THE PROJECT OF A NUCLEAR POWER PLANT UNIT FOR THE GOLDEN TRIANGLE AREA IN EGYPT WITH A TURBINE CAPACITY OF 600 MW

Mohamed Sayed
Egyptian-Russian University, Tomsk Polytechnic University
ISHE, Butakov research center, group 507I

Introduction

Intentionally to preserve the environment from the danger of global warming and with a purpose to comply with the future vision of reducing carbon emissions, most countries focus on switching to advanced technology such as wind energy, solar energy, and thermonuclear reactors or fourth generation fast nuclear reactors, and based on the available resources for each country.

And according to the permanent need for energy in Egypt and in line with Egypt's sustainable development strategy in Egypt Vision 2030, therefore there is a pressing demand for clean energy instead of using fossil fuels, and in order to avoid an increase in carbon emissions. So, in our provided project is an Egyptian NPP power unit for a modern industrial region with a saturated steam condensing turbine with an electric capacity that supports the region, and constitutes total dependence on it, meeting modern requirements of efficiency, reliability and safety.

In the construction of the NPP, during which steam turbines are used with wet steam, and as one of the obstacles facing the designers of these turbines is the compatibility between obtaining high efficiencies that ensure maximum utilization of the potential energy of the steam, and obtaining very low humidity degrees that guarantee safe performance and preserve the working metal structure.

This problem will become evident by comparing several designs in order to achieve what we mentioned above.

The city of construction of the NPP

The city of the NPP building will be in Egypt in the yellow area The Golden Triangle (figure 1) of the map, the city of construction is **El-QUSSIER City** specifically between the two cities of El-QUSSIER and SAFAGA, as it will be located directly on the Red Sea [1].

Fig. 1. Location of Golden Triangle region and NPP [1]

The economic features and characteristics of the region (The Golden Triangle)**:**

- The Golden Triangle is a modern area under construction located in the Eastern Desert on an area of 2,2 million feddans (9500 million square meters) between the governorates of Qena, Safaga, and Qussier.
- It includes industrial, mining, tourism, agricultural and commercial areas. As the region is concerned with mineral and quarry resources such as gold, basalt, white sand, limestone and phosphate rocks.

- The area contains many elements of tourism, such as the extended sea beaches, and archaeological sites.
- The goal of the project (Golden Triangle) is to direct part of the population to live in the new area instead of the Nile Valley, and it is expected to accommodate about 2 million people.
- In addition, The City of Qussier was one of the cities nominated to build a nuclear power plant in the past, but the problem was that the electricity network is located 500 km away, but now there is a project of the Golden Triangle that will consume that electricity [2].

Construction of NPP

According to the requirements of the NPP's location, and based on the average sea water temperature, which is 25,6 °C [3]. So, during this project, and according to our desire to achieve the highest efficiency based on the NPP's location, so we have calculated several different designs, they show in (table 1). With unified initial data for all scheme design, which an initial steam pressure of p_0 =6.5*MPa* was used, and initial steam quality x=1.

Table 1. Thermal Efficiencies of NPP

Scheme design	Type of Cylinders	$G_0, kg/s$	$G_{sg}, kg/s$	η_{npp}^{net}, %	x^{HPT}	x^{IPT}	x^{LPT}
1. Separator+2Reheaters+Separator	HPT+IPT+LPT	898	950	33,4	0,87	0,95	0,91
2. Separator+2Reheaters	HPT +LPT	885	934	34,1	0,87	--	0,86
3. Separator + Separator	HPT+IPT+LPT	974	989	32,3	0,87	0,88	0,90

Through a comparison between them in some parameters, it became clear that the first design (1. Separator+2Reheaters+Separator) was chosen as the best, in order to achieve the most suitable efficiency with an optimal steam quality, and its design is shown in (figure 2).

