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Maintenance Approach to Improve the Reliability of the MAN B&W Generator Set at the Kossodo Thermal Power Plant

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ABSTRACT

The problems related to the production of electrical energy through diesel thermal power plants in the countries of the Sahel, especially that of Burkina Faso, cannot be dissociated from the severity of the environment in these countries. Indeed, the operation of generators during the day in the periods of March, April, May, October and November leads to recurring outages, variations in loads and specific consumption. In addition, an applied maintenance policy that is based on the manufacturer's recommendations remains approximate, leading to high production costs and reducing the service life of generator sets. This article assesses the reliability, availability, specific consumption and load rate of the MAN B&W generator set of 18,4 MW of the Kossodo power plant under often high ambient temperature conditions from 2021 to 2023 and proposes the integration of solar panels in the installed generator set, in order to reduce their daily operating hours. Thus, solar panels will contribute from 07 hours to 17 hours, or 10 hours during the day and 14 hours for the generator, evening and night. To achieve this, monthly operation and maintenance data of the generator set and those of the maximum atmospheric temperature were collected. Thus, this has made it possible to combine solar panels providing a power greater than or equal to that of the generator during the day for 10 hours and a predictive maintenance approach integrating the ambient temperature parameter.

Keywords: Diesel thermal power plants, Predictive maintenance, Ambient temperature, Sahel countries, Burkina Faso

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INTRODUCTION

Electricity is a very important resource for all economies of the world. Global electricity demand is expected to grow at an average rate of 2.11 per cent between 2019 and 2040 [1]. In the 1970s, most power plants were large steam turbine-based units. At that time, nuclear and hydro power plants were very popular in the power range above 1000 MW. Gas turbines are also used to some extent in public and private power plants. Power generation using generators now accounts for about 10 to 15% of the total installed capacity worldwide. This is the result of its high efficiency, power concentration and reliability which have been improved considerably over the last decade. Reducing engine emissions to legally acceptable levels has been a challenge for major diesel engine manufacturers. There is a growing need for more efficient environmental technologies, and this has been a driver for more research [2]. In addition, energy scarcity and impacts on electricity generation policies have affected the supply of electricity generation in many countries [3]. Electricity generation for economic development must meet the social and environmental dimensions of sustainability. However, different countries have different energy resources and therefore different possibilities to generate electricity to meet demand [4]. Burkina Faso, like the other Sahel countries, although it has a significant solar potential, uses mainly diesel thermal power plants equipped with generators for the production of electrical energy [5]. However, these plants are experiencing recurrent outages due to the harsh environment (high temperature and relative humidity) of the country. These factors lead to high production costs, characterized by an increase in specific consumption, a decrease in loads and early failures of the generators. All these devices operate in an environment where temperature and humidity can reach 45°C and 75% respectively [6]. The generators are designed to operate efficiently at sea level under standard reference conditions of air pressure 100 kPa, ambient air temperature 25°C, relative humidity 30% and coolant temperature of supercharging air 25°C [6]. In addition, the maintenance of these generators also remains a challenge to be faced, in that the adopted maintenance policies are still approximate and not adapted to the environmental context of Burkina Faso. After the warranty period granted by manufacturers, thermal power plants face enormous difficulties related to maintenance [6]. When running at low load, the diesel engine is faced with low fuel efficiency, high specific consumption, and condensation of fuel residues on the engine cylinder walls that increase friction and premature wear [7]. In Saudi Arabia, for example, the Saudi Electric Company (SEC) is generated by combustion turbines but these are experiencing a 24% decrease in system capacity during summer due to ambient air temperatures of up to 50°C [8]. Also, the 100MW Heladhanavi diesel power plant in Puttalam, Sri Lanka, is composed of six turbocharged and air-cooled Wartsila 18V46 engines. Specific fuel consumption of engines varies according to ambient conditions. It has been found that this consumption is higher on warm days than on cooler [9]. In addition, based on a study conducted in the Middle East and Iraq that assessed the thermal performance of a gas turbine unit under real weather conditions operating at a rated power of 265 MW under standard conditions (15°C, 1 bar pressure and 60% relative humidity), the results showed that the highest efficiency was achieved during November (34%) at a temperature of 19°C and the lowest efficiency was reached in August (23%) at the highest recorded temperature of 46°C [10]. The effectiveness of conventional technical measures to improve the energy performance of a combined cycle power plant has shown that climate change and global warming have an impact on the performance of thermal power plants [11]. The study consisted of analyzing the impact of temperature on the Average Operating Times (MTBF), the Average Repair Time (MTTR) the Operational Readiness (DOp), the Specific Fuel Consumption (SFC) and the Load Rate (Ch) of the MAN B&W generator set at Kossodo. Finally, the results of a study to monitor the efficiency of gas-fired thermal engines have shown that conventional cooling of ambient air entering the engine room is inefficient, due to increased air temperature at the turbocharger inlet (TC) caused by ambient heat input [12].

