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Performance Analysis of Rankine Cycles at Partial Load using Method of Spencer, Cotton and Cannon

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ABSTRACT: Rankine cycle is a model used to study the operation of power cycles that convert thermal energy into mechanical energy. Thermal energy source provides heat to the working fluid, which changes phase and is turbinated. In the turbine, the working fluid makes rotate the blades, obtaining kinetic energy in the rotating axis of the turbine. purpose of this paper is to study the performance of Rankine cycles at partial load me-using the method of Spencer, Cotton and Cannon. This method allows you to predict performance is entropic steam turbines under conditions other than the nominal ones, using correlation empirical to obtain as a final result an estimate of the performance under partial load conditions. In this project an adaptation is proposed to use the method in pressure operation sliding. A calculation methodology will be developed that allows, through pre-design data of the components of the Rankine cycle, calculate cycle performance and operating conditions of the turbines and heaters of the cycle. The methodology will be used in a program to developed in Matlab, which will allow con guring different options of the Rankine cycle and visualizing the results.

KEYWORDS: Rankine cycle , Spencer, Cotton ,Cannon, isentropic steam turbines isolated

I.INTRODUCTION

The Rankine cycle is a model used to study the operation of power cyclethat convert thermal energy into mechanical energy. Thermal energy source provides heat to the working fluid, which changes phase and is turbinated. In the turbine, the working fluid makes rotate the blades, obtaining kinetic energy in the rotating axis of the turbine. In its most common application, the Rankine cycle uses water as the working fluid. There are Rankine with different working fluids, such as organic Rankine cycles, which they use organic compounds instead of water.Rankine cycles are used today to generate electrical power, and can have powersup to 1 GW in nuclear power plants. The contribution of thermal energy is the main element differentiator between plants. The three most used types of input are coal combustion in thermal power plants, the residual energy of the exhaust gases from the combustion of the gasnatural in combined cycle plants, and the uranium ion in nuclear power plants. the production of electric energy using coal and natural gas was more than 60% of thetotal generated, and production with nuclear energy was 10%. The production of electrical energy through Rankine cycles is the majority worldwide, and although it is expected in the futurethat sources such as coal lose relevance, the flexibility and reliability of Rankine cycles guarantees that they will continue to be used in the future.

II.BASIC OPERATION OF THE RANKINE CYCLE

In Figure 1 the basic diagram of a Rankine cycle is shown for a thermal power plant, whose boiler burns fossil fuel, for example coal. The Rankine cycle in Figure 1 has two water loops (sections A and C), and one loopflue gas (section B). The electric generator converts the kinetic energy of theTurbine shaft rotation in electricity.

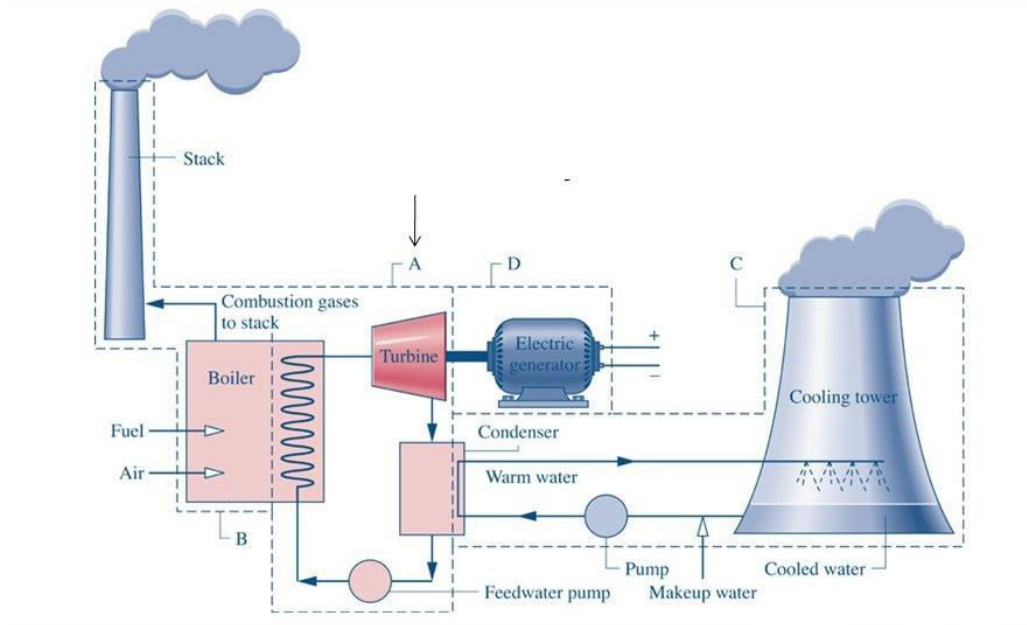


Figure 1 basic diagram of a Rankine cycle

The main water circuit (section A) is the one that will be studied in this project. Its function-Basic procedure is, going clockwise starting with the pump:

