INNOVATIVE MECHANICAL ENGINEERING **ISSN 2812-9229 (Online)**
University of Niš, Faculty of Mechanical Engineering
VOL. 1, NO 1, 2022, PP. 120 - 127

Original scientific paper*

DETERMINING THE CRITICAL OPERATION PARAMETERS OF THE AIR-COOLED CONDENSER IN THE STANARI THERMAL POWER PLANT

J. Škundrić[1], P. Živković[2], D. Knežević[1], D. Đurica[3], B. Bačić[3]

[1] University of Banja Luka, Faculty of Mechanical Engineering, R.S., B. & H.

[2] University of Niš, Faculty of Mechanical Engineering, Serbia

[3] Thermal Power Plant Stanari, Republic of Srpska, Bosnia and Herzegovina

Abstract. *As the technology of materials in use for building boiler and turbine plants develops, the application of air-cooled condensers in thermal power plants becomes increasingly popular. Since air-cooled condensers are a recent addition to thermal power plants, there is still a number of unknown variables regarding their steady and reliable function. Most of them are related to the stochastic nature of the seasonal atmospheric deviations on the annual level. The most dominant quantities responsible for those atmospheric deviations are, of course, ambient air temperature, wind speed and direction. This paper presents an analysis of the mentioned quantities measured at the thermal power plant in the Stanari location, with a goal to determine the most critical conditions a condenser must operate in.*

Keywords: *Thermal power plant, Air-cooled condenser, Wind speed, Air temperature, Critical parameters.*

INTRODUCTION

The process of condensation in a thermal power plant is fundamentally the process of heat transfer from the discharged steam to the environment of the considered thermodynamic system. In order to efficiently conduct the process, an appropriate heat exchanger is needed, and the most common devices of that type are either water-cooled or air-cooled heat exchangers. Until recently, air-cooled condensers were not used in thermal power plants because the technology of materials used in steam boilers and turbine plants

---

***Received July 16, 2021 / Accepted September 17, 2021.**

Corresponding author: Jovan Škundrić
University of Banja Luka, Faculty of Mechanical Engineering, Republic of Srpska, Bosnia and Herzegovina
E-mail: jovan.skundric@gmail.com

was on the level which had been limiting the overall efficiency of the plant and not leaving enough room for further decreasing the efficiency by using the air-cooled condenser. So, condensing processes in thermal power plants were, almost exclusively, organized in water cooled condensers, which would use either water from a nearby river, or recirculated water from dedicated wet cooling towers. Such a design has a major advantage compared to the air-cooled condensers by means of significantly higher efficiency considering the heat transfer and consequently almost steady condensing pressure and the heat drop in the thermodynamic cycle of the plant, but it also requires having enough water on the site where the thermal power plant is built. Recently, the technology of materials has significantly improved, which has also led to the improvement of thermal power plants overall efficiency, finally leaving enough room for using air-cooled condensers when necessary.

Given all this, in scenarios where we have a coal mine and an appropriate nearby site for a thermal power plant, but we do not have a river or enough water for wet cooling towers, an air-cooled condenser can be, and usually is, an appropriate alternative [1]. Since air-cooled condensers operate in a much more stochastic environment and with cooling media of a much lower specific heat and density than the water-cooled designs do, it is very important to conduct a thorough analysis of the meteorological conditions the condenser must operate in [2,3].

The mentioned analysis implies the adequate series of measurements of the meteorological parameters on the plant's location and those parameters are in the first place ambient temperature, wind speed and direction [4].

This paper examines the operating conditions of the air-cooled condenser in thermal power plant in Stanari, Republic of Srpska, by means of analysing the data measured by the local meteorological station within the plant.

THERMAL POWER PLANT STANARI AIR-COOLED CONDENSER PROPRTIES

Fig. 1 provides a simplified scheme of an air-cooled condenser, where the element which represents the condenser in the scheme is just one of the thirty cells within the actual condenser in the Stanari thermal power plant. Often, condensers of this type are designed in a way that the suction side of cells is not protected from the side wind. Such a design is used for the Stanari thermal power plant condenser.

