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Enhancing the Performance of West Tripoli Power Plant Gas Turbine Unit using Absorption Chiller

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Abstract:
Thermodynamics plays a fundamental role in understanding and optimizing the performance of gas turbine power plants. As well known that the gas turbine power plants are sensitive to inlet air temperature, as it directly influences their efficiency and power output. Inlet cooling systems, therefore, emerge as critical components in enhancing gas turbine performance, particularly in regions with high ambient temperatures.

This research study the significance of adding an absorption chiller system to the West Tripoli gas turbine power plant, a crucial energy infrastructure asset in Libya. The research explores the process of adding an absorption chiller into the plant's operation, leveraging its ability to utilize waste heat from the gas turbines to operate the absorption chiller.

The work performed in this paper is modeling and improving the performance of a single gas turbine unit used in the West Tripoli power plant using the IPSEpro software. Furthermore, an absorption chiller was modelled for stabilizing the gas turbine inlet conditions.

The result indicates that by stabilizing the inlet air temperature, the absorption chiller effectively enhances the gas turbine performance such as, efficiency, leading to a notable increase in power output. This improvement translates into significant economic benefits for the power plant and contributes to the overall stability of Libya's electricity supply.

Keywords: Exergy efficiency, gas turbine, absorption chiller, thermal efficiency, exergy destruction

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تعزيز أداء الوحدة الغازية محطة غرب طرابلس باستخدام مبرد الامتصاص

م. فهد الطيب المنتصر [1]، أ.د. نوري محمد الشول [2*]
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الملخص
تلعب الديناميكا الحرارية دورا أساسيا في فهم وتحسين أداء محطات توليد الطاقة للتوربينات الغازية. وكما هو معروف جيدا أن محطات توليد الطاقة بالتوربينات الغازية حساسة لدرجة حرارة الهواء الداخل، لأنها تؤثر بشكل مباشر على كفاءتها وإنتاج الطاقة. لذلك، تظهر أنظمة تبريد المدخل كمكونات حاسمة في تعزيز أداء التوربينات الغازية، خاصة في المناطق ذات درجات الحرارة المحيطة المرتفعة. يدرس هذا البحث أهمية إضافة نظام تبريد الامتصاص إلى محطة توليد الطاقة بالتوربينات الغازية في غرب طرابلس، وهي أحد أصول البنية التحتية الحيوية للطاقة في ليبيا. يستكشف

البحث عملية إضافة مبرد امتصاص إلى تشغيل المحطة، والاستفادة من قدرته على الاستفادة من الحرارة المهدرة من التوربينات الغازية لتشغيل مبرد الامتصاص.

العمل المنجز في هذه الورقة هو نمذجة وتحسين أداء وحدة واحدة من التوربينات الغازية المستخدمة في محطة توليد الطاقة في غرب طرابلس باستخدام برنامج IPSEpro. بالإضافة، تم نمذجة مبرد امتصاص لتثبيت ظروف مدخل التوربينات الغازية.

تشير النتيجة إلى أنه من خلال المحافظة على درجة حرارة الهواء الداخل للضاغط عند 15 درجة مئوية، يعزز مبرد الامتصاص بشكل فعال أداء التوربينات الغازية، مما يؤدي إلى زيادة ملحوظة في إنتاج الطاقة. يؤدي هذا التحسن إلى فوائد اقتصادية كبيرة لمحطة توليد الكهرباء ويساهم في الاستقرار العام لإمدادات الكهرباء في ليبيا.

الكلمات المفتاحية: الانتاجية، الكفاءة الحرارية، التوربين الغازي، مبرد الامتصاص، الطاقة المهدورة.

Introduction

Generally, gas turbine power plants operating in hot climate conditions suffer from a decrease in output power and thermal efficiency during the hot summer months. The typical combustion turbine on a hot summer day, loses about 20% from its output power than on a cold winter day. As a result, several cooling techniques and technologies have been involved over the years to reduce the degradation of turbine output power [1]. Therefore, cooling the turbine inlet air back to the ISO conditions which are, a temperature of 15ºC and relative humidity of 60% can restore. The design point performance.

M. Ameri, and S. Hejazi [2] stated in their study paper that for each 1ºC increase in ambient temperature, the power output will decrease by 0.74%, and also that the variation in the ambient temperature in summer months produces a typical loss of 20% of the rated capacity.

Inlet Cooling Methods

It is well known that ambient temperature, humidity and pressure are important factors in gas turbine performance. Thermodynamic analyses exposed that thermal efficiency and specific output decrease with an increase in humidity and ambient temperature as shown by Tsujikawa and Sawada [3]. El-Hadik [4], carried out a parametric study on the effects of ambient temperature, pressure, humidity and turbine inlet temperature on power and thermal efficiency. He concluded that the ambient temperature has a great impact on gas turbine performance, which increases with the turbine inlet temperature and pressure ratio. Reductions of power and efficiency due to a 1K temperature growth were found to be around 0.6 and 0.18% respectively. Inlet cooling methods in GT units, particularly in regions with high ambient temperatures and humid conditions. By reducing the inlet air temperature, these methods contribute to increased power output, improved fuel consumption, and reduced emissions. Ambient temperatures are typically decreased using the following methods:

1. Evaporative Cooler Systems: Water is distributed over media (such as wood wool fibers, or corrugated paper impregnated with anti-rot salts) through which the inlet air passes to be cooled and humidified [5].

2. Fogging Systems: Water is injected into the air through nozzles and creates a fog of small water droplets, 5e20 mm in diameter. The systems are divided into two subgroups as, a) Saturated systems, where the air is saturated before the compressor and, b) Overspray systems, where more water than is needed for saturation is injected. Water droplets enter the compressor, evaporate and cool the air [5].

3. Mechanical Chiller Systems: The mechanical chillers used in these systems could be driven by electric motors, steam turbines or engines. Drawing the inlet air across cooling coils, in which either chilled fluid or refrigerant is circulated, cools the air to the desired temperature. [6].

4. Absorption Chiller Systems: Similar to the mechanical refrigeration systems except that instead of using mechanical chillers, these systems use absorption chillers that require thermal energy (steam or hot water) as the primary source of energy and require much less electric energy than the mechanical chillers [6].

Absorption Chillers

The concept of using a chemical reaction to create a cooling effect dates back to the 1700s, but it wasn't until the 1800s that the first practical absorption chillers were developed. In 1824, French engineer Ferdinand Carré developed the first working absorption chiller, using ammonia as the refrigerant and water as the absorbent. AC systems utilize a heat source such as heat of gas turbine waste gases, heat of HRSG waste gases and heat of solar energy to generate chilled water. The chilled water is passed through a heat exchanger to cool the ambient air temperature. AC systems typically employ lithium-bromide Li-Br and water, with the Li-Br solution being the absorber and the water acting as the refrigerant. Such systems can typically produce chilled water of 6–7 °C [7].