MATERIALS AND METHODS

Materials

The Kossodo thermal power plant is designed for continuous operation using HFO (heavy fuel oil) and DDO (distillate diesel oil) and has eight (08) generator sets from three (03) different manufacturers.
The generators are shown in table 1 below:

Table 1: The generators of the Kossodo thermal power plants

Type of Group	Manufacturer	Rated Power (MW)	Available Power (MW)	Year of Commissioning
18V28/32H	MAN B & W	3 800	3 000	2000
BV16M 640	DEUTZ	6 460	5 500	2000, rehabilitated in 2017
BV16M 640	DEUTZ	6 460	5 500	2000, rehabilitated in 2017
BV16M 640	DEUTZ	6 460	5 500	2003
BV16M 640	DEUTZ	6 460	5 500	2004
18VW 32	Wartsilä	8 032	6 000	2006, rehabilitated in 2017
18VW 32	Wartsilä	8 032	6 000	2006, rehabilitated in 2017
18V48/60 B	MAN B & W	18 390	16 500	2006

This study focuses on the 16.5 MW MAN B&W generator, as it alone contributes about 31% of the plant's total capacity. In addition, the entire MAN B&W fleet of generators contributes more than 43% of the country's thermal output. In order to know the ambient temperatures and relative humidity of the group which will be used to analyze their effects on the indicators of operation and maintenance, a recorder was installed for this purpose. The characteristics of this apparatus are shown in Table 2 below.

Table 2: Temperature and relative humidity data logger characteristics

Manufacturer	Type of meter	Measure	Type of display used	Temperature measurement accuracy (measurement using probe)	Interface	Temperature measurement resolution	Temperature measurement range for non-contact temperature measurement
UNI-T	Data logger	Temperature and relative humidity	LCD	±0,4°C	USB	0,1°C	-30...70°C

Methods

The monthly maintenance and operation reports of the generator, as well as the temperatures were collected to carry out this study. Thus, the parameters considered are: accidental unavailability, specific fuel consumption, load rate, number of failures, energy produced and fuel consumption of the generator. Thus, in the analysis of the data, the descriptive statistics method was used to calculate these parameters.

Calcul des indicateurs de fonctionnement de la centrale MAN B&W

For better monitoring of the plant operation, three (03) operating indicators are considered. Note the Specific Fuel Consumption (SFC), the Charge Rate (Ch) and the Atmospheric Temperature (φ) which corresponds to the temperature of the intake air of the thermal engine of the generator.

Charge Rate (Ch)

The charge rate refers to the actual power delivered by a generator, taking into account its rated power and operating time. Long-term operation of low-load generators promotes condensation of combustion residues on the cylinder walls, which, after a certain time, increases friction, decreases engine efficiency and increases fuel consumption per kilowatt-hour produced. On the other hand, operating the generator set at low loads is the major factor in the aging and wear of the combustion system [13]. The following formulas provide the charge rate (Ch) and the monthly average charge rate (Chmoy) of the generator.

$$C_h = \frac{Sn*Ts}{Sf*Tg} \qquad (1)$$

With:
S_n: Rated power in MW
T_S: Specific Power Time in hours
S_f: Power supplied in MW
T_g: Total Operating Time in hours

$$C_{hmoy} = \frac{\sum_{i=1}^{n} Chj}{Nj} \qquad (2)$$

With:
C_{hj} = Daily load rate
Nj = Number of days per month

Average Specific Fuel Consumption (SFC)

The SFC is an indicator of the fuel consumption of a combustion engine as a function of power output and time. The HFO (Heavy Fuel Oil) reference SFC values of the Kossodo generator set manufacturers according to ISO conditions at 85% load rate range from 182 to 185 g/KWh, with a lower calorific value of 41 175 Kj/kg [6]. The formulas below illustrate the calculation of SFC and monthly average SFC.

$$SFC_{HFO} = \frac{Qc*Dc*1000}{Pe} \qquad (3)$$

With:
Q_C = fuel consumption in litres
D_C = density of HFO consumed
P_e = energy produced KWh

$$SFC_{moy} = \frac{SFC_{HFO}}{Nj} \qquad (4)$$

Average atmospheric temperature

Temperature data obtained with the logger for the periods 2021 to 2023 were analyzed and calculated using the following formulas:

$$\varphi_{moy} = \frac{\sum_{i=1}^{n} \varphi maxj}{Nj} \qquad (5)$$

With:
φ_{maxj} = maximum daily temperature
Nj = number of days per month

In addition, the cooling of the diesel engine is only controlled by the coolant outlet temperature, which is generally maintained at 85°C [14]. Thus, cooling the parts and keeping them in an optimal temperature range is an important part of engine operation [14]. In addition, the effects of the inlet temperature mainly include two (02) points, namely the turbo-compressor outlet temperature and the engine coolant temperature. The condition of the intake or atmospheric air has a significant effect on the behaviour of the internal combustion engine. Indeed, the increase in the temperature of the intake air will reduce its performance, with the increase for example in the coolant temperature [15]. Thus, the following formula relates the atmospheric or intake air temperature, coolant temperature (turbo compressor outlet temperature) and isentropic efficiency of the compressor [16].