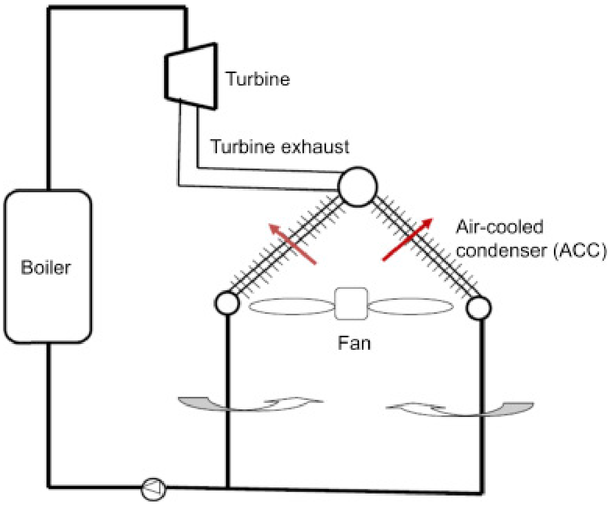

Fig. 1 Air-cooled condenser simplified scheme [5]

The main thermodynamic mechanism in the condenser is the convective heat transfer to the surrounding air. Obviously, the low air temperature combined with proper mass flow of the air are the desirable conditions. This also means that atmospheric conditions in which either the air temperature is increased or the air mass flow is disturbed in some way are the least convenient ones.

As previous research by numerous authors has shown, [6,7] the major issues with the air-cooled condenser exist in hot summer days when ambient air temperature is high enough to cause a problem. In such a case, the temperature difference between the ambient air and the temperature of condensation at the desirable pressure becomes too small for efficient heat transfer. In addition to the high radiation from the Sun at that time of the year, it is more than obvious that condensing pressure will inevitably rise. A certain increase in condensing pressure leads to the decreasing efficiency of the plant, meaning higher fuel consumption. Unfortunately, not rarely the increase can be of such an extent that the mass flow of fresh steam must be decreased, and the demanded power of the plant simply cannot be reached, [7]. Moreover, the higher condensing pressure increases the condensing temperature and less steam is being extracted for the regenerative heating of the condensate. The consequence is an even higher mass flow of the steam streaming into the condenser for the same power, further worsening the plant operation.

Since the temperature is just one part of the operational issues [7], it is obvious that the air mass flow must be carefully considered too. As mentioned before, the air mass flow strongly depends on its velocity, which is being maintained with 30 axial fans, each of nearly 10 meters in diameter. The fans used can achieve very high air flow rates, but, being designed as axial, the pressure gains are rather small and consequently rather easy to be disturbed. One of the main factors which disturb the air flow is a side wind on the suction side of the fans. Side wind, if its speed is high, provokes sub-pressure on the suction side which increases the pressure head the fan must overcome, which lowers the flow of the air being forced across the condenser. Another, and maybe even bigger problem with the side wind, is the disturbance of the air flow field which further leads to either uneven or even incomplete air flow across the panels of the condenser which can dramatically worsen the temperature field in the panels. The previous research has shown that the wind as a disturbing factor for condenser operation in the thermal power plant in Stanari becomes critical only when joined with high outdoor temperatures [8]. The days with extreme outdoor temperatures and relatively strong wind, as well as their influence on the condenser operation are the subject of this paper.

MEASURING EQUIPMENT

The measurements were conducted using the Weather Station PCE-FWS 20N and the Ultrasonic Anemometer YOUNG 86000.

PCE-FWS 20N is a professional calibrated weather station which includes sensors for measuring air temperature, relative air humidity, air pressure, rainfall, wind speed and direction. The station itself is designed as a wireless equipment with the transmitter powered both by a solar panel and batteries. The transmission frequency of the weather station is 868 MHz.