Kakaras et al. [8] presented a computer simulation of the integration of an innovative absorption chiller for reducing the intake air temperature in gas turbine plants. The simulation results for two test cases were presented: a simple cycle GT and a combined cycle plant. They concluded that the effect of ambient air temperature variation results in a large penalty in the plant's performance for high ambient temperatures. The results from the integration of an evaporative cooler and of the air-cooling system under consideration showed the gain in power output and efficiency. The absorption chiller system demonstrated a higher gain in power output and efficiency than evaporative cooling for a simple cycle gas turbine. The results for the combined cycle case also showed that the absorption chiller can considerably increase the power output. Similarly, Ameri and Hejazi [2] have carried out feasibility of installing an absorption chiller system to cool the inlet air to the Chabahar power plant gas turbines (Six frame-5 gas turbines with the rated power of 16.60 MW). It has been shown that the average power output can be increased by as much as 11.3%. The maximum power augmentation is around 1.2 MW. The electric energy generation is increased by 14000 MWh/year. In [9], Boonnasa et al.analyzed the possibilities of improving the power output of the Combined Cycle Power Plant (CCPP) in Bangkok by reducing intake air temperature down to 15ºC. They proposed an absorption chiller to cool the inlet air. Authors reported, that it is possible to improve the output power of the gas turbine by 10.6% and the CCPP by 6.24%. Payback period of capital investments by 3.81 years.

Libya is one of those countries which have hot summer climate main aim of this paper is focused on improving the performance of the existing power plant 671 MW Simple Cycle Power Plant (SCPP) which is located west of Tripoli the SCPP consists of 4 units of SGT5-PAC 2000E Siemens gas turbines with each theoretically delivering 167MW. The performance assessment of the power plant was conducted by modelling only one GT unit (SGT5-PAC 2000E Siemens) by using IPSEpro software and then validating the IPSEPro model with actual data as well as the AC model with existing unit data. It should be noted that the process of adding an AC to the GT unit can be identically applied to the rest of the units in the West Tripoli power plant.

Plant description

West Tripoli Power Plant

The West Tripoli Power Plant is a SCPP with four units which have a gross output capacity of up to 671 MW. It is located on the Mediterranean coast, about 10 kilometers west of Tripoli, in Janzur, Tripoli.

The main detail of this plant is shown in Table1. The other mechanical and auxiliary systems of the plant include fuel tanks, an air intake structure, an exhaust gas diffuser, air-cooled heat exchangers, and a compressor cleaning unit. The plant is also fitted with continuous emission monitoring system (CEMS) and distributed control system (DCS).

Table 1: West Tripoli Power Plant Configuration.

Power Plant	Tripoli West Power Plant
No. of Units	4
Constructed By	ENKA İnşaat ve Sanayi A.Ş.
Date of Operation	2022
Type of Fuel	LDO LNG
Type of Turbine Rated Capacity	SGT5-PAC 2000E 167MW
Type of Generator Rated Capacity	SGen5-100A 180MVA
Manufacturer	Siemens

Methodology

IPSEpro Software

IPSEpro is a set of software modules for creating process models and then using these models throughout the lifecycle of process plants, IPSEpro is based on the concept of "standardized" components that are used to build the model of a complete process. Each model is mathematically represented by a set of equations and variables. To build the mathematical model of a process means to join all equations of the component models into a single system of equations. IPSEpro provides efficient data management, powerful mathematical methods, and an intuitive graphic interface (based on Windows) so that the user can fully concentrate on the technical aspects of his problems [10].

IPSEpro has flexibility at two levels, known as the component and process levels. The first, provides unlimited flexibility in defining the characteristics of the component models that are used for modeling processes. This allows the user to build component model libraries that exactly match his application requirements, while the second, allows complete freedom in arranging the available components in order to represent a process scheme. A graphical user interface facilitates and accelerates substantially the development of process schemes, and the presentation of the results of calculations. The user can compute energy and exertion with the use of this software, which can compute all of the thermodynamic parameters of the process streams [10]. In this project a custom unit named "Full

Comprehensive Library" was created using Model Development Kit (MDK) which contains all the components required for the modeling process.

Modelling and Validation

The GT unit for the West Tripoli power plant is presented, followed by the validation of the model using IPSEpro and also additionally the thermodynamic equations for this process are provided, Furthermore, the AC system model that is also presented with the working parameters and also the thermodynamic equations.

Modelling of Gas Turbine Unit for West Tripoli Power Plant

The GT unit that is modeled is the Siemens SGT5–2000E. The modeling of the GT unit was done based on nominal conditions for the Model ISO parameters that were taken from [11]. The model constructed in IPSEpro consists of an air compressor, a combustion chamber, a gas turbine, and a generator, which was modelled by selecting the GT block from the advanced power plant library. The inlet of the compressor was connected to an ambient air source, the outlet of the turbine was connected to an ambient sink, and the combustion chamber was connected to the fuel source. Figure 1 shows the schematic diagram of the GT unit. The ISO values of ambient air temperature, pressure, pressure ratio, exhaust mass flow rate and temperature were used to perform the modelling of the SGT5–2000E Turbine, the assumptions made in the modelling of the Power plant as [11], follow that the simulations are performed at steady state, also neglecting the transient impact caused by start-up and shut down during operation and finally, the pressure drops was considered for each component nominal pressure drops. Table 2 shows the ISO conditions for the GT unit and also the validation of the simulated model.

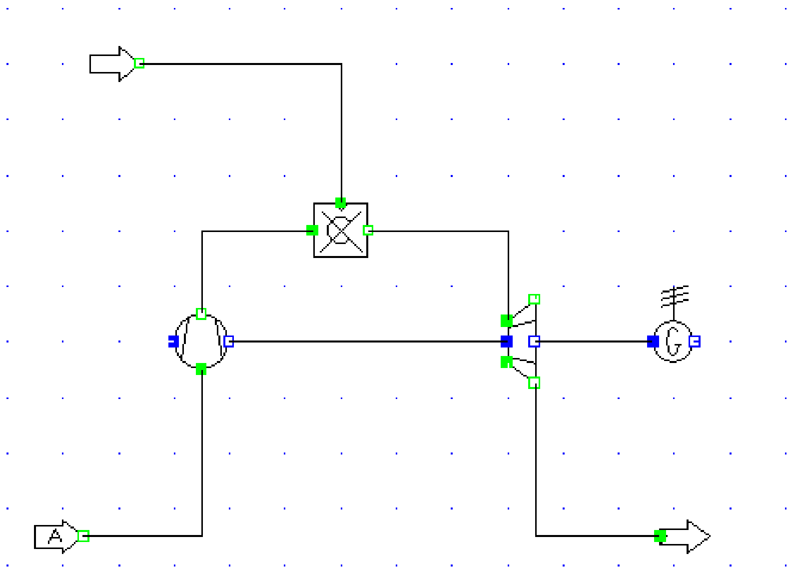

Figure 1: Gas Turbine Unit Model in IPSEpro.

