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Performance Analysis and Assessment of Ihovbor Power Plant, Edo State, Nigeria

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Abstract:- This paper presents the analysis of Key Performance Indicators carried out on four (4) Gas Turbine Generators at Ihovbor Power Plant, Benin City, Edo State for a period of four (4) years (2019 -2022). The study was done through an exhaustive collection of data from operational records and plant data sheets recorded by operators in the power station. This investigation used the NERC/IEEE std 762 generator performance indices amongst other calculated Key Performance indices in the evaluations and analysis of the collected data. The result of the analysis reveals that the overall availability factor (Equipment availability factor and Energy Availability factor) for the individual years were 53.49, 50.00, 58.33 and 56.48 respectively for Equipment Availability factor and 21.65, 6.13, 4.44 and 15.72 respectively for Energy Availability factor which is against industry best practices of 80 – 99%. Also, the capacity factors for the individual years are 17.75, 4.75, 3.78 and 13.30 respectively which is against industry best practices of 50 – 80%. Also, the results reflects a low overall average MTBF for the individual units which are 70.67, 70.66, 49.08 and 9.65 respectively and a high overall average MTTR for the individual units which are 202.14, 146.10, 488.47 and 670.52 respectively. The shortfall in performance levels of the plant is attributable to low plant availability due to frequent unit breakdowns/failures, overdue maintenance outage of some units, inefficient preventive and predictive maintenance programs, instability of the national grid system, and inadequate supply of gas among others. Measures to improve the performance indices of the plant were suggested.

I. INTRODUCTION

In recent years, the demand for reliable and efficient energy sources has intensified globally, with a particular emphasis on sustainable and high-performance technologies. Among these, gas turbine power plants have emerged as pivotal players in meeting energy needs due to their operational flexibility, relatively lower emissions, and ability to provide reliable power. In Nigeria, a nation rich in natural gas production but grappling with significant energy challenges, optimizing power generation infrastructure is critical for supporting economic growth and enhancing the quality of life [1].

Nigeria's power generation capacity is pegged at about 16,384MW. This capacity is mainly from hydro and gas-fired thermal power plants, with the hydro plants having a capacity of 2,062MW and gas-fired with a capacity of 11,972MW. Other sources such as Solar, wind, diesel and heavy fuel oil (HFO) have a combined capacity of 2,350MW [2]. Unfortunately, the Nigeria's transmission capacity currently hovers around 7,500MW and 8,000MW, though electricity generation on the national grid has been fluctuating between 4,000MW to 5,000MW for several years [3]. This, amongst several other reasons has forced the National Control Centre to prioritise generation dispatch among the power plants. For one, the National Control Centre (NCC) located in Osogbo, a unit of the Transmission Company of Nigeria (TCN) has tended to favour the Independent Power Producers (IPPS), who come under the protection of their Power Purchase Agreements (PPAs).

Whereas the NDPHC owned by all the federal, state and local governments should ordinarily be the industry's backbone, it has become an entity that is resorted to after other interests have been satisfied. For instance, it is always the first to be directed to shut down its operations when there's a fluctuation in the system, leading to massive loss of revenue [4].

The performance evaluation of gas turbine power plants is essential for understanding their effectiveness in the Nigerian context, where the energy sector faces unique challenges including fluctuating fuel quality, varying ambient conditions, and frequent operational stresses. This research focuses on the comprehensive assessment of a gas turbine power plant situated in Nigeria, aiming to provide insights into its operational efficiency, reliability, and areas for improvement.

The significance of this study lies in its potential to contribute valuable data and recommendations for optimizing the performance of gas turbine systems in Nigeria. By analyzing various performance metrics and operational parameters, this research seeks to identify critical factors impacting the plant's efficiency and reliability. This will not only enhance the operational effectiveness of the specific plant under review but also offer broader implications for similar facilities across the country.

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Understanding the operational dynamics and performance constraints of gas turbine power plants in Nigeria can lead to more informed decision-making, better maintenance strategies, and improved energy security. This introduction outlines the scope of the research, highlights the importance of performance evaluation, and sets the stage for an in-depth exploration of the gas turbine power plant's performance in Nigeria.

- *Overview of the Ihovbor Power Plant*

Benin Generation Company Limited, commonly known as Ihovbor Power Plant (6º24'20"N 5º41'00"E) is located at Ihovbor Community, a suburb of Benin City, Edo State. It was one of the Power stations built under the National Integrated Power Project (NIPP) [5].

The National Integrated Power Project was conceived in 2004 by the President Olusegun Obasanjo administration to address the issues of insufficient electric power generation and excessive gas flaring from oil exploration in the Niger Delta region. Hence, ten (10) new power plants were proposed to be built of which Ihovbor Power Plant is one of them[6].

Ihovbor Power Plant is a 451MW (ISO 507.6MW) Open Cycle Gas Turbine (OCGT) Power plant. It is a General Electric Frame 9E DLN-Type gas turbine with four (4) gas turbines each having a capacity of 112.75MW (ISO 126.9MW) [7].

Construction of the power plant started in 2005 and was completed between 2013 and 2014 with each units having different stages of commissioning and reliability run [8].

Gas supply to the plant is through the Escravos-Lagos Pipeline System (ELPS). Each Gas turbine utilizes 30mmscf of gas at Maximum capacity making the total gas supply requirement for all the turbine to be 120mmscf [8].

Power Evacuation from the Power Plant is through the Ihovbor-Osogbo Transmission Line (H7V) and the Benin-Ihovbor Transmission Line (B7V) each handling a capacity of about 650 MVA each [8].

Fig 1 Gas Turbine Area of the Ihovbor Power Plant

II. METHODOLOGY

Data on power generation and outages, as well as durations and reason(s) for the outage, of the plant were obtained for all the four units. These data were collected from the plant's daily operational log book and outage reports over a 4-year period, from January 2019 to December 2022 from the operations department. Quantitative analytical approach in line with the NERC and IEEE 762 std generator performance indices was adopted to appraise the performance characteristics of the case study plant. The units were appraised individually as well as the overall plant for every indicator. The following data were collected:

- **Installed Capacity:** This is the total installed capacity of all units potentially operational in the month. It is the maximum rated output of the generator designated by the OEM – General Electric. It is expressed in Megawatts (MW) and is given as 112.75MW per unit which is 451MW for the total capacity of the power plant.
- **GT Synchronization Time:** This is the instantaneous time at which the gas turbine is synchronized to the grid. It is time at which the process of matching the frequency of a generator is achieved. In simple term, it is the time at which the unit starts generating power to the public. This happens when the Generator Circuit Breaker is closed. This data is captured by the Control room operator in their log sheet.