$$\eta_c = \frac{\Delta Tis}{Ts - Ta} \quad \text{où} \quad \Delta Tis = Ta.\left(\pi c^{\gamma-1/\gamma} - 1\right)$$

$$Ts = \frac{\frac{\Delta Tis}{\eta c.Ta}}{\eta c} \quad (6)$$

With:
Ta = atmospheric temperature
Ts = turbo compressor output temperature
ηc = isentropic efficiency
ΔTis = change in atmospheric temperature
c = isentropic pressure
γ = constant

Indicators maintenance of plant MAN B&W

The reliability of the plant is the probability that it will perform the function for which it is designed under specified conditions for a predetermined period. It relates to the frequency of outages [17]. The calculated reliability indices were the Average Repair Time Technique (MTTR), Average Operating Time (MTBF) and Operational availability (D_{OP}), using failure data obtained from the MAN B&W 2021 to 2023 generator set.

Calculation of MTBF

The Average Operating Times (MTBF) or mean time between two (02) failures is obtained by dividing the sum of the operating times by the number of failures [18]. It is also obtained from the opening time To, subtracting the downtimes.

$$MTBF = E(t) = \int_0^{+\infty} tf(t)dt = \int_0^{\infty} R(t)dt = \frac{TBF}{N} \quad (7)$$

With:
E(t) = mathematical expectation
N = number of breakdowns
tf (t) = R(t) = reliability
TBF = time of good operation

Calculation of MTTR

The Average Repair Time Technique (MTTR) is a maintainability indicator. It refers to the overall time expected to complete a corrective maintenance or repair divided by the total number of failures [18]. The MTTR is included in the Downtime (TA). Indeed, the TA takes into account not only the MTTR and especially the Logistic Time (TL). The long TA of the generator set of the plant is due to the TL (order of spare parts, planning of technical assistance...).

$$MTTR = \int_0^{\infty} tg(t) = \int_0^{\infty} M(t)dt = \frac{TTR}{N} \quad (8)$$

With:
tg (t) = M(t) = maintenability
N = number of breakdowns
TTR = technical breakdown time

Calculation of D_{Op}

Readiness is the level at which a component or system is accessible and operational when required. Usually, it is impacted by the MTTR and MTBF [18]. It is a question of taking into account the actual conditions of operation and maintenance. This is availability from a user point of view. At the Kossodo thermal power plant, generators are running at full capacity. Average Downtime (MTA) can be calculated by:

$$MTA = \frac{\sum_{i=1}^{n} TA}{N} \quad (9)$$

$$D_{OP} = \frac{MTBF}{MTBF+MTA} \quad (10)$$

The average operational availabilities over the interval of one year and over three (03) years are given by the following formulas :

$$D_{Opmoy} = \frac{Tc}{Tc + Tci} \quad (11)$$

$$Dopmoy = \sum_{i=1}^{n} \frac{Dop}{n\ \text{année}} \quad (12)$$

With:
T_c = average cumulative time of good operation per year
T_{ci} = average cumulative downtime per year
D_{Opmoy} = average operational readiness

Stages of dimensioning the photovoltaic solar generator

Step 1: Determination of daily energy requirements (Bej) [19]

$$Ej = \sum Pu * Nbr * dt \quad (13)$$

With:
Ej= Daily energy consumption in (Kwh/j)

Pu: Unitary power in (W)
Nbr: number of devices
dt: daily usage time in Hours
In addition, the data on sunshine are expressed in KWh/m²/j. They can be taken at the site. In Burkina Faso, average solar irradiation is estimated at about 5.5 KWh/m²/j [20].

Step 2: PV generator power calculation [21]**.**

$$\mathrm{Pg} = \frac{\mathrm{Et}}{\mathrm{k} \times \mathrm{Ens}} \quad (14)$$

With:
Pg: Peak power (Wc)
Et: Total energy consumed
K: Correction factor (depends on inverter efficiency)
Ens: Sunshine (kWh/m²/day).

Step 3: Inverter selection [22]**.**

$$\mathrm{P_{Ond}} = \mathrm{P_{max}} + 10\%\mathrm{P_{max}} \quad (15)$$

With:
P_{Ond}: Power Inverter
P_{max}: Maximum power of all equipment

Step 4: Cable sizing and wiring diagram

IPV-ond, is the current flowing through the PV solar modules and inverter. IPV-ond = Pond/U. Knowing the cable lengths (L in m) and associated voltage, current (I in A) passing through these cables, maximum line resistance, voltage drop (U in V) and copper resistivity (ρ = 1.6. 10 Ωm), the cable cross-section is calculated by S= ρ(LxU/U). These formulas are in accordance with the work of dimensioning and installation PV [23].