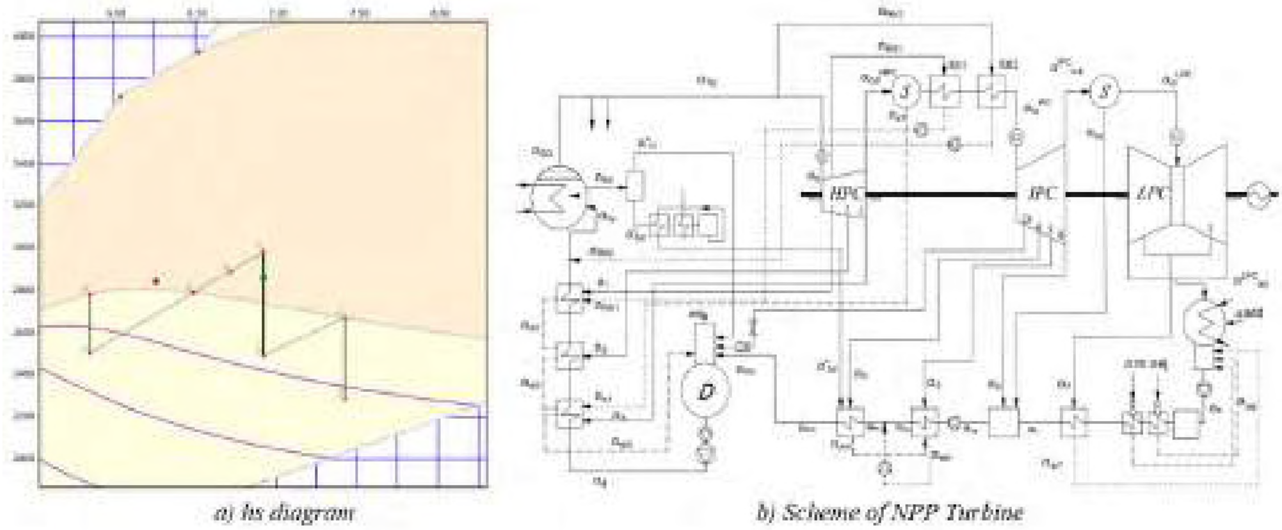

Fig. 2. Thermal Scheme of NPP Turbine

Design of turbines

Design of the high-pressure turbine (figure 3a), the pressure inlet after a little loss in throttle valve, was a p_0 = 6,3 MPa, with one direction-flow rate, and five stages, and relative error between first and last heat drop $\delta \approx 0$ %, which creates a smoothness in the design, and the critical frequency n_{cr} =9805 rpm, which keeps the turbine balanced at high speeds.

Design of the intermediate-pressure turbine (figure 3b), the pressure inlet $p_0 = 1{,}147$ MPa, one direction-flow rate, and four stages, relative error between first and last heat drop $\delta \approx 0{,}31$ %, and the critical frequency n_{cr} = 8802 rpm, similarly it achieves the condition of frequency.

The efficiency of converting thermal energy into kinetic energy in the nozzles are η_n = 96 %, and in the blade is η_b = 81 %, and average efficiency for one stage for stator and blade are 93 %.

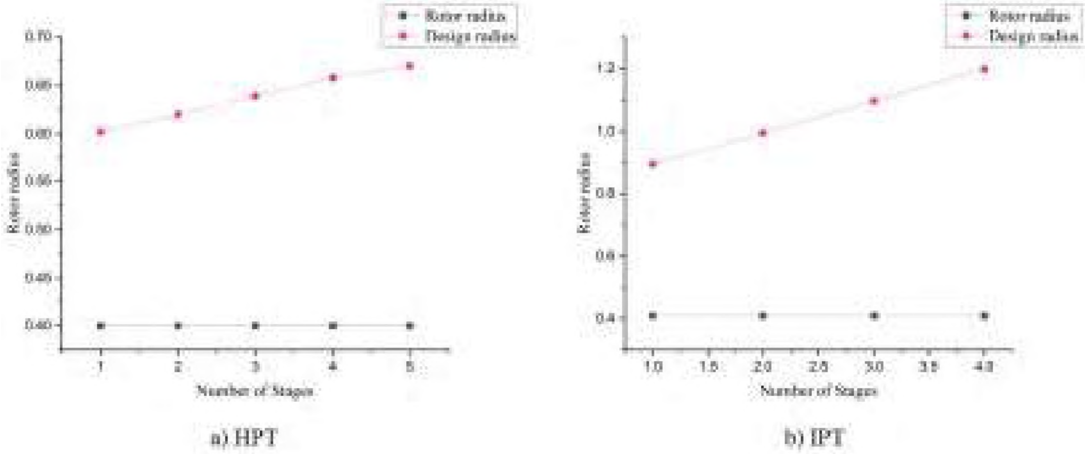

Fig. 3. Stages design of HPT, and IPT

Design low-pressure turbine (figure 4), the pressure inlet p_0 = 0,07962 MPa, with a two direction-flow, three stages, relative error between first and last heat drop $\delta \approx 0{,}52$ %, and the critical frequency n_{cr} = 9915 rpm, here it is enough also to keeps the turbine balanced at very high speeds at low pressure, and as a comparing the number of flows for Titanium Material $N_{Titanium}$ = 6 Flows, with the number of flows for Steel Material N_{steel} = 8 Flows. So, Titanium material has been selected, for the better performance with convergence of costs.