The YOUNG 86000 Ultrasonic Anemometer is a 2-axis, no-moving-parts wind sensor. It was designed for general meteorological applications requiring accurate and reliable measurement. The sensor features a wide operating range. It measures wind speed and direction based on the transit time of ultrasonic pulses between three transducers. Measurement results are available as calibrated analog output signals, or serial data using RS-232 or RS-485 ports. Continuous serial output or polled operation may be used. Serial format options include a direct connection to YOUNG Wind Tracker displays, marine NMEA systems, data loggers, or other compatible serial communication devices.

Table 1. Weather Station PCE-FWS 20N specifications

No.	Measured value	Range	Resolution	Accuracy
1	Air temperature	-40 ÷ 60°C	0.1	±1°C
3	Relative humidity	1 ÷ 99%	1%	±4% within 20..80% ±6% within 80..99%
4	Rainfall	0 ÷ 9999 mm	0.3 mm at <1000 mm 1 mm at >1000 mm	±6%
5	Wind speed	0 ÷ 50 m/s	0.1	±1 m/s at <5 m/s ±10% at >5 m/s

Table 2. YOUNG 86000 Ultrasonic Anemometer specifications

No.	Measured value	Range	Resolution	Accuracy
1	Wind speed	0 ÷ 75 m/s	0.01	±2% at 0 ÷ 30 m/s ±3% at 30 ÷ 75 m/s
2	Wind direction	0 ÷ 360°	0.1°	±2°

DATA AND DISCUSSION

The data from the meteorological station within the plant were sorted and presented in three diagrams (Figs. 2, 4 and 5). Fig. 2 shows the daily averages of the outdoor temperatures and the wind speeds for the year 2020 [9]. One can notice that the highest average outdoor temperatures were present in the period from late July to late August and that their values were around 28°C. As presented in Fig. 2, the average wind speeds for that period did not exceed 3 m/s, which is in perfect accordance with the wind map from the global wind atlas, presented in Fig. 6 [10].

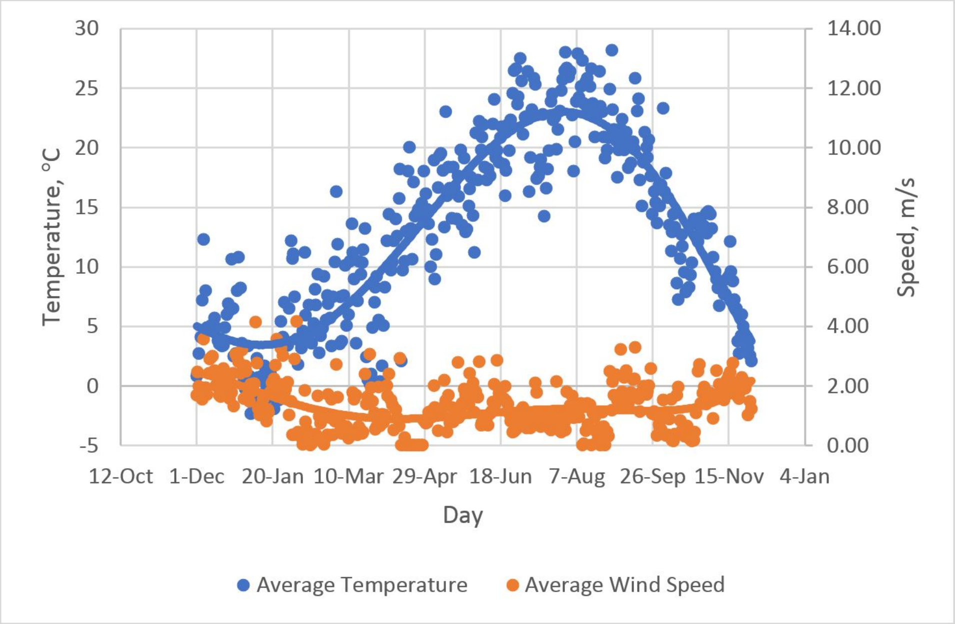

Fig. 2 Average outdoor temperature and average wind speed in 2020. at the plant site