SIMILAR WORK

Mohamed et al. (2025) proposed a system, modelled during the simulation with a 50 KW diesel generator (DG) and a 30 KW photovoltaic system. Its operation is simulated using MATLAB/Simulink, with realistic weather data based on historical solar radiation patterns in Qalyubia City. The load demand follows a typical daily consumption curve, starting with a low value in the early morning hours (from midnight to 7 am), with the DG operating independently to meet the energy needs of the system. The PV system produces electricity when the sun rises at around 7 o'clock, and the demand for charge increases significantly. From 07:00 to 17:00, the system experiences peak demand (approximately 50 kW), during which the PV system produces energy in combination with the DG. The solar generator's output is minimal in the middle of the day (from 12:00 to 14:00), when the energy requirement is at its maximum. During this period, the DG takes over and the solar generator provides the rest of the energy only when needed [24]. Also, Elkelawy et al. (2025) examined the sustainability of diesel power plants. The integration of photovoltaic solar panels and the optimization of operational practices are crucial steps to align diesel power generation with global sustainable development goals [25]. According to a study by Hutasuhut et al. (2022), the diesel/micro-hydro scenario can produce 35.6 MW/year of electrical energy, while the diesel/photovoltaic operating scenario produces 12,20 MW of electrical energy/year. This improves the reliability of the generator set over 25 years [26]. In addition, Dmitrienko et al. (2021) proposed the most common variants for schematic construction of hybrid solar photovoltaic/diesel thermal (PVD) plants which are the separate operation of the two plants, the operation of the photovoltaic power plant in parallel with the local electricity network consisting of diesel generators and the hybrid variant, providing for the possibility of separate and joint operation of the plants. Variants that save fuel and extend the life of diesel generators [27]. The combination of photovoltaic panels and diesel engines is one of the most common ways to supply rural communities with electricity. These hybrid systems can reduce the cost of generating electricity in these isolated systems because they use free energy to balance the power produced by diesel engines [28].

RESULTS AND DISCUSSION

Results

MAN B&W Generator Maintenance Indicators

Table 3 below shows the monthly values of MTBF, MTTR and DOmoy for 2021, 2022, 2023.

Table 3: Indicateurs de maintenance du groupe électrogène MAN B&W 2021 à 2023

Month	TA (h)	N	MTBF (h)	MTTR (h)	D_{omoy} (%)
January	224	13	340,96	17,25	90,03
February	1420	6	49,66	454,33	29,56
March	836	11	93,06	254,13	62,54
April	569	22	74,05	26,88	73,65

May	925	13	73,87	259,15	58,55
June	1531	12	80,86	253,41	57,40
July	1389	11	63,41	287,91	37,76
August	1130	11	73,46	273,73	49,37
September	1027	14	60,15	257,84	52,45
October	1401	11	51,77	257,84	37,23
November	1469	11	31,79	383,79	31,98
December	938	9	107,83	264,16	57,97

Based on Table 3 above, the average operational availability 2021-2023 of the generator set has increased from 29.56% to 90.03%. Indeed, only the month of January has registered availability of 90.03% for the rest, it is less than 75%. Availabilities deemed low, which are impacted by MTBF, MTTR and TA. A situation that is far from contributing to the development of SONABEL during these years. In addition, the standard deviations of MTBF, MTTR and DOp are calculated taking into account their mean values over the three (03) years indicated above.

Analysis of the correlation between MTBF and mean maximum atmospheric temperature

Thermal power plants generally have good reliability at the time of first commissioning but decrease over time due to several factors including poor maintenance policy and high air temperature [29]. The MTBF is an indicator of reliability. It allows to know the life of the parts of the generator. Figure 1 below shows the evolution of the MTBF and the mean maximum atmospheric temperature of the Kossodo MAN B&W plant in 2021, 2022 and 2023. The highest MTBF was observed in January 2022, with 732 hours, corresponding to a temperature of approximately 42°C. The figure also shows that the higher the temperature, the lower the MTBF. Thus, the temperature is an instigator of the fall in MTBF on the three (03).

