Al-Farouk journal of sciences
Volume (2), Issue (1) (March, 2026)
ISSN: 3135-2359

مجلة الفاروق للعلوم
المجلد (2) العدد 1 مارس 2026
ردمد: 3135-2359

Isentropic efficiency Investigation in Al-Khoms Steam power Plant

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تاريخ الاستلام: 2026/01/13 تاريخ المراجعة 18 / 2 / 2026 تاريخ القبول:2026/03/12- تاريخ النشر: 2026 /03/24

ABSTRACT

The aim of this study is to investigate the isentropic efficiency of the high and intermediate pressure turbines in the third unit of the Al-Khoms steam power plant. Two samples of data have been used in this work. The first one was collected from the start-up data sheet of the power plant with a load of 120 MWH, and the second was collected from the current operation data sheet (June 2023) with a load of 96 MWH. The Engineering Equation Solver program (EES) has been used to represent h-S diagrams of the turbines in both samples of data and for the calculation. The results of the study show that the current isentropic efficiency of the high-pressure turbine is 41% and the intermediate-pressure turbine is 89%, while the commissioning start-up isentropic efficiency of the high-pressure turbine is 85% and the intermediate-pressure turbine is 98%, indicating that the isentropic efficiency of the turbines of the power plant decreased with time, especially in the high-pressure turbines, which decreased by 51%.

المستخلص

الهدف من هذا البحث هو دراسة الكفاءة الايزونتروبية لتوربينات الضغط العالي والمتوسط في الوحدة الثالثة لمحطة الخمس البخارية. تم استخدام عينتين من البيانات في هذا العمل، حيث تم جمع العينة الاولى من بيانات بدء التشغيل لمحطة توليد الكهرباء بحمولة 120 ميجاوات ساعة، والثانية تم جمعها من بيانات التشغيل الحالية (يونيو 2023) بحمولة 96 ميجاوات ساعة. تم استخدام برنامج حل المعادلات الهندسية (EES) لتمثيل مخططات الانتروبي - الانتالبي للتوربينات لكلا العينتين من البيانات. أظهرت نتائج الدراسة أن الكفاءة الايزونتروبية الحالية لتوربين الضغط العالي هي 41% وتوربين الضغط المتوسط 89%، في حين أن الكفاءة الايزونتروبية عند انشاء المحطة للتوربين عالي الضغط هي 85% و توربين الضغط المتوسط 98% مما يشير إلى أن الكفاءة الايزونتروبية لتوربينات المحطة انخفضت مع الزمن وخاصة في توربينات الضغط العالي التي انخفضت بنسبة 51%.

Keywords: Al_khoms steam power plant, isentropic efficiency, steam power plant, steam turbine.

1- INTRODUCTION

A rankine cycle is a heat engine with a vapor power cycle. The common working fluid is water. The cycle consists of four processes: isentropic expansion (steam turbine), isobaric heat rejection (condenser), in which the pressure of the working fluid remains constant; isentropic compression (pump), in which external work is done on the working fluid by means of pumping operation; and isobaric heat supply (steam generator or boiler), in which heat from the high temperature source is added to the working fluid to convert it into superheated steam [1].

Steam turbines are complex equipment with a long life cycle. Technology improvements driven by the need for higher efficiency led to a new generation of steam turbines. Since a steam turbine is costly equipment, a decision must be made regarding replacing or retrofitting it after careful consideration of the actual technical condition and efficiency. The first step in decision-making is the assessment of the energy performance investigation of the steam turbine [2]. In a steam turbine, only expansion of the working fluid (steam) takes place; there is no combustion or compression; it is just an expander; therefore, it is accepted as the simplest machine that converts heat energy to mechanical energy. On the other hand, it is the most efficient machine [3]. In figure 1, h_2 represents the actual exit enthalpy, and h_{2s} represents the isentropic exit enthalpy. The efficiency of a real turbine (isentropic efficiency) is defined as the ratio of the actual shaft work to the shaft work for an isentropic expansion between the same inlet and exit [1]. According to the first and second laws of thermodynamics, the adiabatic process, where entropy remains constant, provides the maximum energy for work. The difference in enthalpy (h_1-h_2) is the maximum when the lowest enthalpy (h_2) is reached at the exit conditions. The ideal expansion is, therefore, a vertical line. The usual isentropic efficiency for high-pressure turbines (HPT) is in the range of 62% to 84%, and for low-pressure turbines (LPT), it is in the range of 74% to 89% [2, 3, 4].