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- **GT Shutdown/Trip Time:** This is the instantaneous time at which the gas turbine is taken off or trips from the grid. It is the time at which the units stops generating power to the public. This happens when the Generator Circuit Breaker (GCB) is opened. This data is captured by the Control room operator in their log sheet.
- **GT Fired Hours/Unit Operating Hours:** This is the total hours when the Gas Turbine is started. It is calculated automatically and obtained from the Central Control Room HMI. It is also captured on a daily basis by the Control room operator in their log sheet.
- **Energy Generated:** This is the sum of the total energy generated which was captured on a daily basis. This was obtained per unit from the log sheet as recorded by the control room operator.
- **Gas Consumed:** This is the sum of the total gas consumption which was captured on a daily basis. This was obtained per unit from the log sheet as recorded by the control room operator.
- **Planned Outage Hours:** These are the hours the unit was out due to planned maintenance activities which includes preventive maintenance programs or scheduled outages as recommended by the OEM.
- **Grid Disturbance Hours:** For an available unit, this is the total duration a unit was out due to grid disturbance. The grid disturbance could be as a result of a Total or partial Grid Collapse resulting to the unit tripping or as a result of High Grid Frequency forcing the system operator to request that the unit is shut down. Also, a loaded evacuation line can force the system operator to request that a unit is shut down.
- **Gas Supply Interruption Hours:** For an available unit, this is the total duration a unit was out due to gas supply interruptions. This could be as a result of No/low gas supply from the Gas Supply network.
- **Power Station Failure Outage Hours:** This is the total duration a unit was out due to faults from the power plant. A fault can be detected through signals on the units which may force the unit to trip or shut down by the operator. For example, a faulty temperature thermocouple can force the unit to trip.
- Empirical data obtained from plant records (which were discussed above) from 2019 to 2022 were used to analyse the power plant performance. Information on the following was used in the analysis.
- **Availability Factor:** The availability factor (A_f) of a power plant is the amount of time that it is able to produce power over a certain period of time divided by the amount of the time in the period. The availability factor is a measure of the ability of the power plant to perform its operational function. A distinction is made between equipment availability and energy availability. While Equipment availability Factor (Equipment A_f) or otherwise called Mechanical Availability is the ration of available time (operating and standby time) to the calendar period, Energy availability Factor (Energy A_f) or otherwise called Commercial Availability is the ration of available energy to maximum possible energy based on the installed capacity in the period under report. Both are represented mathematically as:

$$Equipment\ A_f = \frac{T_{ah}}{T_h} \times 100\% \quad (1)$$

Where,

T_{ah} is the Total Available Hours of the units in a given period.

T_h is the Total Operating/Period Hours in a given period

$$Energy\ A_f = \frac{T_h - T_{oh}}{T_h} \times 100\% \quad (2)$$

Where,

T_h is the Total Operating/Period Hours in a given period.

T_{oh} is the Total Outage Hours in a given period.

- **Load Factor:** Load Factor (L_f) is defined as the ratio of the average load to the peak load in a given period. Since the average load is always less than the peak load, the lead factor is always less than unity. It is represented mathematically as:

$$L_f = \frac{E_{av}}{E_{md}} \quad (3)$$

Where,

E_{av} is the average energy generated in a given period.

E_{md} is the maximum energy demand for the given period

- **Capacity Factor:** Capacity Factor (C_f) is the amount of power that is generated during a specific time period, compared to the amount of power that could have been produced if operating at full output for that same time. Capacity factor is expressed in percent. It is represented mathematically as:

$$C_f = \frac{E_g}{C_{in} \times T_h} \times 100\% \quad (4)$$

Where,

E_g is the Total Energy Generated in a given period.

C_{in} is the installed capacity.

T_h is the Total Period Hours in a given period.

- **Plant Use Factor:** This is the ratio of the actual energy generated during a given period to the product of capacity of the unit and the number of hours the unit has been in operation during the period. This is a modification of the plant Capacity factor in that only the actual number of hours that the unit was in operation is used [9].

$$PU_f = \frac{E_g}{C_{in} \times T_{rh}} \times 100\% \quad (5)$$

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Where,

E_g is the Total Energy Generated in a given period.

C_{in} is the installed capacity.

T_{rh} is the Running/operating Hours in a given period.

The Plant Use Factor can only be calculated as the ratio of the Capacity Factor to the Energy Availability Factor/

- **Unplanned Capability Loss Factor:** Unplanned Capability loss factor (UCLF) is defined as the percentage of maximum energy generation that a unit is not capable of supplying to the National Grid because of unplanned energy losses. Energy losses are considered unplanned if they are not scheduled at least four weeks in advance. This refers to unplanned events that is under management control e.g. load loss due to operating errors or inadequate maintenance. A low UCLF value indicates that the plant is reliably operated and highly available.

$$UCLF = \frac{P_{Loss(within\ management\ control)}}{Max_{energy}} \text{ x } 100\% \quad (6)$$

Where,

Max_{energy} = Unit capacity x No. of units x 24 x No. of days in the month

$P_{Loss(within\ management\ control)}$ = MW capacity of losses within management control x downtime of Load Loss

- **Planned Capability Loss Factor:** Planned Capability loss factor (PCLF) is defined as the percentage of maximum energy generation that a unit in not capable of supplying to the National Grid because of planned energy losses. This occurs during a scheduled or planned outage. A scheduled or planned outage is an outage that occurs when a unit is deliberately taken out of service, usually for purpose of preventive maintenance or repair [10]. PCLF is determined by the maintenance regimen of the Power Plant. A relatively low value for PCLF as compared to the maintenance regimen may indicate that not enough opportunities are made available to perform maintenance activities.

$$PCLF = \frac{P_{Loss(preventive\ maintenance)}}{Max_{energy}} \text{ x } 100\% \quad (7)$$

Where,

Max_{energy} = Unit capacity x No. of units x 24 x No. of days in the month

$P_{Loss(within\ management\ control)}$ = MW capacity of losses within management control x downtime of Load Loss

- **Other Capability Loss Factor:** Other Capability loss factor (OCLF) is defined as the percentage of maximum energy generation that a unit in not capable of supplying to the National Grid because of unplanned external energy losses. This refers to losses associated to unplanned events that are beyond management control e.g. grid instability, gas constraints, transmission line losses etc. A low value of OCLF indicates that factors outside of management control are not significantly contributing to loss of capacity due to unplanned external events.

$$OCLF = \frac{P_{Loss(beyond\ management\ control)}}{Max_{energy}} \text{ x } 100\% \quad (8)$$

Where,

Max_{energy} = Unit capacity x No. of units x 24 x No. of days in the month

$P_{Loss(beyond\ management\ control)}$ = MW capacity of losses within management control x downtime of Load Loss

- **Mean Time Between Failures:** The Mean Time Between Failures (MTBF) is defined as the time when a unit is out for maintenance to the next time it was declared unavailable for maintenance after being put back to service. It is simply the time between inherent failures of a unit. It is expressed in hours and calculated as:

$$MTBF = \frac{T_{rh}}{N_f} \quad (9)$$

Where,

T_{rh} is the Running/operating Hours in a given period.