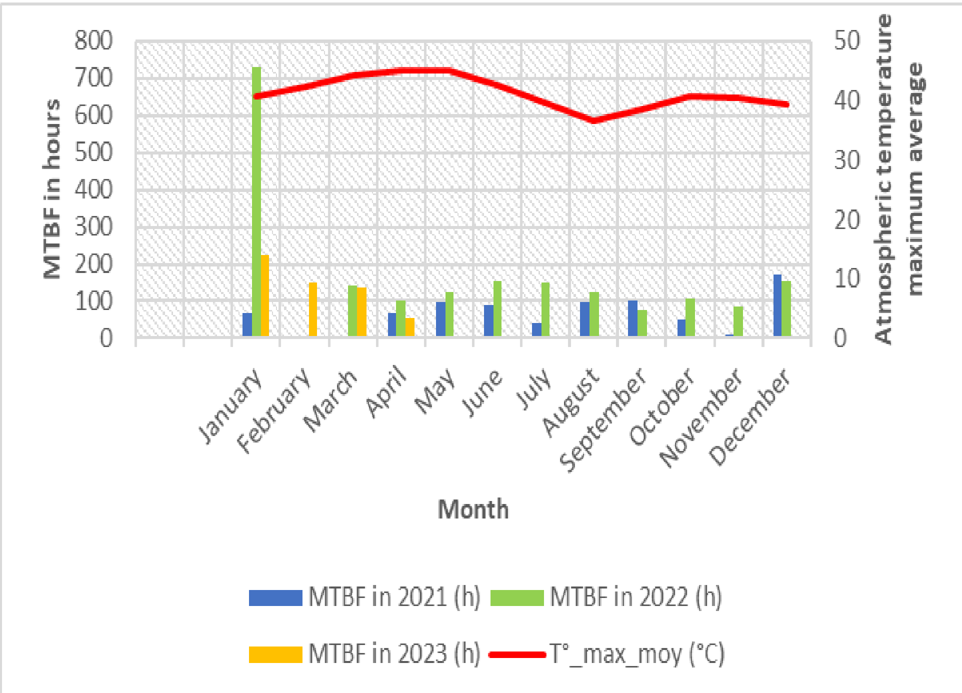

Figure 1: Curves of the evolution of the MTBF from 2021 to 2023 and mean maximum atmospheric temperature

MTBF, MTTR and operational availability analysis

Availability is the level at which a component or system is accessible and operational at a time when required. It is usually impacted by the MTTR and MTBF [30]. The average technical repair time (MTTR) is a measure based on the maintenance of repairable components. It represents the average time required to repair a component failure (Shopeju & Oyedepo, 2021). Figure 2 below shows that the DOpmoy in 2021, 2022 and 2023 of the generator set varied from 29.56% in February to 90%, which corresponds to the month of January. Apart from the month of January, the DOpmoy remained below 73% in the other months. The MTTR varied from 17 hours in January to 454 hours in February. Indeed, except for the months of January and April, the other months recorded MTTR greater than 250 hours, which corresponds to more than 10 days of downtime at each outage.

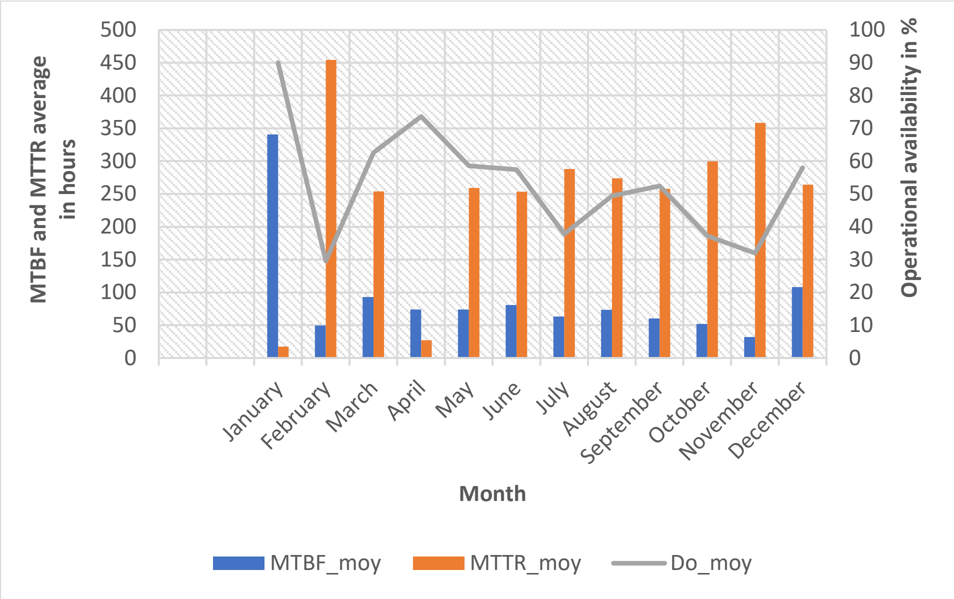

Figure 2: Evolution curves of MTBF, MTTR and DOpmoy from 2021 to 2023

Analysis of the correlation between SFC and mean maximum atmospheric temperature

In order to make the best use of thermal power plants, some indicators are observed among which we can mention, the fuel consumption, the specific consumption and the load rate of the generator [31]. Figure 3 below shows the evolution of SFC as a function of atmospheric temperature. Calculated SFC above the reference value of 185 g/kwh in 2021, 2022 and 2023. There are high SFC from March to May, 225 g/kwh corresponding to temperature peaks that reached 44°C in 2021, 232 g/kwh in April where the measured temperature is 44°C and 209 g/kwh in August with a temperature of 39°C in 2022. In 2023, the SFC changed from 217 to 220 g/kwh between January and April when the temperature also rose from 41 to 44°C. The generator remained after that, unavailable for the rest of the year. Thus, a correlation is observed between atmospheric temperature and SFC.