Table 2: GT Unit Model validation for ISO Design Data.

Parameters	ISO Values [11]	Model Values
Power (MW)	166	165.93
Heart Rate (kJ/kWh)	10375	10400.742
Thermal Efficiency (%)	34.7	34.61
Turbine Exhaust Temperature (°C)	541	538.11
Exhaust mass flow rate (kg/s)	525	523.341
Pressure Ratio (rp)	12	12
Ambient air temperature	15	15
Ambient air pressure (bar)	1.013	1.013
Lower Heating Value, LHV (MJ/kg)	45.011	45.011

Performance Criteria

The exhaust gas temperature from the turbine is determined by equation (1) as provided in [12], [13], with the pressure ratio calculated as in equation (2). Furthermore, equations (3 to 9) were used to determine the various performance metrics of the GT model taken from [11].

$$T_4 = T_3 \left[1 - \eta_T \left(1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}} \right) \right] \tag{1}$$

$$r_p = \frac{p_3}{p_4} \tag{2}$$

Where T_4 is the exhaust gas temperature, T_3 is the temperature at the inlet of the turbine, η_T is the turbine isentropic efficiency, γ is the specific heat capacities ratio and r_p is the turbine pressure ratio. The work done by compressor WC and turbine WT was evaluated using equa tions (3) and (4) respectively. Also, the thermal power of the GT unit $P_{thermal}$ was determined by applying equation (5).

$$W_C = \dot{m}_a c_{pa} (T_2 - T_1) \tag{3}$$

Where $\dot{m}_a$ is the air mass flow rate, c_{pa} is the air specific heat capacity, T_2 is the temperature at the outlet of the compressor and T_1 is the temperature of the inlet of the compressor.

$$W_T = \dot{m}_g c_{pg} (T_4 - T_3) \tag{4}$$

Where $\dot{m}_g$ is the gas mass flow rate, c_{pg} is the gas specific heat capacity.

$$P_{thermal} = W_T - W_C \tag{5}$$

The electrical power generated, P_{net} is expressed in equation (3.6).

$$P_{net} = P_{thermal} - P_{loss} \tag{6}$$

Where Ploss is defined as the total losses for mechanical, generator and auxiliary losses.

The gas turbine thermal efficiency η_{GT} was computed as given in equation (7), the heat rate of the GT unit (HR) was computed using equation (8) and the CO2 emission rate was calculated using equation (9) as taken from [14].

$$\eta_{GT} = \frac{P_{net}}{\dot{m}_f \, LHV} \tag{7}$$

Where $\dot{m}_f$ is the fuel mass flow rate, LHV is the lower heating value.

$$HR = \frac{3600}{\eta_{GT}} \quad (8)$$

$$CO_2 Emission = \frac{3600\, \alpha\, \dot{m}_f}{P_{net}} \quad (9)$$

Where α is 3124 kg CO2 per tonne of natural gas.

Energy analyses is used to calculate the losses in the system by concentrating on the amount of energy in each process stream but without any information about the quality of the energy content. On the other hand, exergy analysis clearly shows the location of energy degradation by focusing on the quality as well as quantity of energy [15].

The total inlet and inlet $\dot{E}_i$ and exit $\dot{E}_i$ exergy can be determined as a sum of physical $\dot{E}_{ph}$, chemical $\dot{E}_{ch}$, potential $\dot{E}_{po}$ and kinetic $\dot{E}_{ki}$ exergies in the absence of magnetic, electrical, and nuclear exergies as shown in equation (10).

$$\dot{E} = \dot{E}_{ph} + \dot{E}_{ch} + \dot{E}_{po} + \dot{E}_{ki} \quad (10)$$

In this project, the potential exergy is neglected, due to assuming the environment and stream elevations difference to be small and also, the kinetic exergy is neglected because this is ignored in many studies of exergy if it is assumed that a velocity gradient is absent [14]. By neglecting both terms, the total Exergy is expressed as equation (11).

$$\dot{E} = \dot{E}_{ph} + \dot{E}_{ch} \quad (11)$$

$\dot{E}_{ph}$ Represents the total physical exergy rate of moving the stream from its initial state to the dead state, The specific physical exergy e_{ph} for the stream was calculated as in equation (12).

$$e_{ph} = (h_i - h_0) - T_0(s_i - s_0) \quad (12)$$

Where h_i, s_i represent the initial enthalpy and entropy respectively T_0, h_0 and s_0 are the dead state of values temperature, enthalpy and entropy, respectively.

$\dot{E}_{ch}$ is the total stream chemical exergy rate due to the variation of the composition from the stream state to the dead state. The specific chemical exergy e_{ch} of the stream was calculated as in equation (13).

$$e_{ch} = \sum x_k e_{k,ch0} + RT_0 \sum x_k ln(x_k \gamma) \quad (13)$$

Where x_k is the components concentration, $e_{k,ch0}$ is sthe tandard chemical exergy of component k, and γ is component chemical potential coefficient that is equal to one for the ideal mixture. It should be mentioned that this term could vanish if no change in the fluid composition occurs [16].

Finally, the Exergy efficiency η_{exergy}, Exergy Destruction $\dot{E}_D$ were calculated using equations (14-15) as taken from [14].

$$\eta_{exergy} = \frac{P_{net}}{\dot{E}_\iota} \quad (14)$$

$$\dot{E}_D = \dot{E}_\iota - \dot{E}_e - P_{net} \quad (15)$$

Meteorological Data

Power are affected by environmental change. In this project, the Dry Bulb Temperature (DBT) is taken into consideration. The data of meteorological DBT related to Tripoli, Libya, was collected on a monthly basis from [17]. Tripoli, the capital and largest city of Libya, is nestled on the northwestern coast of the country, facing the Mediterranean Sea. It is known for its Hot and Dry

Summers, Mild and Wet Winters. Figure 2 shows the monthly maximum and minimum DBT temperatures and the DBT temperature for each month of the year 2023.

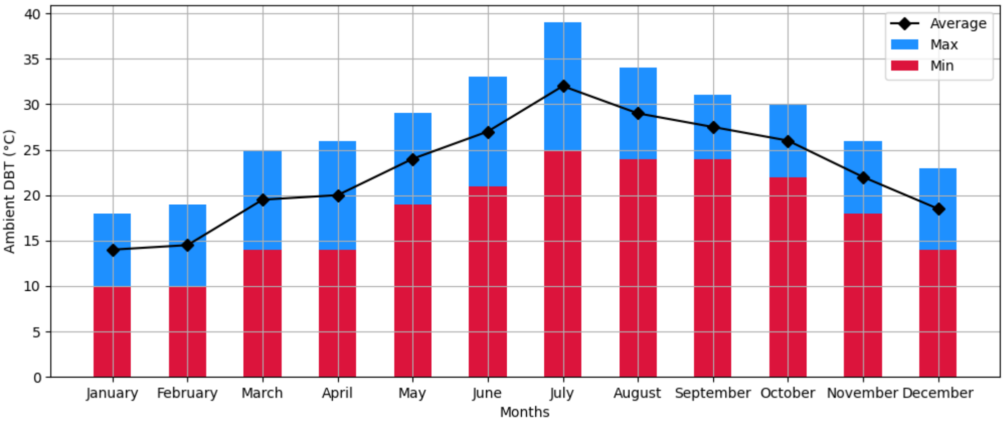

Figure 2: Monthly Maximum, Minimum and Average DBT Temperature for Tripoli City, Libya 2023 [17]

The highest and lowest monthly DBTs were 39°C and 10°C in July and January respectively while the annual average was 22.83°C. Moreover, from January the monthly average temperature starts to rise and reaches its highest temperature in July after which it declines.