1. The water is driven by the pump into the boiler. The pump can be electric, or it can be coupled to a secondary turbine fed with steam extracted from the turbine principal.
2. In the boiler, thermal energy is supplied to the working fluid to change from liquid phase to steam. The boiler is made up of several circuits of different designs, depending on their function is to heat liquid water, evaporate or heat superheated steam.
3. The superheated steam that comes out of the boiler passes through the turbine, where it loses pressure and temperature. In the turbine, the passage of steam makes the blades rotate, obtaining energy kinetics on the rotary axis.
4. When leaving the turbine, the steam is collected in the condenser, where it goes back to the liquid. The condensate is sent to the pump, closing the cycle.

In the condenser, the heat given off when the steam changes phase (energy not used by the turbine) is rejected outside. The cooling water circuit (section C in Figure 1.) cools the condenser and transfers the heat to the environment. This circuit can be cooled with natural draft or forced draft cooling towers, and there are also large-scale power plants size that are cooled by river or sea water.

III. PROPOSED SYSTEM MODEL

In this paper, a regenerative Rankine cycle with six closed heaters is proposed. The cycle It has two high pressure heaters and four low pressure heaters. The boiler is considered as a black box, that is, its operation is not modeled, but only the conditions at entry and exit are taken into account. In Figure 2 the Rankine cycle study sample as shown in the program. In the diagram, the steam turbine is separated into three stages (high pressure, medium pressure and low pressure), according to the separation of the turbine into three bodies used in the power plants modern. The study configuration chosen is the one given as an example of calculation in the method by Spencer, Cotton and Cannon. In this study configuration, The steam turbine is separated into three bodies (high, medium and low pressure). In central high power, it is common for medium and low pressure turbines to be double-flow (the mass flow is divided in two, passing to two symmetrical turbines), and there may be cases in which have more than one low pressure turbine body. The condenser at the outlet of the low pressure turbine. Condensate and feed water pumps are located after the condenser and the deaerator respectively. The feedwater heaters (FWH), separated into a high pressure train and a low

pressure train. The high pressure train sends the condensate to the deaerator, and the low pressure train sends it to the condenser. The high pressure turbine feeds a single FWH, as does the medium pressure turbine. The low-pressure turbine powers the four low-pressure FWHs. The open heater or deaerator, which has as its extraction steam collected at the outlet of the medium pressure turbine. The proposed system model given in the method of Spencer, Cotton and Cannon [1] is shown in Figure 2. The Spencer, Cotton and Cannon method consists of a methodology based on empirical data to predict the isentropic performance of steam turbines at partial loads. In the method of Spencer, Cotton and Cannon, corrections for estimate the efficiency of the electric generator and the mechanical losses of the turbine. Not have implemented these corrections, because they do not involve major changes in the results and they are highly dependent on specific turbine models. It can be seen in the diagram that the low-pressure turbine is double-flow, with some of the extractions being different on each of the two sides. This does not affect the model used, since the double-flow turbine is symmetrical with respect to the entry point (the two sides are of identical design and construction), and the enthalpy values are the same as if a single flow turbine.