N_f is the number of failures in the same period.

- **Mean Time to Repair:** For a repairable system, the Mean Time to Repair (MTTR) is defined as the time between the start of a failure and the time the unit is restored back to normal operation. It is also expressed in hours and calculated as :

$$MTTR = \frac{T_{oh}}{N_f} \quad (10)$$

Where,

T_{rh} is the Total Outage Hours in a given period.

N_f is the number of failures in the same period.

- **Unit Reliability:** Reliability is simply the probability that a device or system will operate for a given period of time without failure, and under given operating conditions [11]. It is calculated as an exponential function and is expressed mathematically as:

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$$R(t) = e^{\left(-\frac{t}{MTBF}\right)} \quad (11)$$

Where,

t is the total time for the given period.

III. RESULTS AND ANALYSIS

In order to analyze the actual performance of the Power Plant, several indicators that give important information about the status of power plant operability were considered. The analysis is divided into three sections namely: Operational indicators, the reliability indicators and the loss factors as shown in Figure 1. The operational indicators shows how the plant has been utilizing its capacity over the period under review, the reliability indicators shows how well the system has been operated over the same period and the loss factor shows the cause of the individual losses to the system.

The input data for the analysis was obtained from the operator's data sheet and log book at the Power plant and the output gives quantitative information about the actual status of asset care of the utility. Reason for shortfalls where necessary was analyzed and summarized; and recommendation made.

The Power plant under study is comprised of four units which can be operated independently. The analysis was performed on average performance of all the units. Data was obtained from 2019 to 2022. Table 4.1 shows the operational data analysis for each year.

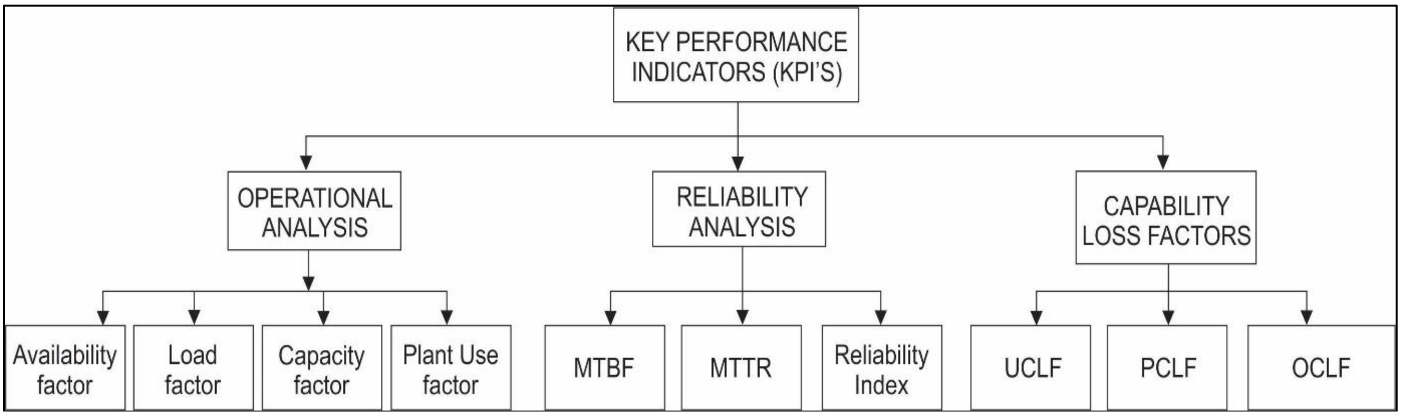

Fig 2 Structure of Research Analysis

Table 1 Running Hours of each unit from 2019 - 2022

Total Running Hours for each Gas Turbine per year				
	GTG-1	**GTG-2**	**GTG-3**	**GTG-4**
2019	4,755.30	2,539.90	0.00	298.30
2020	1,341.70	888.00	0.00	0.00
2021	402.00	849.80	347.20	0.00
2022	604.20	2392.90	2470.60	0.00

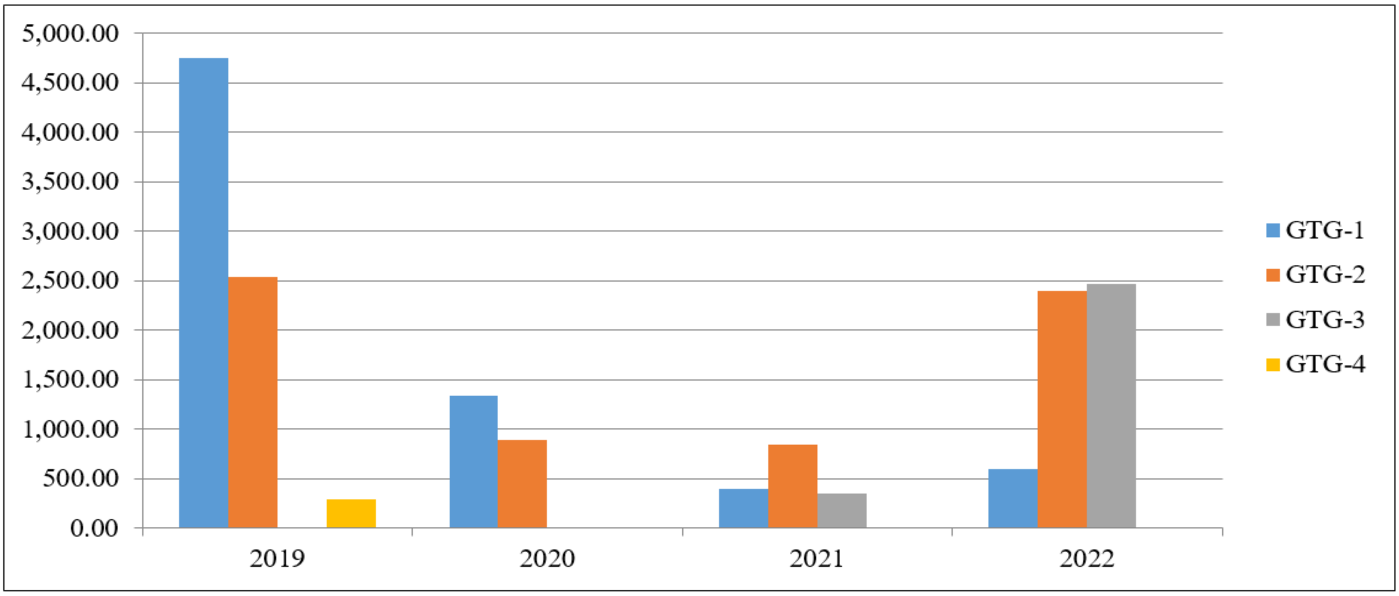

Fig 3 Plot Showing Running Hours for Individual Units from 2019 - 2022

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Table 2 Operational Analysis from 2019 -2022