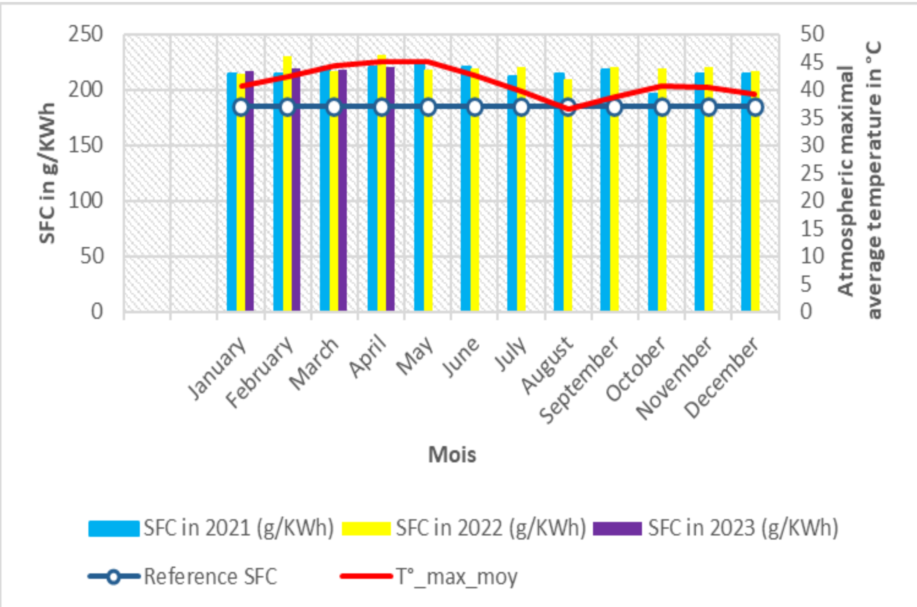

Figure 3: SFC evolution curves in 2021, 2022, 2023 relative to the baseline moy and SFC reference

In 2021, 2022 and 2023, the charging rates of the generators could not reach the average charging rate of 85% according to ISO conditions. In 2021, it rose from 0 to around 82%. For example, between May and August, the load changed from 79 to 82%, while the temperature dropped from 44 to 39°C and from 82 to 73% from August to October for a temperature that changed from 39 to 43°C. In 2022, It approaches the mean value when the atmospheric temperature drops from 44 to 39°C between May and August. When the temperature increases from 40 to 44°C between January and May, the load moves away from the reference value of the load. In 2023, the load changed from 77 to 76% for a temperature that varied from 40 to 44°C. Thus, there is a negative influence of the high atmospheric temperature on the load of the generators. The situation is shown in Figure 4 below.

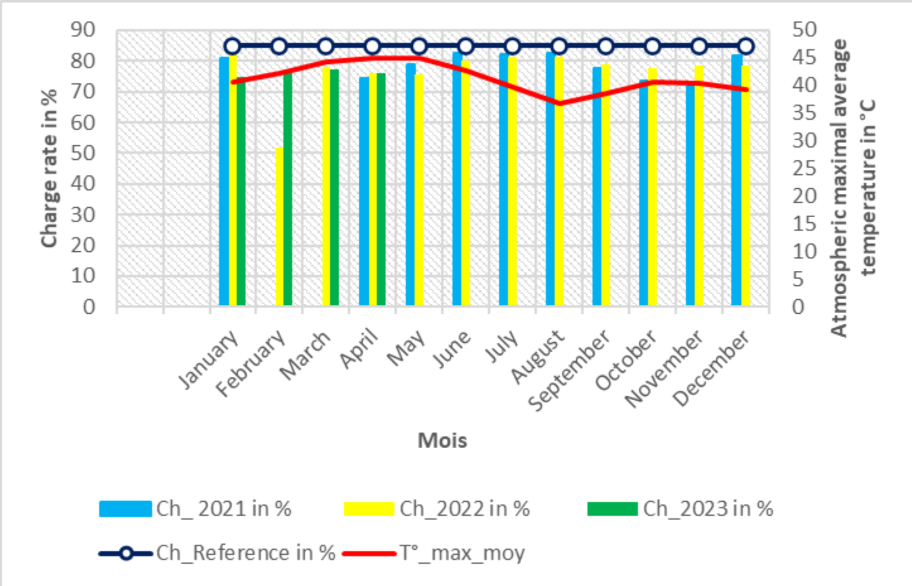

Figure 4: Curves of the evolution of the Ch in 2021, 2022, 2023 with respect to φmoy and the reference Ch.

Generator Breakdown Analysis

Figures 5 below show circular statistical images divided into slices, to show the major causes of the 2021-2023 cumulative generator outages. It is clear that the high temperature of the engine bearings is the main cause of stoppages, with 62%. With 15%, the turbo compressor failures come in second position. The remaining causes are also important, but negligible in both (02) cited above.