Results and Discussion

The performance of the modelled GT unit is evaluated using both energy and exergy analysis. Moreover, the simulated results of the thermodynamic properties for the modelled AC are presented. Finally, a com- parison between the GT unit with and without the AC is displayed.

Parametric study of West Tripoli Power Plant Modelled GT Unit

After the model gas turbine unit built using IPEpro software and validated against the actual data. The GT the performance of the GT under varied ambient temperature conditions (from 15°C to 50°C) and at load variation is displayed as characteristic curves in Figure 3 to Figure 11.

Figure 3 shows how the electrical power output (MW) is affected with changes in the ambient temperature and different load conditions for the GT unit. At 100% load and 15°C, the GT generates 165.93 MW. It can be seen that the output power is decreased by an average of 3.45% for every 5°C ambient temperature rise for the 100% load condition. For the 75% load, the reduction was about 4.7% and for the 50%, 25% load the reduction was about 3.41%. The reduction is mainly because as the ambient temperature increases, the air density decreases and therefore reduces the air mass flow that is flowing intothe compressor which results in reduced power output.

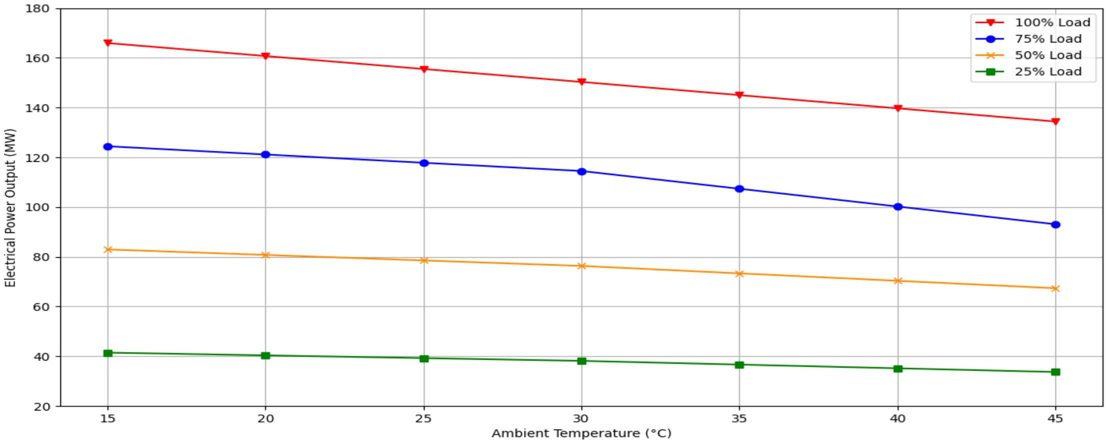

Figure 3: Effect of Ambient Temperature on Output Power at Different Loads.

Correspondingly, Figure 4 shows the thermal efficiency of the GT unit at different loads. The thermal efficiency is proportionally related to the output power and therefore, it can be seen as the ambient temperature increases, the thermal efficiency decreases. At 100% load and 15°C, the GT thermal efficiency is 34.61% and it is reduced by an average of 1.33% for every 5°C ambient temperature rise. For the 75%, 50%, 25% load conditions, the thermal efficiency drops by 1.73%, 2.23% and 3.25% respectively. A high inlet air temperature also increases the compressor work and therefore the fuel mass flow decreases, which lowers the thermal efficiency of the GT unit. Figure 3, shows the behavior of the exhaust stream temperature in relation to the ambient temperature at different loads. Higher ambient temperatures can decrease the efficiency of the turbine, meaning more energy is lost through friction and heat transfer within the turbine which leads to increased exhaust temperature. In Figure 5, for all the loads, the average increase of the exhaust temperature for every 5°C increase in ambient temperature was approximately 0.78% and the maximum increase was found to be 23°C at 75% load.

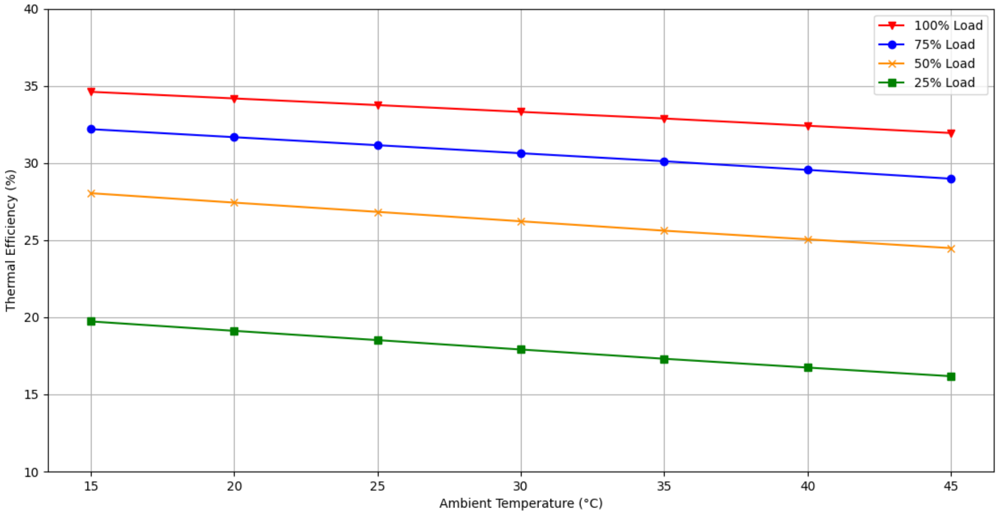

Figure 4: Effect of Ambient Temperature on Thermal Efficiency at Different Loads.