		2019	2020	2021	2022
Equipment Availability Factor	%	53.49	50.00	58.33	56.48
Energy Availability Factor	%	21.65	6.13	4.44	15.72
Energy Generated	GWh	698.04	188.13	148.71	521.94
Capacity Factor	%	17.75	4.75	3.78	13.30
Plant use Factor	%	81.70	73.92	82.44	84.30

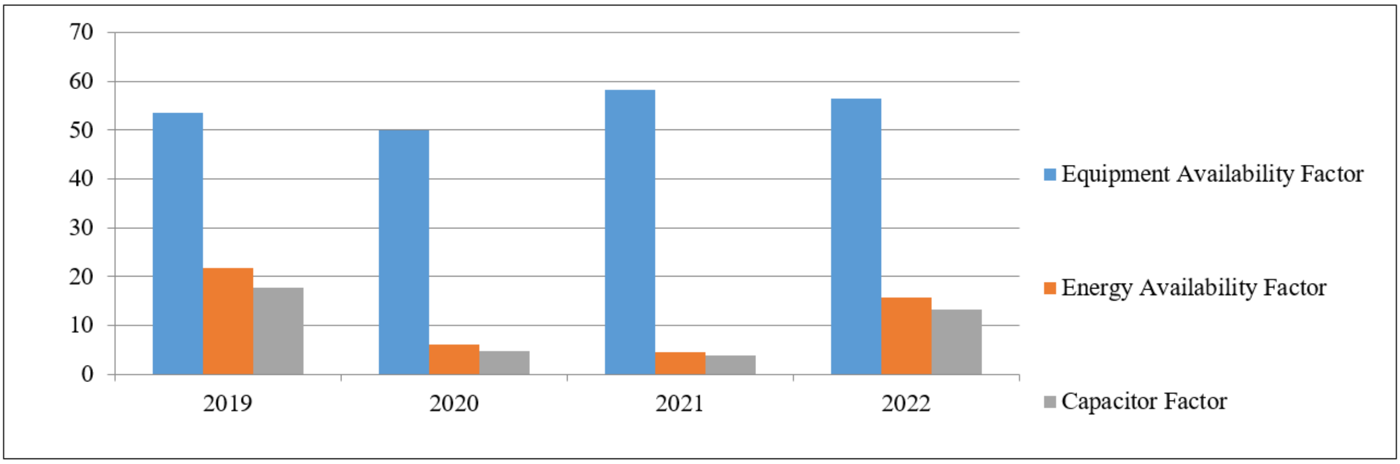

Fig 4 Plot Showing Equipment Availability Factor, Energy Availability Factor and Capacity Factor from 2019 – 2022

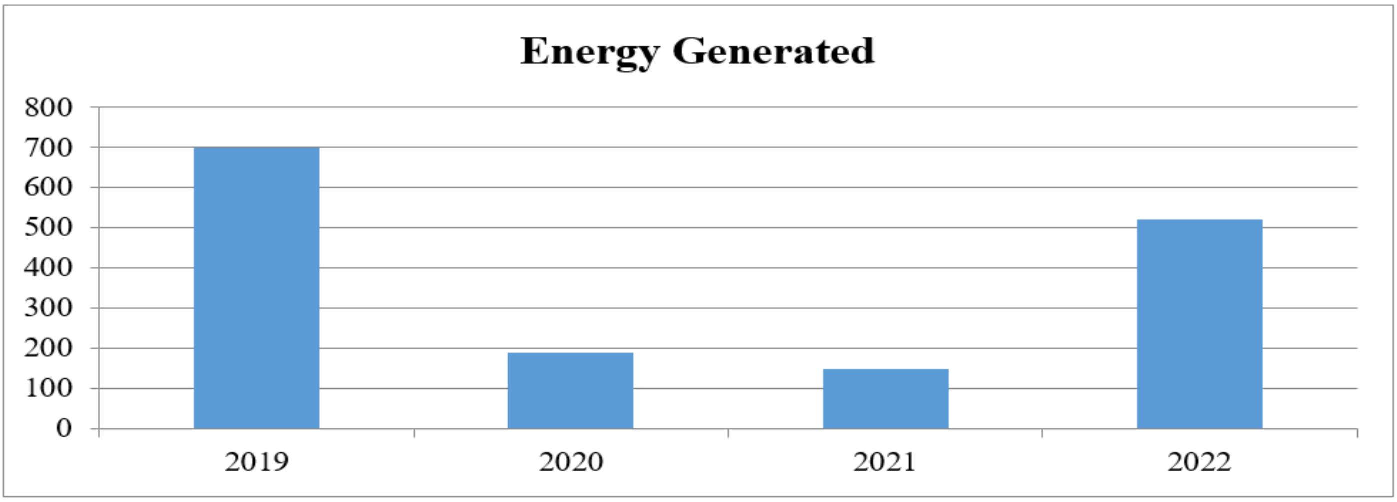

Fig 5 Plot Showing Total Energy Generated from 2019 – 2022

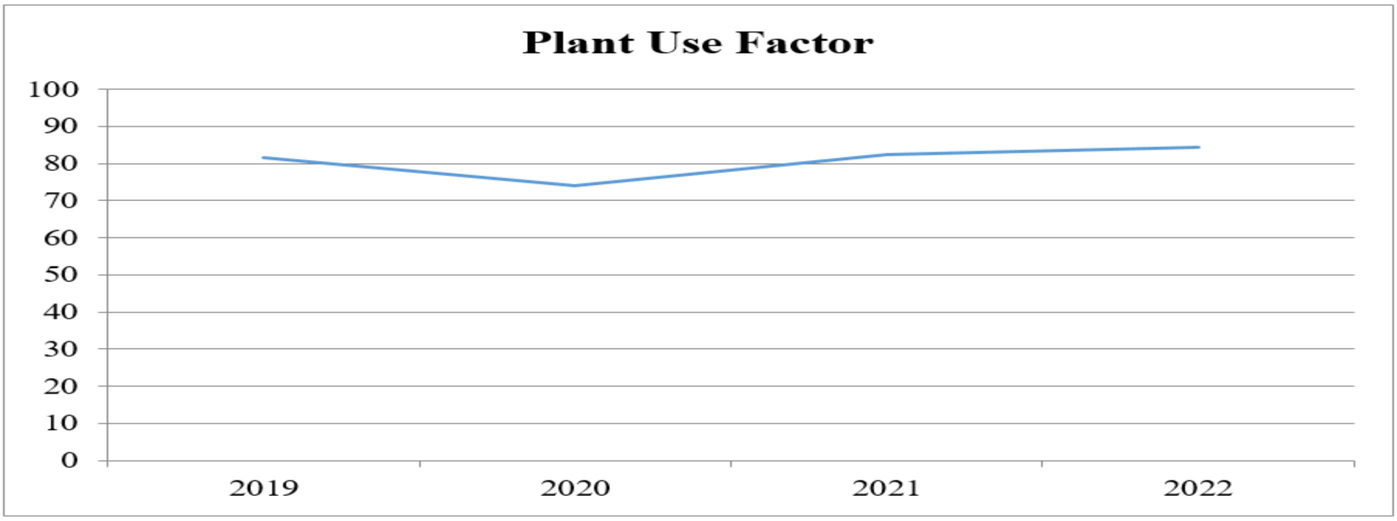

Fig 6 Plot Showing the Plant use Factor from 2019 - 2022

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Table 3 Units Reliability Analysis from 2019 - 2022