2- PLANT DESCRIPTION

Al-Khoums steam power plant is one of Libya's power stations. It has four units with a capacity of 120 MW per unit, working on HFO, LFO and NG. Each unit has a high-pressure turbine, an intermediate-pressure turbine and a low-pressure turbine. The plant started up in 1982, and it is still operating and feeding the public network to date. During that period, the plant was subjected to several emergencies and periodic maintenance, but the operating time and life span of the plant played a major role in reducing its efficiency.

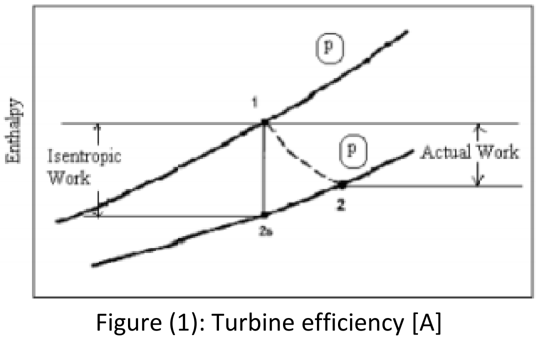

Figure (1): Turbine efficiency [A]

3- OBJECTIVE OF THE STUDY

The aim of this work is to study and represent the isentropic efficiency of the high and medium pressure turbines located in the third unit of the Al-Khoms steam power station, using the plant's initial commissioning data and current operational data to show the extent to which the isentropic efficiency changes over time

4- ISONTROPIC EFFICIENCY INVESTIGATION

The data of the studied unit (June 2023 data and commissioning data) are listed in Table 1, and they were plotted on an enthalpy-entropy diagram for both high-pressure turbine (HPT) and intermediate-pressure turbine (IPT), as shown in figures (2), (3), (4), and (5), using Engineering Equation Solver software (EES).

Table (1):
Data for the third unit of the studied plant

	june 2023 data	commissioning data
specific enthalpy h_6 [Kj/Kg]	3410	3433
specific enthalpy h_7 [Kj/Kg]	3226	3065
specific enthalpy h_8 [Kj/Kg]	3539	3538
specific enthalpy h_9 [Kj/Kg]	3057	3056
specific enthalpy h_{10} [Kj/Kg]	2373	2286

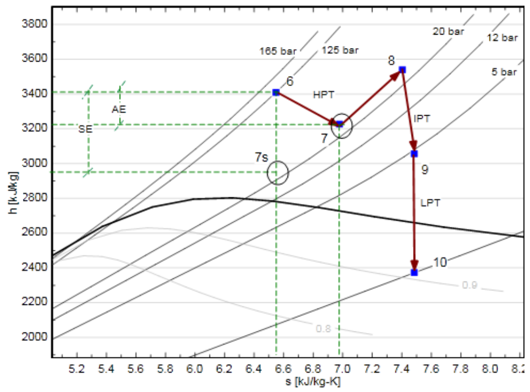

Figure 2: Illustration of actual and isentropic work of HPT (June 2023 Data)

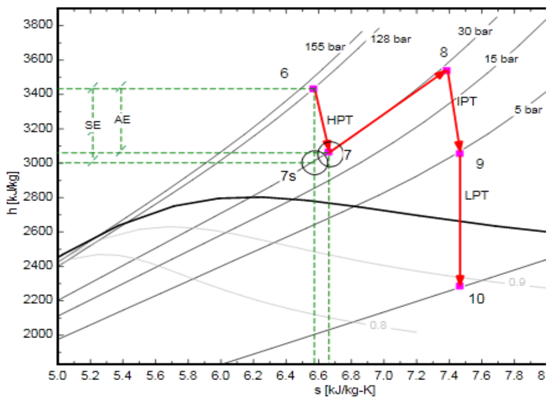

Figure 3: Illustration of actual and isentropic work of HPT (start up data)