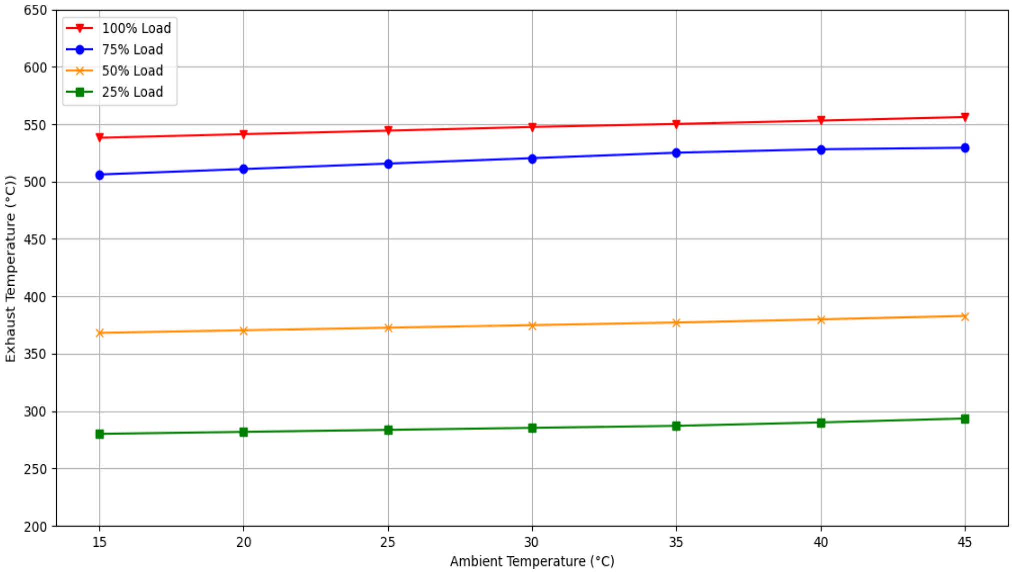

Figure 5: Effect of Ambient Temperature on Exhaust Temperature at Different Loads.

Figure 6 to Figure 8 demonstrate how the air, fuel and exhaust mass flow rate behavior according to changes in ambient temperature and at different loads. At 100% load and 15°C, the air, fuel and exhaust mass flow rates are 512.69, 10.65, 523.34 kg/s respectively and they are reduced by an average of 3.03%, 2.15%, and 3.02% respectively, for every 5°C ambient temperature rise. For the 75%, 50%, and 25% load conditions, the air mass flow rate drops by 2.4% for all loads, the fuel mass flow rate drops by 1.73%, 1.2% 2.47% respectively and finally, the exhaust mass flow rate drops by approximately 2.3% for all loads. Reduced air density and increased compressor work tend to decrease the mass flow with higher ambient temperatures.

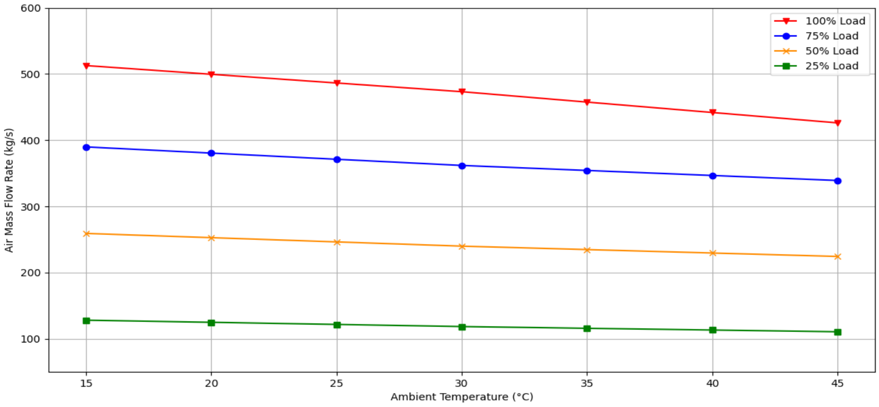

Figure 6: Effect of Ambient Temperature on Air Mass Flow Rate at Different Loads.

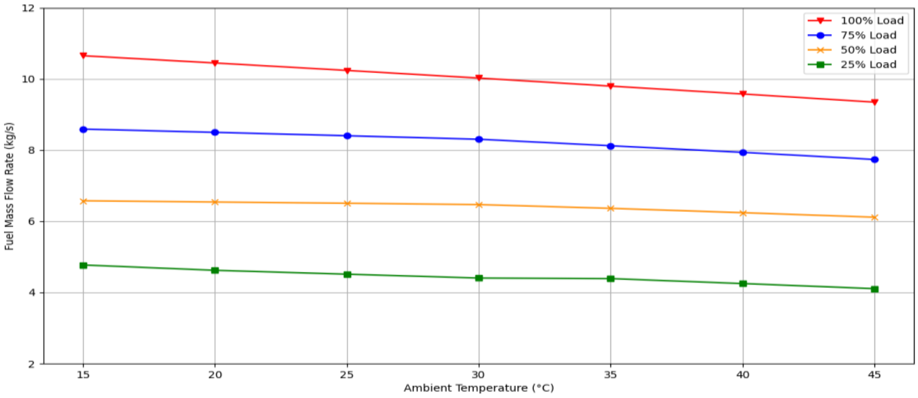

Figure 7: Effect of Ambient Temperature on Fuel Mass Flow Rate at Different Loads

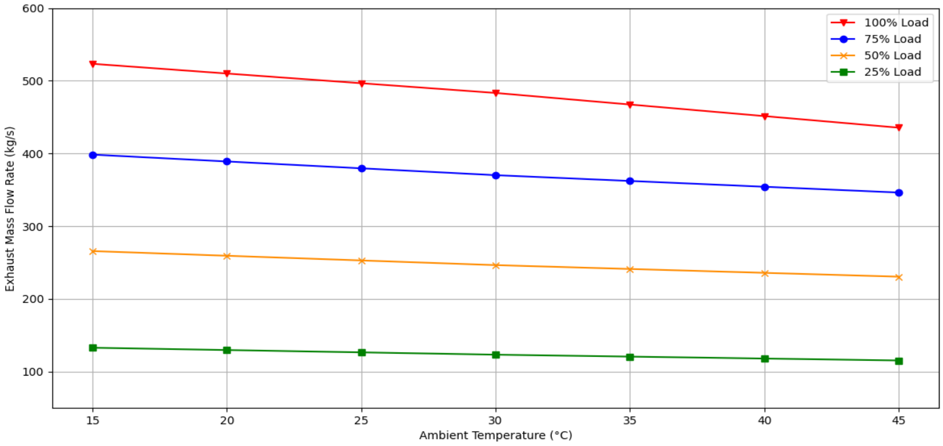

Figure 8: Effect of Ambient Temperature on Exhaust Mass Flow Rate at Different Loads.

Power plants are one of the major sources of carbon dioxide (CO2) emissions globally, contributing significantly to climate change. Therefore, estimating the CO2 footprint from the SCPP is an important factor to assess the environmental impact. Figure 9 shows how the

CO2 emission rate behaves with varying ambient temperatures and under different loads. It is seen that as the ambient temperature increases, the emission rate increases. Among all the load conditions, 25% load demonstrates the highest emission rate and 100% load the lowest rate. For the 100% load condition, the CO2 emission rate increases by an average of 1.35% for every 5°C ambient temperature increase, the 75% load demonstrate an increase of 3.15%, the 50% load shows an increase of 2.28% and the 25% load increase rate is found to be 0.98%.