			GTG-1	GTG-2	GTG-3	GTG-4
MTBF	Hrs	**2019**	199.24	135.61	0.00	9.65
		2020	54.52	43.77	0.00	0.00
		2021	11.00	2.23	12.31	0.00
		2022	17.93	101.01	85.84	0.00
MTTR	Hrs	**2019**	1.94	90.76	730	490.08
		2020	137.11	137.17	732	732.00
		2021	240.89	240.02	486.56	730.00
		2022	428.60	116.45	5.32	730.00
Reliability Index	%	**2019**	45.37	44.74	0.00	6.77
		2020	27.39	26.73	0.00	0.00
		2021	11.40	3.40	13.56	0.00
		2022	13.26	44.62	36.69	0.00

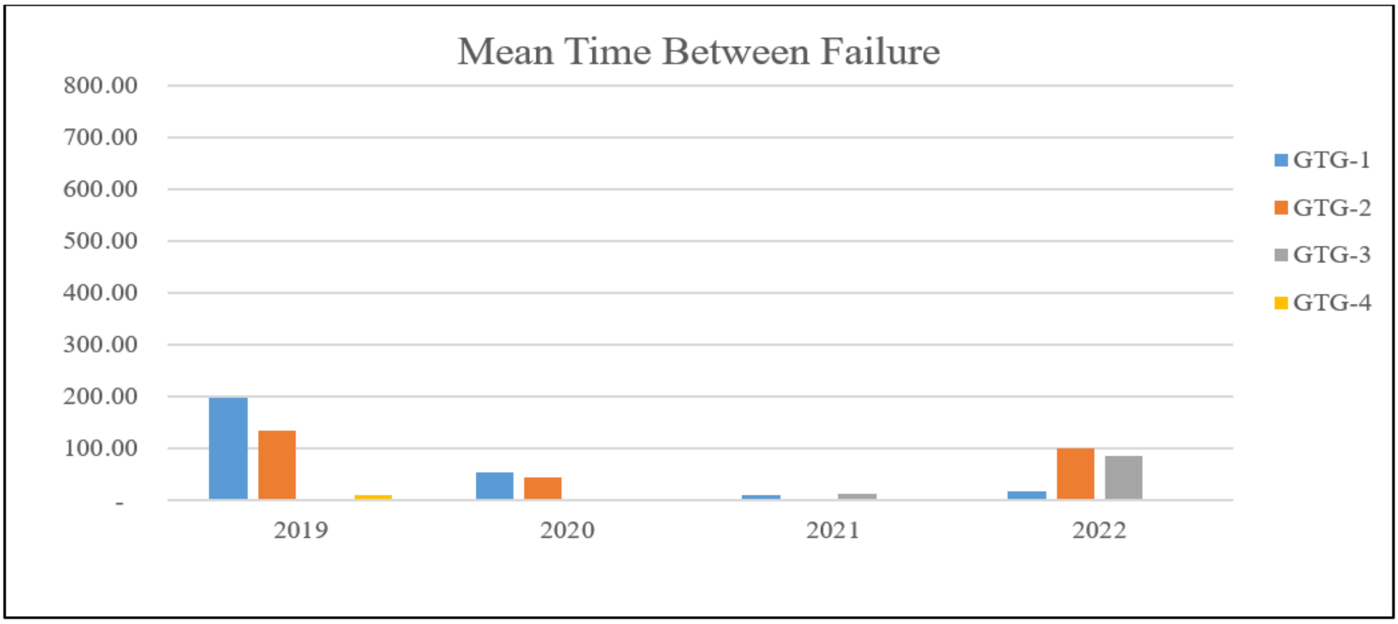

Fig 7 Plot of MTBF for Individual Units from 2019 – 2022

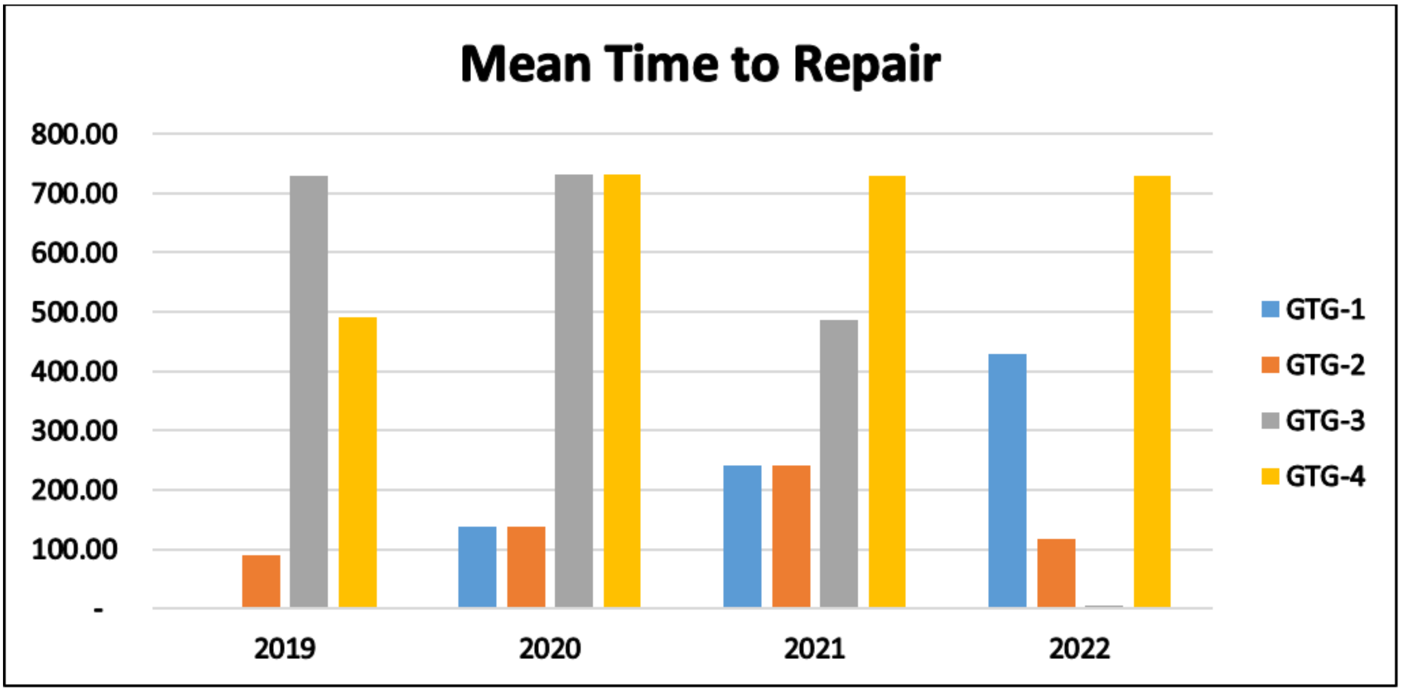

Fig 8 Plot of MTTR for Individual Units from 2019 – 2022