Fig. 4 shows the daily maximums of the outdoor temperatures and the wind speeds. It is obvious that the data presented in Fig. 4 are quite different than the ones in Fig. 2. Such deviations from the average wind speed are in accordance with the Weibull's distribution graph for the wind in August 2020 for the plant's location, presented in Fig. 3, since the shape parameter of the distribution is significantly lower than the Rayleigh's value of 2.0. According to Fig. 4, the most critical period appears to be from August 11 to August 30, with the obvious temperature maximum on August 30. In that period the wind speed, although not in its maximum on the scope of the year, still exceeded 6 m/s.

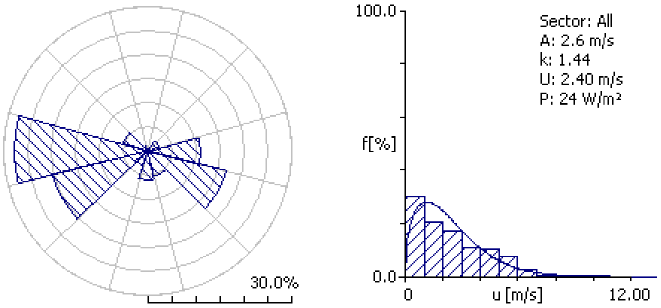

Fig. 3 Wind rose and Weibull's distribution graph for August 2020 at the plant site

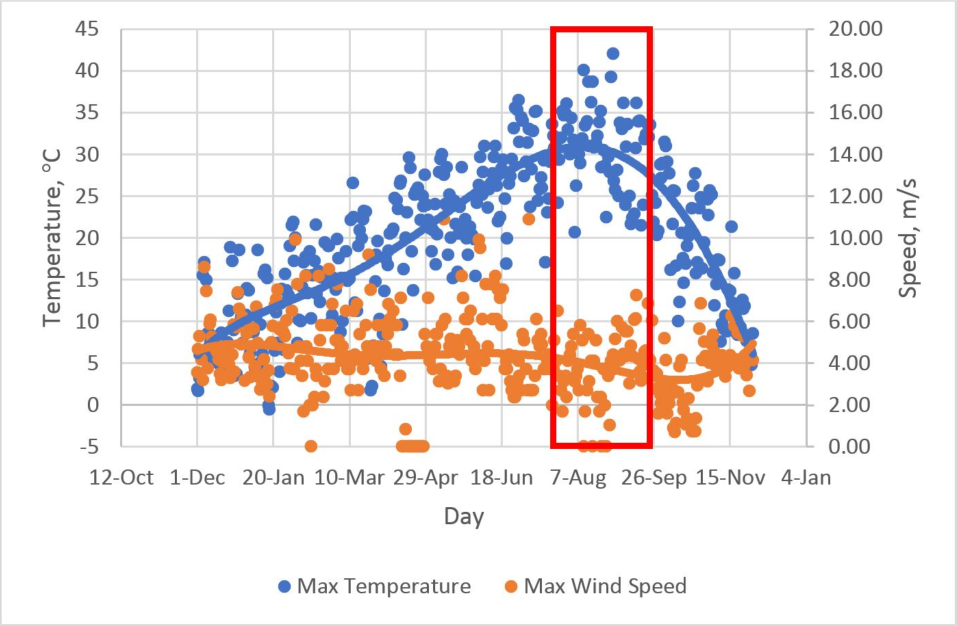

Fig. 4 Maximum outdoor temperature and maximum wind speed for 2020 at the plant site

Since the highest temperature was measured on August 30, the temperatures, wind speeds and associated directions are presented for that day in a minute resolution in Fig. 5. As can be seen in Fig. 5, the period with temperatures above 40°C on August 30, 2020, lasted for approximately 6 hours, roughly from 11:30AM till 5:30PM. In the same period the wind speeds were mostly around 5 m/s with a peak at 3:45PM with a value of 7.40 m/s. It is also important to note that at 3:45PM the outdoor temperature was 41.44°C. Regarding the wind directions, as can be seen in the wind rose for August 2020, in Figs. 3 and 5, it is clear that on the location of the plant only two main directions from which the wind blows appear. Those directions, as visible in Figs. 3 and 5, are west-southwest and east-southeast and are influenced by the shape of the terrain and the highway that was recently built near the plant.