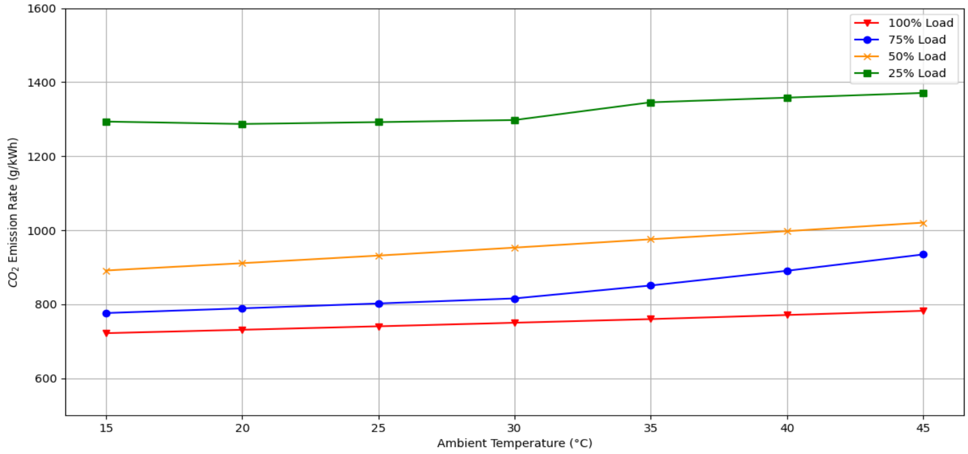

Figure 9: Effect of Ambient Temperature on CO_2 Emission Rate at Different Loads.

Exergy is the portion of energy that can be used to perform useful work in a specific environment, it's not simply the amount of energy available but also its quality and potential to do work. Therefore, exergy efficiency represents the percentage of available energy that is converted into useful work and in contrast, exergy destruction refers to the irreversible conversion of valuable, high-quality energy into unavailable forms like heat. For the exergy analysis, the exergy efficiency and exergy destruction of the GT unit at varying ambient air temperature and under different load conditions were calculated. Figure 10 shows that as the ambient temperature increases, the exergy efficiency decreases. At 100% load and 15°C, the GT exergy efficiency is 38.63%. For each load condition (100%, 75%, 50%, 25%) the exergy efficiency is reduced by an average of 0.24%, 0.55%, 1.5%, 2.8% respectively for every 5°C ambient temperature increase. As the temperature increases, the total input exergy due to natural gas and air decreases and the total output exergy due to exhaust gas increases and therefore, reducing the exergy efficiency.

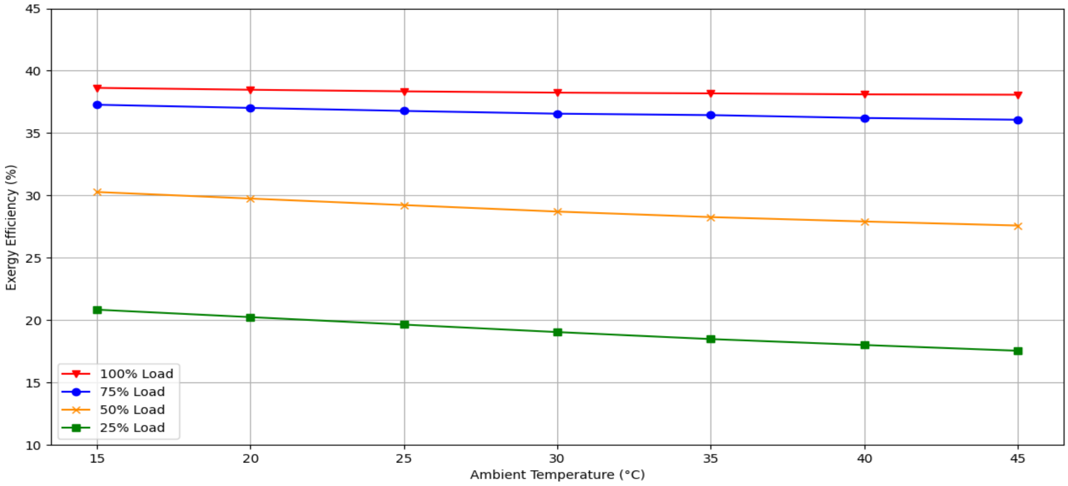

Figure 10: Effect of Ambient Temperature on Exergy Efficiency at Different Loads.

Figure 11 shows how much exergy is destructed as the ambient air temperature increases. It can be seen that at 100%, 75%, the change in exergy destruction is more noticeable because as the ambient air temperature in- creases, the output power drop is more than when compared to the lower load conditions. Furthermore, at higher load conditions, the total input exergy decreases at a higher rate than lower load conditions, which agrees with the expected results.

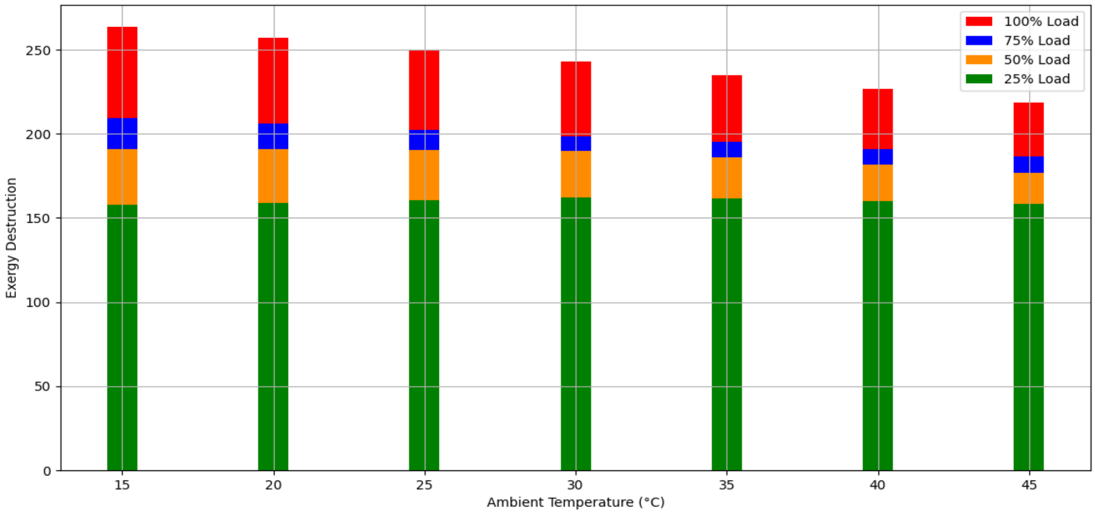

Figure 11: Effect of Ambient Temperature on Exergy Destruction at Different Loads

Real data was acquired from the West Tripoli power plant in a field visit. The data acquired was within a hot day where the ambient air temperature was 46°C. This data was used for comparison with the modelled GT unit where the set values were the output power, air ambient temperature and humidity, then checking for the measured exhaust temperature, to validate that it mimics the behavior of the existing GT unit in the West Tripoli power plant. Table 1 shows the comparison made.