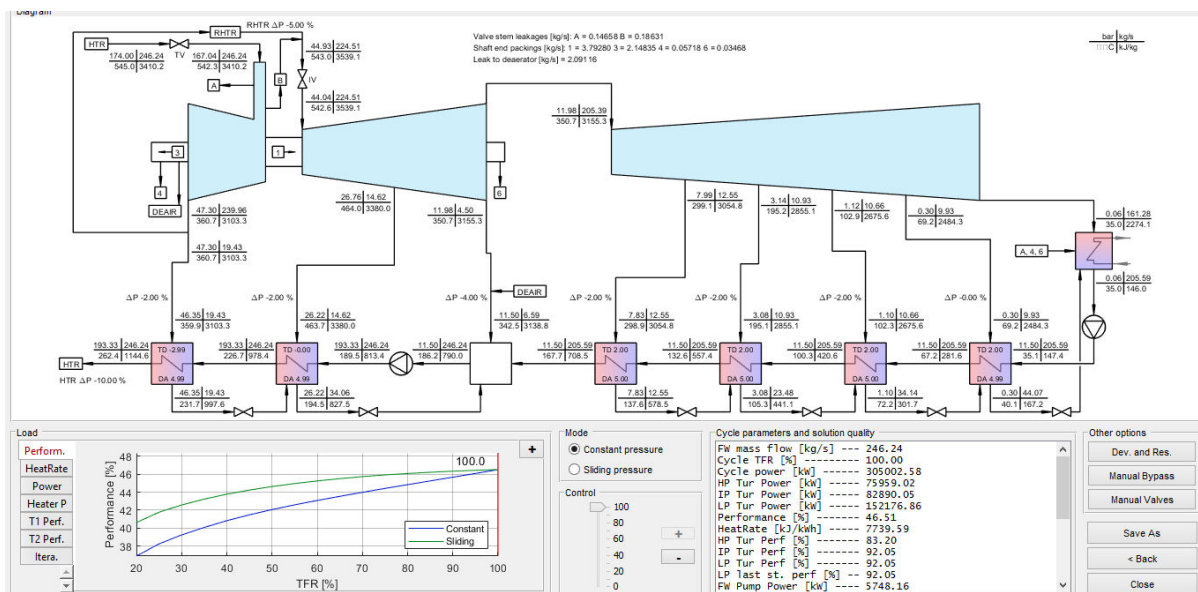


Figure 2 Proposed system model

The last low pressure heater sends the condensate to a pump and mixes it with the main flow. There are no big differences between operating this way or sending the condensate to condenser. In more modern design plants the second is used method, possibly to avoid loss of efficiency caused by using a third pump on cycle. The diagram in Figure 2 shows the Steam Seal Regulator (SS REG.), Which collects leaks 2, 5 and 6. The SSR separates the vapor from the condensate from these leaks, sending the mass flow to the condenser or feed water line as appropriate.

IV. RESULTS ANALYSIS AND VALIDATION

The results obtained with the developed program are studied. The isentropic efficiency values obtained for the turbines with the method of Spencer, Cotton and Cannon [1], the influences of each correction, and the lines of expansion. Two different modes of operation of the heater train will be analyzed. Finally, the results obtained by the calculation method developed will be compared used the method of Spencer, Cotton and Cannon to solve cycles at part load. In partial load, the performance of the Rankine cycle can fall more than 5% compared to the performance under design conditions. It is observed in Figure 3 a difference of at up to a 4% efficiency between sliding pressure mode and constant pressure mode.

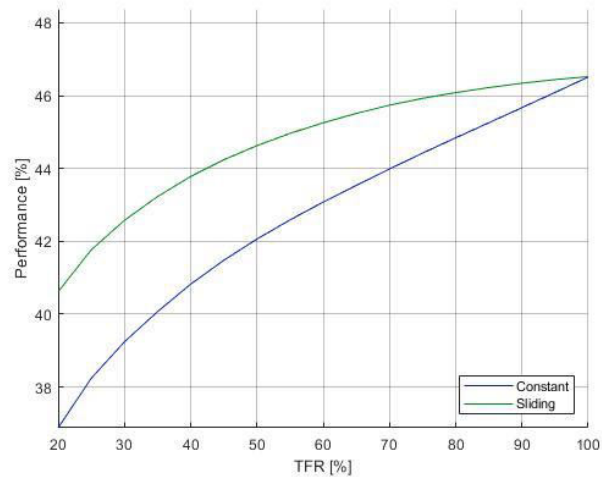


Figure 3: Cycle performance for sliding pressure and constant pressure

In sliding pressure, the high pressure turbine has more energy available (difference enthalpy between the inlet and outlet), and as observed in the Figure4.