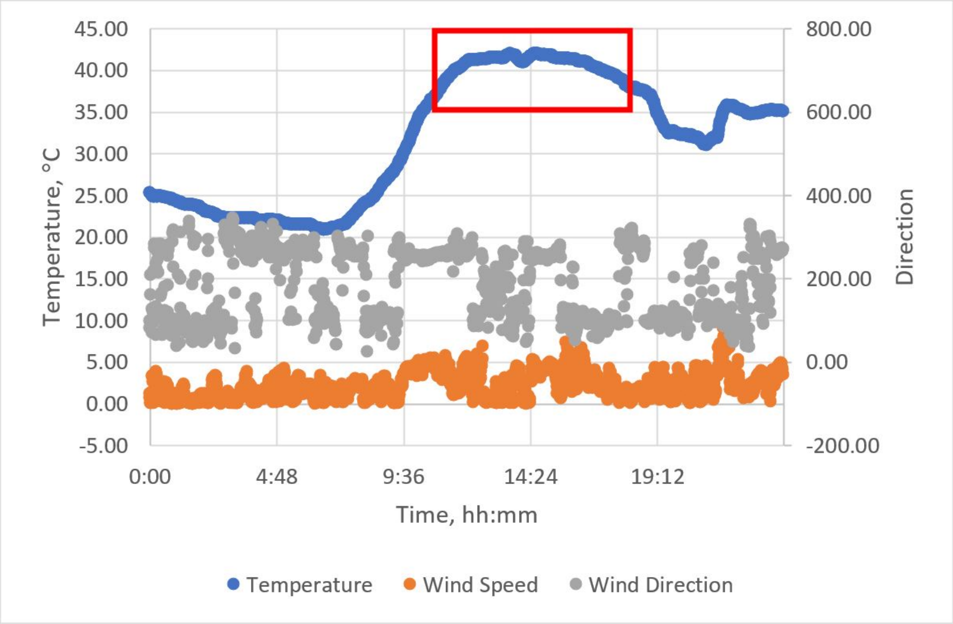

Fig. 5 Outdoor temperature, wind speed and direction in a minute resolution on the plant site on August 30, 2020.