Table 2: Comparison between the existing GT unit and the Modelled GT unit.

	Existing Data [West Tripoli GT Unit]	Modelled GT Unit
Compressor Inlet Temperature (°C)	46	46
Compressor Inlet Pressure (bar)	0.9968	0.9968
Humidity (%)	65.3	65.3
Active Power (MW)	128	128.32
Exhaust Temperature (°C)	538	539.32

As can be seen from Table 2, after setting the model parameters with the exact same conditions as the existing GT unit and then running the simulation to measure for the exhaust temperature, it was found that the difference between the real value and our model's value is approximately 0.245% whichis considered to be within the acceptable error margin.

Performance of West Tripoli Power Plant Modelled GT Unit with AC

The parametric study of the GT unit showed that the ambient temperature variation affects it highly. Therefore, controlling the GT air inlet temperature will result in improving the SCPP plant performance indicators. An AC model is used to cool the inlet temperature and stabilize it at ISO conditions (15℃). Fig.4.10, shows the arrangement at which the GT unit is to be connected to the AC model.

The GT unit inlet is connected to the AC through a heat exchanger in which the chilled water that is produced by the AC chiller cools down the ambient air temperature and the cool air enters the GT unit. The assumption madeis that the AC has the capability of producing chilled water that cools down and stabilizes the inlet ambient air temperature at 15℃ for all different ambient air conditions. The performance evaluation was performed by varying the ambient air temperature from 15ºC to 45ºC with an incremental increase of 5ºC and under 100% load conditions. Figures (13 – 15) display a comparison between the performance of two scenarios which are the GT unit with and without an AC attached.

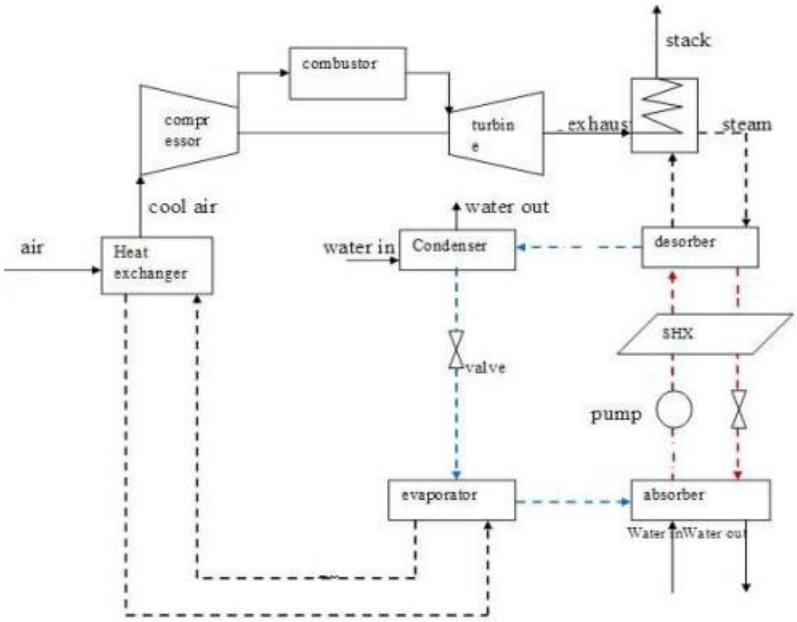

Figure 12: Schematic drawing of GT unit air inlet cooling using a single-effect AC [19]

Figure 13 shows the impact of changing the ambient air temperature over the range from 15ºC to 45ºC on the GT unit output power at full load for both scenarios. It can be seen that by using the AC cooling, the ambient air is cooled down back to ISO condition which leads to power saving and avoids degradation in output power at high temperature conditions. At 30ºC the increase in power output between both scenarios is calculated to be 9.42% and at 45ºC it is found out to be about 19.01%, this shows the significance of cooling the inlet of the GT unit.

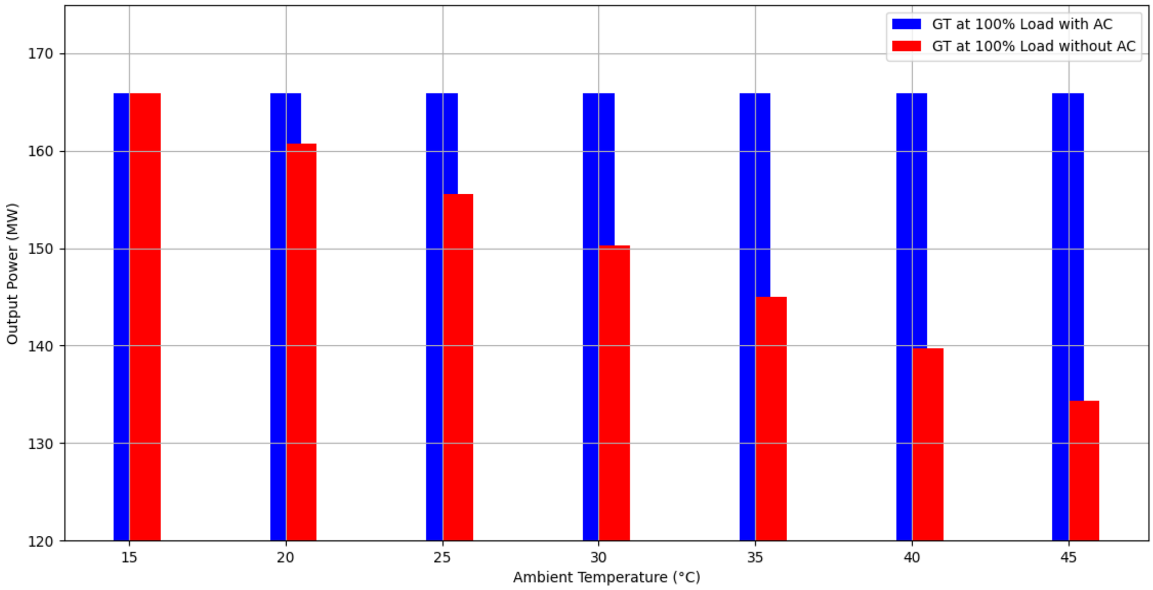

Figure 13: Effect of Ambient Temperature on Output Power at two Scenarios.

Correspondingly, Figure 12 shows the thermal efficiency of both scenarios, where it can be seen that as the ambient air temperature increases, the AC stabilizes the inlet conditions, leading to an improvement in power which means improved thermal efficiency. At 25℃ the increase in thermal efficiency between both scenarios is calculated to be 2.54% and at 40℃ it is found out to be about 6.79%, this shows that the GT performance can be more utilized by using cooling methods. Similarly, Figure 13 shows the exergy efficiency of both scenarios. The improvement factor at 45℃ is calculated to be 1.44%.