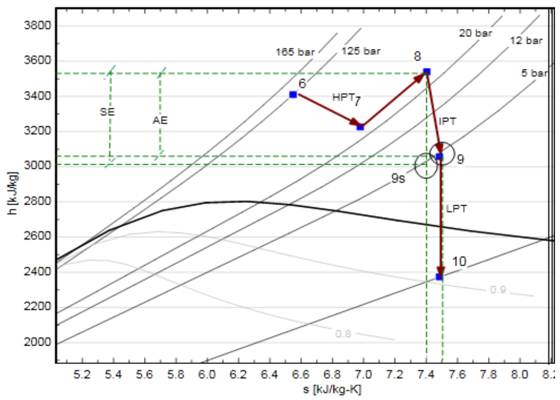

Figure 4: Illustration of actual and isentropic work of IPT (June 2023 Data)

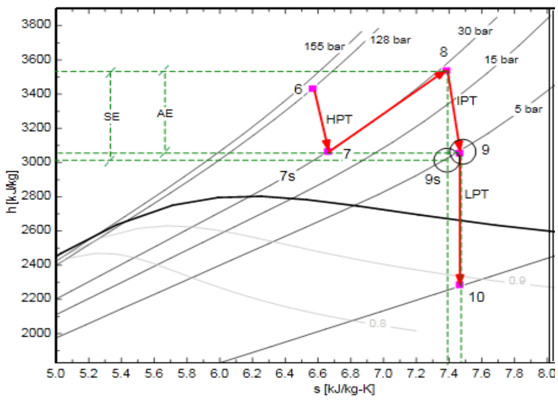

Figure 5: Illustration of actual and isentropic work of IPT (start up data)

In the isentropic process, the specific enthalpy of points 7 (h7s) and 9 (h9s) for both samples can be found using figures (2), (3), (4), and (5), as shown in table 2.

Table (2):
specific enthalpy of point 7 and 9 of the studied plant at the isentropic process

	june 2023 data	commissioning data
specific enthalpy h_{7s} [Kj/Kg]	2960	3000
specific enthalpy h_{9s} [Kj/Kg]	3000	3050

Equations 1 and 2 were utilized to calculate the isentropic efficiency of high-pressure turbine and intermediate-pressure turbine using the data in tables 1 and 2 for both study samples [1, 5].

$$\eta_{HPT} = \left[\frac{h_6 - h_7}{h_6 - h_{7s}}\right] \quad (1)$$

$$\eta_{IPT} = \left[\frac{h_8 - h_9}{h_8 - h_{9s}}\right] \quad (2)$$

5- Result and discussion

The result of the calculations shows that the isentropic efficiency of the high-pressure turbine is 41%($\eta_{HPT} = 41\%$) and the isentropic efficiency of the intermediate-pressure turbine is 89% ($\eta_{IPT} = 89\%$) for June 2023 data. Also, the result shows that the isentropic efficiency of the high-pressure turbine is 85% ($\eta_{HPT} = 85\%$) and the isentropic efficiency of the intermediate-pressure turbine is 98% ($\eta_{IPT} = 98\%$) for commissioning data.

The above results can be achieved by observing figures 2, 3, 4, and 5. It is clear that the HPT's line (point 6 to point 7) in figures 2 and 3 has a big slope, which means a big deviation from the vertical line (point 6 to point 7s) as isentropic behavior. As well, IPT's line (point 8 to point 9) in figures 4 and 5 has a smaller slope, which means less deviation from the vertical line (point 8 to point 9s); this shows that the isotropic efficiency of the intermediate -pressure turbines is higher than the high-pressure turbines for both study samples of this power plant.

5- CONCLUSION

From this study, some points can be concluded, as listed below:

- The current isentropic efficiency of the high-pressure turbine (HPT) in the third unit of Al-Khoms power plant is 41% which is about the half of the isentropic efficiency in commissioning operation (85%)
- The current isentropic efficiency of the intermediate-pressure turbine (IPT) is 89% which is close to the isentropic efficiency in commissioning operation (98%).
- In general, the isentropic efficiency of the high-pressure turbines in this unit of power plant is lower than the isentropic efficiency of the intermediate -pressure turbines.
- The isentropic efficiency of the turbines of the power plant is decreased with time speacialy in the high-pressure turbines.

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