this part, we first evaluated the energy losses during the three of the great heat and presented a proposal of the solutions for the cooling of the water circuit of an engine the thermal power station of electricity production Farcha II of the SNE:

Cooling the air in the ventilated space under the aero-coolers by installing a terrace fogger cools the water in the G5 engine cooling circuit. The water from the LV circuit, which has its own, cools the engine during the heat wave period. This cooling allows us to avoid derating the G5 engine and therefore reduce energy loss.

The cooling of the LV water circuit allows the G5 engine to operate in its normal state without derating during the scorching period; therefore what will allow a significant gain in energy at the SNE during the summer period.

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REFERENCES

[1] SNE, "The monthly report from the regional operations department" SNE, July 2019
[2] WOIS "Manual of interface systeme WOIS, of central Farcha," Wärtsilä; 2012.
[3] D. Jean-Christophe, "Cooling of thermal power stations in a changing climate. The case study presented to the Climate Change Impacts and Adaptation Division," Ouranos Natural Resources Canada; 8 p 2016.
[4] Ngarleita G., "Study of the impact of changing the operation of an LFO thermal power plant to HFO," Master, 2015.
[5] Jean Luc Pallas, "Practical guide to maintenance and repair of diesel engines," ETAI edition (1992).
[6] DEME A, "Study of the causes of thermal overload on a Diesel AGO 195 V16 RVR engine Master, Polytechnic School of Thies, Senegal, 1996
[7] YANTENG N., "Evaluation of the energy potential of SONABEL generator sets from evaporative cooling» Master, 2iE, 2010.
[8] A. Marco, A. Alberto," design and analysis of a cooling control system of a diesel engine, to reduce emission and fuel condumption.ABCM ", Symposium serie in Mechatronics. Vol 5, P40 2012.
[9] IEEE P802.16e/D12,'Draft IEEE Standard for Local and metropolitan area networks-- Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems', October 2005
[10] 3GPP RP-040461, Study Item: Evolved UTRA and UTRAN, December 200
[11] Hassan Moussa- Nahim, "modelisation du systeme de refroidissement du moteur diesel et ses defauts", IET Communications, Vol. 2, Issue 2, Laboratoire LSIS, UMR CNRS 7296, Marseille, JDL'62013 pp. 1-12, 2013.
[12] Nabeche. N, Bounsiar. F, "Etude de refroidissement du l'air par brumisation", Master, Université Mouloud Mammeri de Tizi-Ouzou, Algérie, 2015.
[13] BS ISO 3046-1:2002, Reciprocating internal combustion engines- Performance, Part I
[14] S. R. Baig, F. U. Rehman, and M. J. Mughal, "Performance Comparison of DFT, Discrete Wavelet Packet and Wavelet Transforms in an OFDM Transceiver for Multipath Fading Channel,", 9th IEEE International Multitopic Conference, pp. 1-6, Dec. 2005.
[15] N. Ahmed, Joint Detection Strategies for Orthogonal Frequency Division Multiplexing, Dissertation for Master of Science, Rice University, Houston, Texas. pp. 1-51, Apr. 2000.