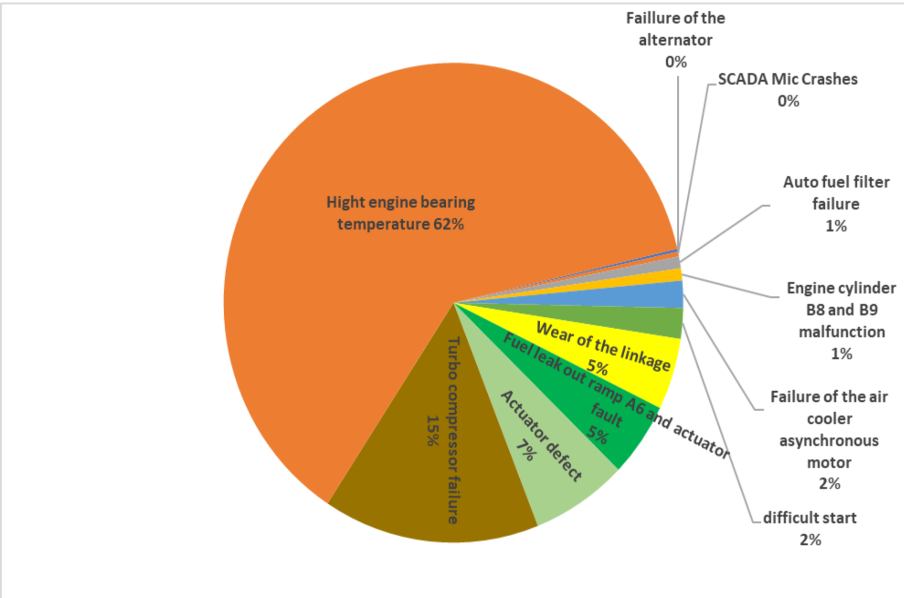

Figure 5: Causes of Generator Break from 2021 to 2023

In order to better understand the causes of the stops illustrated in figure 5 above, an failure modes, their effects and criticalities analysis (FMECA) was made and allowed us to realize that the wear parts of the turbo-compressor are the bearing rings and shaft. In addition, the high temperature of the engine bearings is the cause of wear on the bushings, engine block bearings, and crankpins and trunnions of the crankshaft. Table 4 below shows the average ratio (μ) between the theoretical life (Vt) of the parts and the operational life (VO), estimated over three (03) years (2021, 2022 and 2023).

Table 4: Service life of parts

Pièces d'usure	**V_t (h)**	**V_o (h)**	**$\mu = \frac{Vt}{Vo}$ (%)**
Turbocompressor rings and rotor	12 000	385	3,20
Motor bearing bushings	18 000	83	0,46
Engine bearings and crankshaft	6 000	524	8,73

It is noted that the calculated ratios are low and this is explained by an accelerated degradation of the service life of the wear parts mentioned above. Several factors may be responsible for this situation. Engine coolant temperatures during the study period reached 93°C in March, April and May and 82°C in August. It can therefore be said that this degradation is also supported by the atmospheric temperature in relation to the results of the analysis obtained. To remedy this problem, we propose the replacement of a solar photovoltaic system in order to refrain from operating the group during the day (from 8 am to 6 pm), a maintenance approach centered on temperature, integrating materials science to adapt wear parts.

Maintenance approach incorporating ambient temperature

To validate the maintenance policy of the generator, adapted to the conditions of Burkina Faso, three (03) criteria are considered. These are Readiness (DOP), Reliability (F) and Temperature (T°). With each criterion, there are the specifications presented in table 5 below:

Table 5: Maintenance policy validation criteria

Criteria	**Valeurs**
Good operational readiness	95%
Poor operational readiness	65%
Good reliability	98%
Poor reliability	68%
Good ambient temperature for generators	35°C
wrong ambient temperature for generator sets	40°C

Weightings are assigned to each criterion namely, D_{OP} (readiness) = 0.3, R (Reliability) = 0.3, T° (Temperature) = 0.4 and calculated maintenance policies. We can therefore calculate the values of the Total Interest (TI) for each policy based on the weighting value and specifications of each criterion. Consider the following maintenance policies:

- at T° = 35°C; R = 90% et D_{OP} = 80%
- at T° = 40°C; R = 80% et D_{OP} = 75%
- at T° = 45°C; R = 70% et D_{OP} = 70%

According to the first maintenance policy presented in table 6 above, we obtain:

Table 6: Validated maintenance policy

Formulas	**Total Interest (IT) calculations**	**Values**
(T° poor – T°) / (T° poor – T° good)	IT (T°) = (35°C - 30°C) / (35°C – 25°C)	0,5
(D_{OP} – D_{OP} poor) / (D_{OP} good – D_{OP} poor)	IT (D_{Op}) = (0,8 - 0,65) / (0,95 – 0,65)	0,5
	IT (F) = (0,9 – 0,65) / (0,98 – 0,68)	0,83
(R – R poor) / (R good – R poor)	IT (A) = (0,4 x 0,5) + (0,3 x 0,5) + (0,3 x 0,83)	0,6
	IT (B) = (0,4 x 0,66) + (0,3 x 0,33) + (0,3 x 0,5)	0,51
	IT (C) = (0,4 x 0,75) + (0,3 x 0,16) + (0,3 x 0,16)	0,39

In view of the results obtained, it is noted that maintenance policy A is the best with an IT of 0.6. The recommended ambient temperature is 35°C, reliability 90% and uptime 80%.