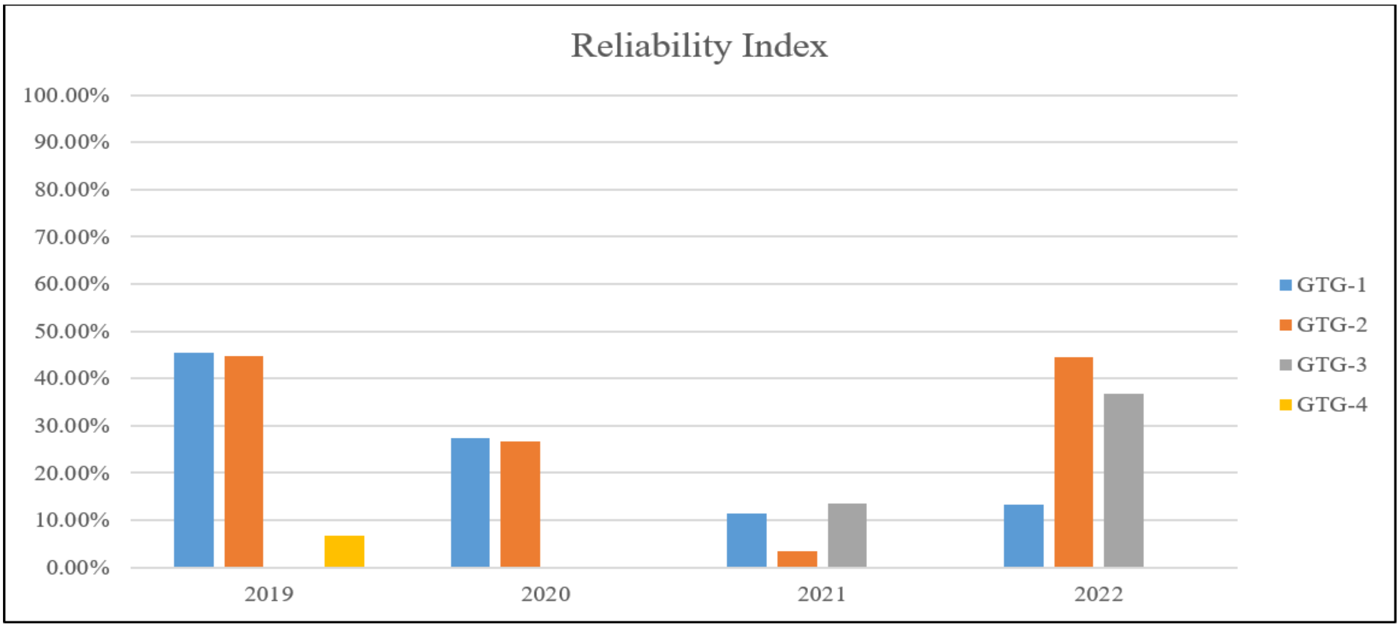

Fig 9 Plot of Reliability Indices for Individual Units from 2019 - 2022

Table 4 Energy Loss by Category from 2019 -2022

ENERGY LOSS FOR THE PERIOD UNDER STUDY (MWH)					
YEAR	**Energy Loss due to Scheduled Maintenance**	**Energy Loss within management Control**	**Energy Loss beyond management control**		**TOTAL**
		Power Station Failures	**Grid Constraint**	**Gas Restriction**	
2019	0.00	471,549.84	100,231.88	200,867.24	772,648.96
2020	0.00	586,769.53	56,728.13	283,959.84	927,457.50
2021	0.00	615,724.22	26,982.66	299,016.56	941,723.44
2022	0.00	434,077.03	4,970.63	392,322.19	831,369.85