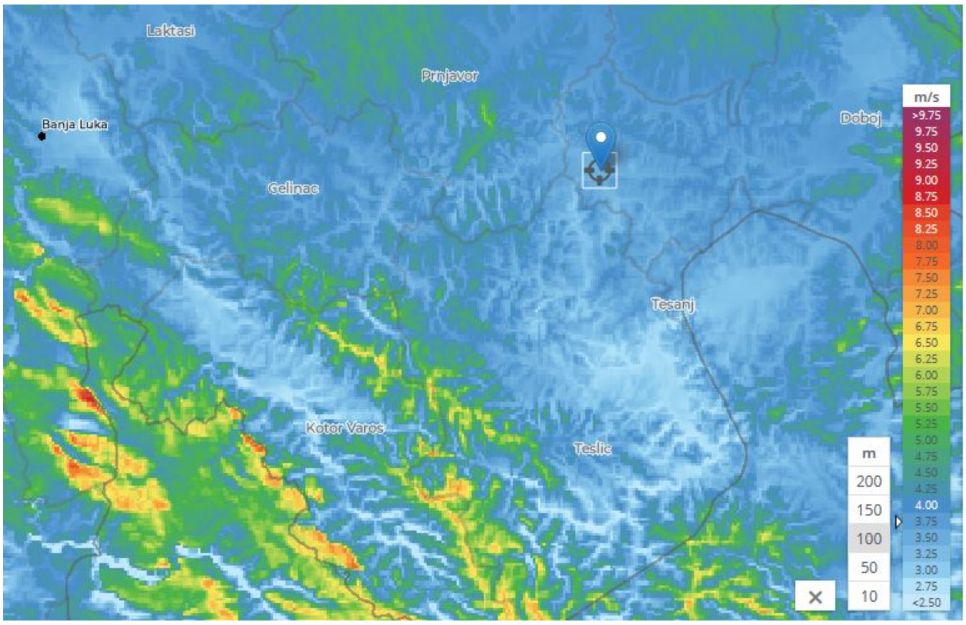

Fig. 6 Wind map [10]

CONCLUSION

The goal of this paper was to seek the critical conditions that can appear on the location of the plant by means of endangering the proper operation of the condenser. As stated in the discussion part, the highest average outdoor temperatures were measured in the period from late July to late August and all their values were around 28°C. The average wind speeds for that period did not exceed 3 m/s. All those values suggest that there should not be any problem with the condenser's operation since those are perfectly within the declared values the condenser is designed for. But, as was mentioned in the discussion part, the maximum measured values provide quite a different picture of the conditions the condenser operates in. Daily maximums for both the temperature and the wind speed are in ranges that severely deflect from the working conditions the condenser is designed for and would surely disturb its proper function, especially when appearing at the same time. Temperatures higher than 40°C will certainly present a problem, as well as the side wind faster than 6 m/s, which can disturb the air flow through the condenser since the air speed the fans produce is around 10 m/s. An even more pessimistic image is presented by the data series measured in a minute resolution for August 30, chosen as a characteristic day regarding extreme values. So, it is more than obvious that in periods like those 6 hours recorded on August 30 the power of the plant will certainly decrease in some noticeable amount, which could not only decrease the profit from the plant but could endanger the stability of the whole electric power system at that time.

Acknowledgement: *I would especially like to thank my esteemed colleagues from the "Stanari" thermal power plant for all the precious help they gave me within the research that has led to this paper.*

REFERENCES

1. Nazar, R., 2020, *Water-reduction potential of air-cooled condensers in coal power plants in India and anticipated trade-offs*, Applied Water Science, 10:162 DOI: 10.1007/s13201-020-01246-8
2. Živković P, Tomić M., Ilić G., Vukić M., Stevanović Ž. Ž., 2012, *Specific approach for continuous air quality monitoring*, Chemical Industry 66 (1), pp 85-93
3. Zhai, H., Rubin, E., 2010, *Performance and cost of wet and dry cooling systems for pulverized coal power plants with and without carbon capture and storage*, Energy Policy 38, pp 5653–5660
4. Živković P, Tomić M., Bakić V., 2020, *Experimental validation of wind energy estimation*, Thermal Science 24 (6), pp 3795 - 3806
5. Blanco, M., Santigosa, L. R., 2017, *Advances in Concentrating Solar Thermal Research and Technology*, Elsevier.
6. Alhamdo, M., Theeb, M., Abdulhameed, J., 2015, *Using Evaporative Cooling Methods for Improving Performance of an Air-cooled Condenser*, Universal Journal of Mechanical Engineering 3 (3), pp 94-106, DOI: 10.13189/ujme.2015.030304
7. M. Pieve, M., Salvadori, G., 2011, *Performance of an air-cooled steam condenser for a waste-to-energy*, Energy Conversion and Management 52, pp 1908–1913
8. Škundrić, J., Živković, P., Mitrović, D., Vukić, M., Đurica, D., Bačić, B., 28-29 May 2021, *Analysis of seasonal deviations influence on air-cooled condenser performances*, Proceedings of 15th Int. Conference DEMI, Banja Luka
9. Data from the meteorological station in thermal power plant "Stanari"
10. Global Wind Atlas. From: https://globalwindatlas.info/, accessed on Feb. 25, 2021.