The generator works in 24hours/24 and 7 days/7 to ensure the availability of electrical energy from SONABEL's national interconnected network. In view of the constraints related to temperature and maintenance policy, it is essential to reduce its operating time per day. Thus, it will only work in the event of solicitation, in the evening or at night when temperatures are low. Currently the generator runs on 24hours/24 and on a weekly basis, its service life is as follows:

- Hours/week = 24x7 = 168 hours/week.
- Hours/month = 168x4 = 672 hours/month.
- Hours/year = 672x12 = 8 064 hours/year.

In 25 years, it will have 201 600 hours of operation.

After the combination of solar panels in parallel with the generator, it will now run 10h/24 per day and always on a weekly basis. Its duration is:

• Hours/week = 14x7 = 98 hours/week.
• Hours/month = 98x4 = 392 hours/month.
• Hours/year = 392x12 = 4 704 hours/year.
In 25 years, it will have approximately 117 600 hours of operation.
In order to improve the reliability of the parts concerned, notably the turbo-compressor, wear parts (linkage...), coupling (valve, camshaft, bearing, crankshaft...), bushings, segments and pistons, could be improved by about 50%. Thus, the results obtained are:
- the reduction of the number of hours of daily operation of the generator, with a combination of photovoltaic panels producing at least 18 MWh per day;
- the reduction of ambient temperature to 35°C maximum using chillers;
- maintaining reliability at 0.9% and operational readiness at 0.8% with a predictive maintenance approach based on ambient temperature.

DISCUSSION

The combined use of a diesel generator with a photovoltaic (PV) module or solar panel will save money through the use of both photovoltaic and diesel systems. Indeed, the additional input of solar energy minimizes fuel consumption [32]. The assessment of the energy benefit (gain) of the tilt angle correction of photovoltaic modules in a hybrid photovoltaic/diesel generator system shows that photovoltaic panels provide clean and renewable energy during the day, while diesel generators provide a reliable backup in times of low solar radiation or high energy demand [33]. In addition, hybrid systems combining solar photovoltaic and diesel generator have become essential. Indeed, they are generally used to deal with growing threats to the environment and the rapid depletion of fossil fuel resources. The operation of diesel generators poses significant sustainability challenges, particularly with regard to greenhouse gas emissions and air quality. They emit about 0.15 to 0.2 kg of CO_2 per kWh [34]. An analysis of the reliability of a group of internal combustion engines in a power plant is made using optimization methods for artificial neural networks. Indeed, maintenance indicators such as MTBF, MTTR, availability and reliability were analyzed with the objective of developing a computer model capable of predicting the key reliability indicator. The Weibull distribution can also be used to provide parameters and curves after the exploitation of the time between failures and Technical Repair Times (TTR) (Tatsinkou Fogang and al., 2024). Of all the studies presented above, none has addressed a maintenance approach to improve the reliability and availability of generating sets, thanks to the combination of photovoltaic solar panels. Our study was concerned with the analysis of reliability, maintainability, operational readiness and atmospheric temperature of a 16.5 MW generating set of the Kossodo thermal power plant. It has thus shown the impact of ambient temperature on reliability and operating indicators of the generator set and ends with a sketch of maintenance approach based on ambient temperature.

CONCLUSION

This study has made it possible to know the difficulties related to the production of electrical energy of the MAN B&W generator set of the Kossodo power plant. It illustrates the consequences due to high ambient temperature and poor maintenance policy of the generator. Average operational readiness was 26.47% in 2023, 56.54% in 2021 and 80.06% in 2022. Values below the targets to be achieved for a better maintenance policy. In addition, the analyses have shown that atmospheric temperature has a negative effect on maintenance indicators, including MTBF, MTTR and DOP. It is also responsible for the low load and the increase in specific consumption of the generator, with technical consequences on the thermal engine and economic consequences on SONABEL. Also, considering the nature of the majority of the failures identified, we can see the impact of atmospheric temperature. In the future, a maintenance approach focusing on the ambient temperature of the generators in the Sahel countries
will allow an adapted maintenance policy to be applied and reduce the daily operating time of the generators. They can be requested in the interval of time from 6pm to 7am.

ABBREVIATIONS

DDO: Distillate diesel oil
DOP: Availability operational
FMECA: Failure modes, their effects and criticalities analysis
HFO: Heavy fuel oil
IT: Total Interest
MTTR: Average technical repair times
MTBF: Average operating times
MW: Megawatt
MWh: Megawatt-hours
SFC: Specific fuel consumption
SONABEL: Burkina Faso National Electricity Company

TTR: Technical repair time
T°: Temperature

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