Table 5 UCLF, PCLF and OCLF from 2019 - 2022

	UCLF	**PCLF**	**OCLF**
2019	47.74%	-	30.62%
2020	59.36%	-	34.51%
2021	62.65%	-	32.91%
2022	43.95%	-	40.33%

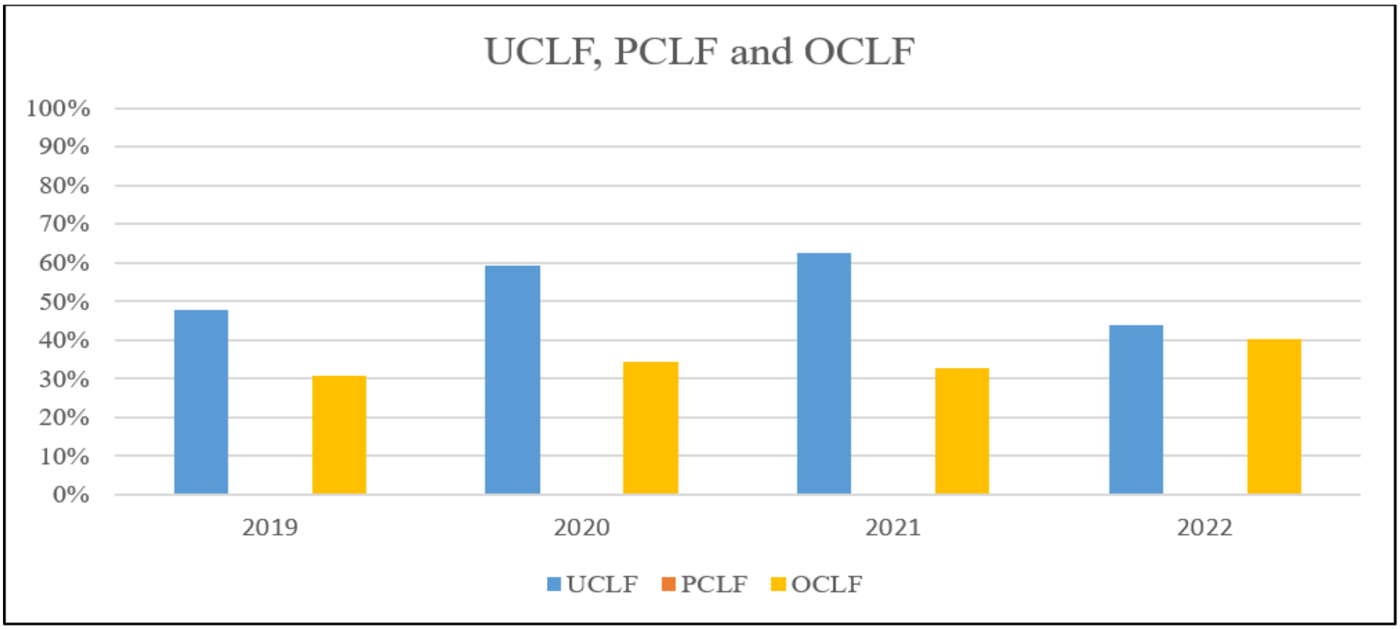

Fig 10 Plot of the Plant Capability Loss Factors from 2019 - 2022

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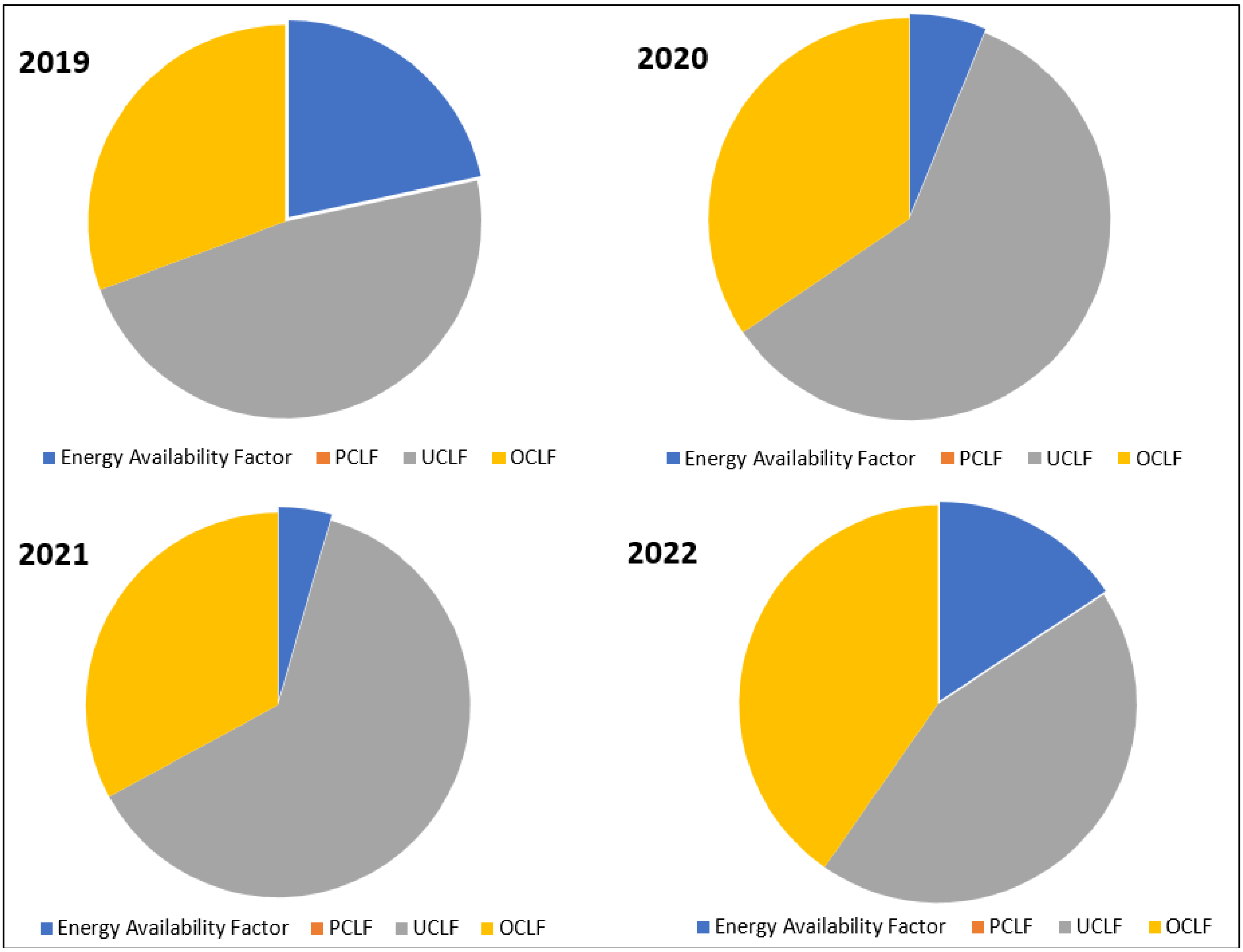

Fig 11 Graphical Summary of the Plant's Operations from 2019 -2022

IV. DISCUSSION

The Ihovbor Power Plant is a General Electric Frame 9E Open Cycle Gas Turbine having four (4) units with each having an installed capacity of 112.75MW totalling 451MW. The units were commissioned between 2013 and 2014 and since then, it has been operational till date. The analysis of the power plant from 2019 – 2022 was thoroughly conducted and the outcome is discussed below.

From Figure 3, while every other unit ran at some point within 2019 to 2022, GTG-4 did not run at all from 2020 to 2022. From the data, it was seen that a failure in GTG-4 occurred sometime in 2019 and was never rectified even till 2022. Also, GTG-3 did not run at all in 2019 due to a failure in the unit which was rectified around 2020 when the unit was finally run. However, it can be seen that the units were ran less frequently. This can be attributed to low gas supply, grid instability/ transmission evacuation constraints and frequent failure from the power plant.

Fig. 4 shows a relatively low Equipment availability of less than 60% for all the years under study. Unfortunately, even with the low Equipment availability recorded, the plant generated less than 50% of this availability and less than 25% of the total capacity of the plant throughout the years under review. This is shown in Fig 4 with the Energy Availability reading 21.65%, 6.13, 4.44% and 15.72% and the Capacity Factor reading 17.75%, 4.75%, 3.78% and 13.30% for the individual years. Comparing this performance to industry best practices of 80 – 99% for Availability factor and 50 – 80% for Capacity factor [12], this is extremely poor. While, this low indices can be attributed to poor maintenance regime, inadequate gas supply and grid network, this will be further narrowed when the capability loss factors are discussed.

Also, the plant use factor as shown in fig. 6 highlights the shortfall between the Energy Availability Factor and the Capacity Factor. This shows that even while the unit is on the grid, it does not generate at full capacity as it should have. The Plant Use Factor shows a shortfall of about 19.30% in 2019, 26.08% in 2020, 17.56% in 2021 and 15.70% in 2022. These shortfalls can be attributed to:

- Reduction in unit load as instructed by the grid controller to ensure adequate balancing of the grid's frequency.

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- Reduction in unit load so as not to surpass the allocated gas volume to the station when the station is not allocated the required daily volume of gas.
- The unit response to the grid as in accordance to the Grid code Section 15.8.3a which states that every generating units when synchronised to the Power system shall operate at all times under the control of a Governor Control System [13].
- Operational Inefficiency of the unit due to mechanical wear out.