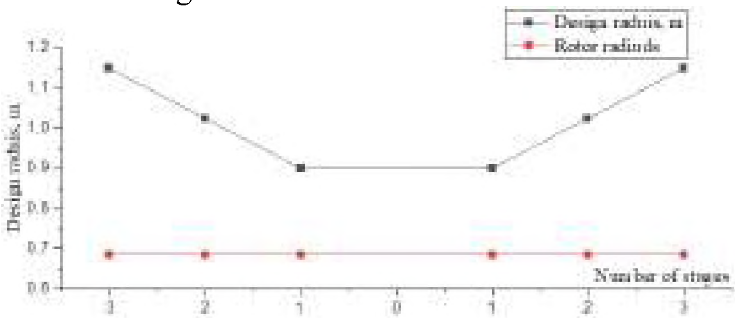

Fig. 4. Stages design of LPT

Table 2. Indicators of NPP's parameters

Name:	**Equation**	**Value**
Thermal loading of a steam generating unit	Q_{SG}, MW	1667,0
Thermal loading of turbine	Q_T, MW	1659,0
Turbine Plant efficiency	$\eta_{TU} = \frac{N_e}{Q_T}, \%$	36,2
Efficiency of pipelines connecting between the SGs and the Turbines	$\eta_{pip2} = \frac{Q_T}{Q_{SG}}, \%$	99,5
NPP Gross efficiency	$\eta_{npp}^{Gross} = \eta_{RU} \cdot \eta_{PiP1} \cdot \eta_{SG} \cdot \eta_{PiP2} \cdot \eta_{TU}, \%$	35,1
Efficiency of a steam generating unit	$\eta_{SGU} = \eta_{RU} \cdot \eta_{pip1} \cdot \eta_{SG}, \%$	97,5
The specific flow rate of nuclear fuel (natural uranium) requires at nuclear power plants	$b_{nf} = \frac{1000}{24 \cdot \bar{B} \cdot \eta_{Nb}} \cdot \frac{x_n - x_o}{x_e - x_o}, g/MW \cdot h$	0,0339
Specific flow rate of degraded fuel for the electrical supply at nuclear power plants (block)	$b_{Ndf} = \frac{0{,}0537}{\eta_{Nb}}, g/MW \cdot h$	0,161

Conclusion

During this project, and in order to reach the optimal values in relation to the construction site of the nuclear plant, and after comparing a number of different designs that were compared, the design mentioned above was chosen (1. Separator+2Reheaters+Separator), which contain three Cylinder: High, Intermediate and Low-pressure.

The design has achieved the efficiency for NPP Net η_{npp} = 33,4 %, and Turbine Plant efficiency η_{TU} = 36,2%, bearing in mind that the design is distinguished high final steam quality for all cycles of HPC, IPC and LPC, 87 %, 95 % and 91 % respectively, these humidity values give ample opportunity for the turbines to operate at minimal erosion, which ensures structural stability within the safe range, and thus reducing design, operating and repair costs.

In addition, according to statistics, a nuclear power plant with a capacity of 600 MW, prevents the release of 4,80 tons of carbon dioxide annually from a coal-fired plant of the same capacity, and prevents the release of 240 tons of carbon dioxide annually from a natural gas plant [4].

Eventually, the results obtained are competitive results, competing and more than with already existing nuclear plants, as it gives compatibility between high efficiencies and the required steam quality.

LITERATURE:

1. “بسم الله الرحمن الرحيمA vailable resources in the golden triangle area. Prof. Dr Ahmed A. Melegy Head of Geological Sciences Deprt. Natinal Research. - ppt download.” https://slideplayer.com/slide/7944548/ (accessed Nov. 12, 2022).
2. “The golden triangle – Egypt Mining Forum | 4 July 2022, Cairo, Egypt.” https://www.egyptminingforum.com/conference-programme/project-spotlight/2022/companies/the-golden-triangle/ (accessed Sep. 06, 2022).
3. “Red sea, Egypt – Average Annual Weather - Holiday Weather.” https://www.holiday-weather.com/red_sea/averages/ (accessed Sep. 06, 2022).
4. Sayed, A. M. Nuclear energy in the face of global warming / A. M. Sayed // Научная инициатива иностранных студентов и аспирантов : Сборник докладов II Международной научно-практической конференции, Томск, 26–28 апреля 2022 года. – Томск: Национальный исследовательский Томский политехнический университет, 2022. – P. 802-806. – EDN LDDQAQ.

Научный руководитель: к.пед.н. С.В. Лавриненко, доцент НОЦ И.Н. Бутакова ИШЭ ТПУ.

ВЛИЯНИЕ ЗАКОНА ЗАКРУТКИ ЛОПАТКИ ГАЗОВОЙ ТУРБИНЫ, ЗАКРУЧЕННОЙ ПО ЗАКОНУ ПОСТОЯНСТВА ЦИРКУЛЯЦИИ, НА НАПРЯЖЕННО-ДЕФОРМИРУЕМОЕ СОСТОЯНИЕ

А.С. Романов, М.А. Лаптев, В.В. Барсков
Санкт-Петербургский политехнический университет
ИЭ, ВШЭМ, группа 3231303/90301

Увеличение мощности и усложнение конструкции турбомашин сопровождается повышением требований к их надежности. Повышение ресурса турбомашин также является одной из основных задач улучшения качества. Поскольку рабочая лопатка турбины является высоконагруженным элементом любой турбомашины, то к ней предъявляются высокие эксплуатационные требования, выраженные в надежности и долговечности данного элемента. На эксплуатационные качества рабочей лопатки сказывается большое количество факторов, одним из которых является её закрутка. Таким образом, цель текущего исследования заключается в определении влияния закрутки лопатки газовой турбины, закрученной по закону постоянства циркуляции.

С помощью внутренних пакетов ANSYS Static Structural и CFX был произведен сопряженный анализ напряженно-деформированного состояния (НДС) лопатки, построенной по закону постоянства циркуляции. Статический анализ НДС состоит из нагрузок, возникающих в