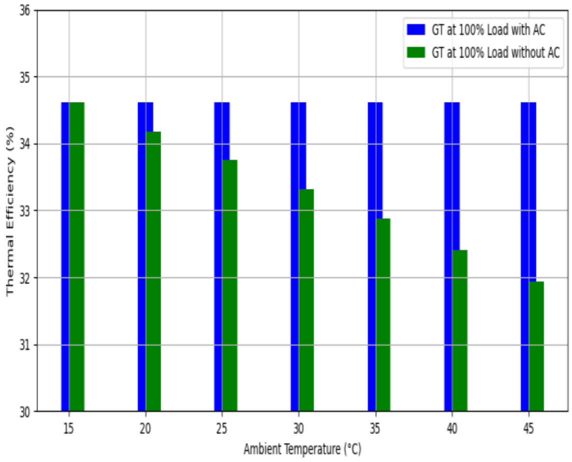

Figure 14: Effect of Ambient Temperature on on Thermal Efficiency at two scenarios.

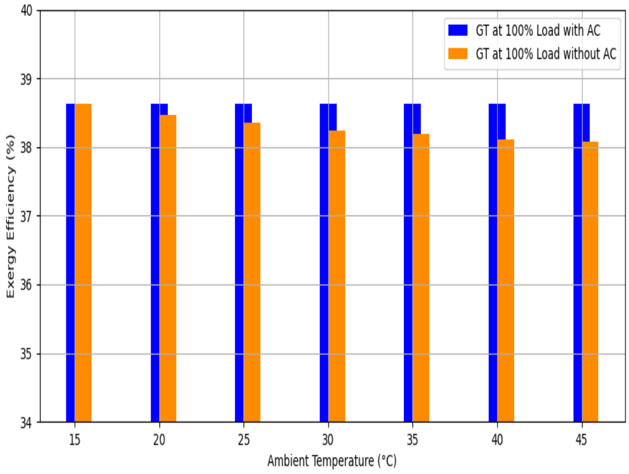

Figure 15: Effect of Ambient Temperature Exergy efficiency in two scenarios.

Figure 16 shows the effect of change in ambient temperature on the GT unit output power at every month. As can be seen the output power declines with ambient air temperature rise. June, July and August are the peak of temperature and thus record the lowest output power. This can be solved by using an absorption chiller powered by the exhaust gas, where the AC cooling is delivered to the GT inlet air, which leads to power saving and avoids degradation in output power. The increase in output power when using the AC in the months June, July and august, are calculated to be 8.15%, 11.98%, 9.64% respectively. This displays the importance of cooling methods such as the AC for power plants in Libya, especially in the summer period where there is a high increase in ambient air temperature.

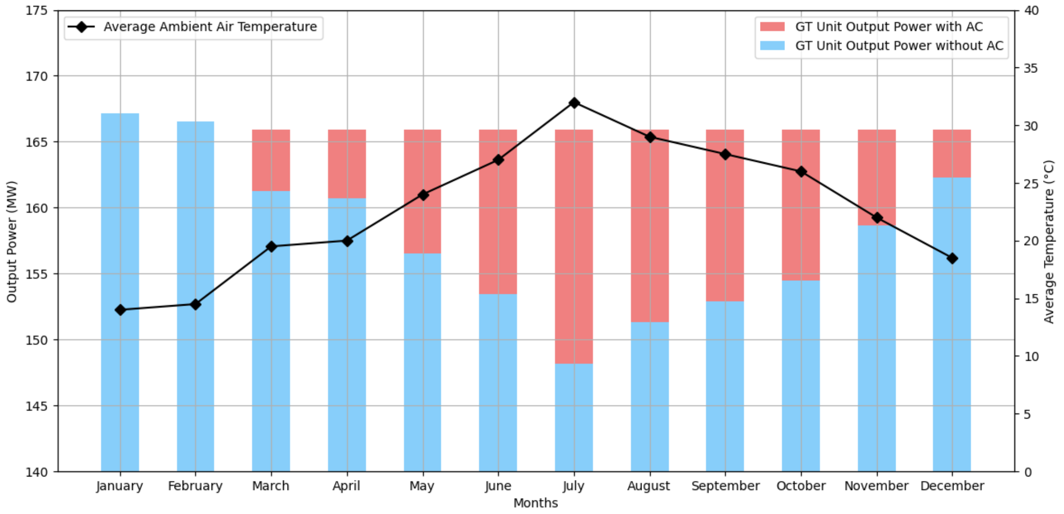

Figure 16: Average Temperature and Corresponding GT Unit Output Power for Each Month Over the Year.

Conclusion

This paper was carried out to build, validate and assessment the thermal and exergy analysis of the existing sample cycle power plant and proposed absorption chiller using IPSEpro software. The result showed he following:

- In this paper, the West Tripoli Power Plant was chosen. For simplicity, only asingle GT unit was investigated.
- The proposed model was coupling the standalone GT unit with a Single Effect LiBr-H_2O AC through a heat exchanger to cool the inlet ambient air temperature down to ISO conditions.
- The GT unit and the Single Effect LiBr-H_2O AC were both modelledand validated using IPSEpro software.
- The meteorological data collected for 2023, indicates that Tripoli suffers from high temperatures in the summer the highest is 39°C in Julyand the lowest is 10°C. The yearly average is calculated to be 22.8°C.
- The evaluation process was performing energy analysis to observe the output power, thermal efficiency, and CO_2 emission. Exergy analysis to observe exergy efficiency and exergy destruction. Finally, Economic analysis to observe the economic indicators of the GT unit and determine its profitability.
- At 100% load and ISO conditions (15°C, 60% relative humidity and 1.013bar pressure), the modelled standalone GT unit generates 165.93 MW with thermal efficiency 34.61%. As the ambient air temperature increases, the output power and the thermal efficiency are reduced.
- The air, fuel and exhaust mass flow rate are decreased as the ambientair temperature increases. On the other hand, the exhaust temperatureincreases as the ambient air temperature increases.
- The CO_2 emission rate was calculated to assess the environmental impactof the GT unit. It is found that as the ambient temperature increases,the emission rate increases.
- The exergy efficiency represents the percentage of available energy that is actually converted into useful work and was found to be 38.63% for the standalone GT unit at ISO conditions and 100% load.
- The parametric study showed that the ambient temperature variation highly affects the GT unit. Therefore, the AC was used to cool the inlettemperature and stabilize it at ISO conditions.
- The parametric comparison between the standalone and with AC GT unit showed that there is a significant improvement in high ambient temperature.
- Comparing the Standalone and AC GT unit against the meteorological data obtained shows that there is an increase in power that canbe achieved when using the AC in the months of June, July and August, which are calculated to be 8.15%, 11.98%, 9.64% respectively.

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