Figure 7 shows that there is relatively short Mean Time Between failures resulting from incessant failures of the units. This reflected on the reliability of the units as seen in fig 8 as it shows no unit has an average of more than 50% for the entire period under study. GTG-4's reliability was the lowest as the unit was observed to be out of service since 2019.

Also, from Fig. 8, the Mean Time to Repair is relatively high which shows the response time given to maintenance to bring a unit back to service is quite slow. This confirms that the maintenance practice in the power plant is abnormally poor and the following can be depicted from this:

- Untimely supply of spares/Lack of spares to conduct corrective maintenance
- Inefficient preventive & predictive maintenance program leading to consistent failure of units
- Inadequate experience of staff/Lack of required staff skill level to quickly tackle faults when they occur.

Fig. 10 highlights the Unplanned Capability Loss Factor (UCLF) which was the highest, followed by Other Capability Loss Factors. Unfortunately, the Planned Capability Loss Factor (PCLF) was zero throughout the entire period as it was observed that the station conducts its scheduled maintenance only after the unit has experienced a break down failure. This can be as a result of early break down failures before the equipment reaches its established scheduled date for preventive maintenance. This further confirms the issue of poor maintenance practice in the station.

Table 5 further highlights that power station failures plays a major role of contributing to the capability losses, Gas constraints was a second major contributor to the capability loss factor and followed lastly by Grid constraints.

Fig. 11 highlights the plant's operational summary for the years under study. As it can be seen, the sum of the Energy Availability, Planned Capability Loss Factor, Unplanned Capability Loss Factor and Other Capability Loss Factors gives the total output of the plant for every given period. These show that the plant experienced a high Loss Factor compared to its Energy Availability or otherwise called Commercial Availability.

V. CONCLUSIONS

Ihovbor Power Plant is one of the 23 thermal power plants and one of the ten (10) NIPP power plants operating in Nigeria. The performance of a thermal power plant is majorly hinged on the plant's energy generation which is a function of the available power output and the running hours. Optimum energy generation, demands that the units generate to maximum possible capacity and operate for adequate running time and invariably break down/fail less frequently. To increase their capability of responding to changing circumstances, it is necessary to prolong the life of the plants by stepping up the level of regular maintenance.

A study on the performance analysis has been made and its performance evaluated using appropriate mathematical and statistical models. The evaluation was based on collected data from the Ihovbor power plant for a period of four years (2019 – 2022). The main performances that were studied include availability, reliability, capacity factor, Capability Loss Factors, MTBF and MTTR. These parameters were compared to the best industrial practices and target values.

The average mechanical availability and capacity factor of the plant throughout the period under study were found to be approximately 54.58% and 9.90% respectively. The Average MTBF obtained for the individual units (GTG-1: 70.67, GTG-2: 70.66, GTG-3: 24.54 and GTG-4: 2.41) shows that there is a relatively shorter time before a failure occurs. This has definitely impacted on the average unit's reliability index (GTG-1: 24.35%, 29.87%, 12.56% and 1.69%). The MTTR shows that there is a longer period taken to bring the unit back to service as can be observed in the obtained readings (GTG-1: 202.14, GTG-2: 146.10, GTG-3: 488.47 and GTG-4: 670.52).

The average Unplanned Capability Loss factors for the period under review was 53.43%; which means that more than half of the plant's capacity was los to Power Station Failure. The Planned Capability Loss Factor stood at zero throughout the entire period. The average Other Capabilities Loss Factor for the period under review was 34.59%. Unfortunately, the plant is limited to an average commercial availability of about 11.99% for the entire period.

This gives a poor performance of the plant's operational capabilities and the following recommendations are suggested to ensure the plant runs optimally.

- A robust and effective preventive and predictive maintenance should be adopted. However, having a CMMS in place can help achieve optimal deployment of the preventive and predictive maintenance programs.
- A gas sales Agreement should be considered to ensure regular supply of gas.
- A Power purchase agreement should also be considered to ensure priority is given to the plant for efficient evacuation of its generated power.
- Availability of mandatory spares should be upheld to ensure swift response to corrective maintenance.

- Timely execution of scheduled maintenance outages to ensure unit operates efficiently and optimally.
- Training of staff is essential to ensure they have the required skilled level to quickly clear out faults as they arise.
- Proper documentation and continuous operational analysis is advised to ensure records are always in place when required.

REFERENCES

[1]. Megbowon, I. O., and T. O. Oyebisi. 2005. *A* reliability assessment of the south western transmission lines of the Nigerian National Grid. *FUTAJEET* 4:17–22.

[2]. Okechukwu Nnodim (23, February, 2023). New Project will raise transmission capacity to 25,000MW – FG. *Vanguard Newspaper*, https://tinyurl.com/3fd44b48

[3]. Emmanuel Adeh (2022). NIPP: Taking advantage of Nigeria's wasting power assets. *Thisday Newspaper*, https://www.thisdaylive.com/index.php/2022/10/04/nipp-taking-advantage-of-nigerias-wasting-power-assets/

[4]. Ude, Chiziterem, Towards a Legal Framework for the Introduction of Smart Cities as a Solution to Energy Poverty and Carbon Emissions in Nigeria (August 16, 2023). Available at SSRN: https://ssrn.com/abstract=4542405 or http://dx.doi.org/10.2139/ssrn.4542405

[5]. Ihovbor Environmental Management Plan (2018), Ihovbor Power Plant, pp. 7 – 9

[6]. *Nigerian National Integrated Power Project*. In Wikipedia, The Free Encyclopedia. Retrieved 07:35, July 31, 2024, from https://en.wikipedia.org/w/index.php?title=Nigerian_National_Integrated_Power_Project&oldid=1193085852

[7]. Ihovbor Power Plant overview [Online], retrieved from NDPHC website https://ndphc.net/ihovbor [Assessed on May 30, 2024]

[8]. Ihovbor Annual Reports (2019 -2022), Benin Generation Company Limited, Ihovbor, pp. 3-5

[9]. Infrastructure Consortium for Africa (ICA, 2011). Regional power status in African power pools report. Tunisia: African Development Bank. p. 11-12

[10]. Oyedepo, S. O., and R. O. Fagbenle. 2011. A study of implementation of preventive maintenance Programme in Nigeria Power Industry—Egbin Thermal Power Plant case study. *Energy Power Eng*. 3:207–220.

[11]. Obodeh, O.,& Esanubor, T. (2011). Reliability assessment of WRPC gas turbine power. *Journal of Mechanical Engineering Research*, 3(8), 286-292. doi:https://doi.org/10.5897/JMER.9000040

[12]. Oyedepo, S. O., Fagbenle, R. O., Adefila, S. S., & Adavbiele, S. A. (2014). Performance evaluation and economic analysis of a gas turbine powerplant in Nigeria. *Energy Conversion and Managemen*t, 79, 431-440. doi:10.1016/j.enconman.2013.12.034

[13]. NERC, The Grid Code for the Nigeria Electricity Transmission System, https://nerc.gov.ng/resources/grid-code/