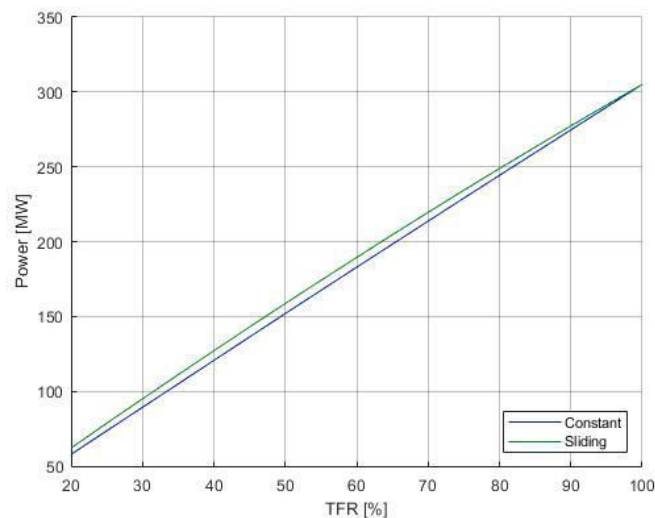


Figure 4: Power of the high pressure turbine at constant and sliding pressure

In Figure 5 the Ts diagram is shown of the cycle study design conditions. It can note that the lines of the closed heaters are evenly spaced, and that the Turbine expansion lines have approximately the same slope (through put is entropic very similar). In Figure 6.6 the Ts diagram shown in the partial load cycle in sliding pressure and constant pressure, at a TFR of 30%.

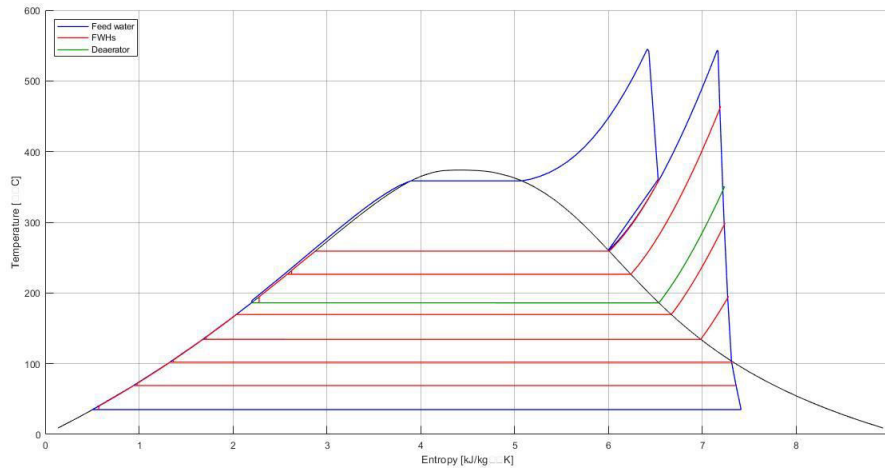


Figure 5: Ts diagram of the full load cycle

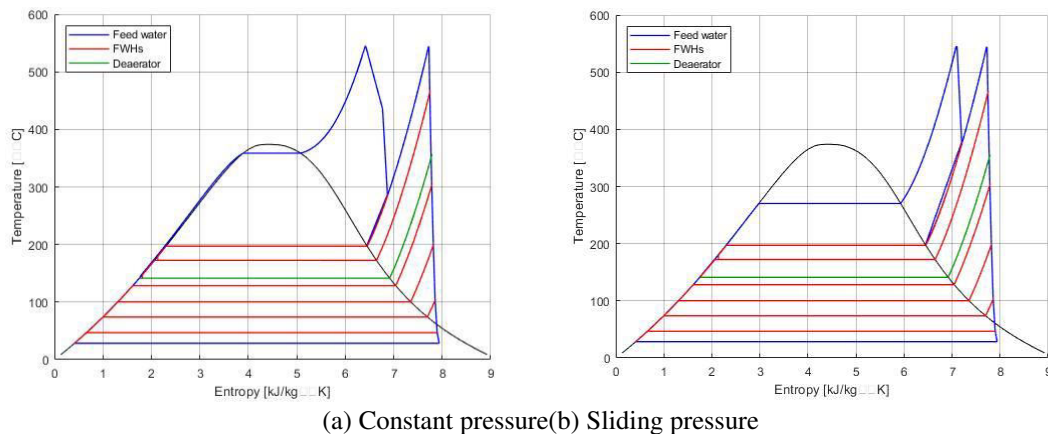


Figure 6: Ts diagram of the partial load cycle (TFR = 30%)

In sliding pressure, evaporation in the steam generator occurs at lower pressure, while at constant pressure it occurs at the same pressure as at full load. At constant pressure, the steam passes through the semi-closed control valves, closing pressure position and enthalpy in the process. In sliding pressure, the valves are fully open and there are no losses. Heater lines are closer together at part load, due to less drop pressure produced in turbines. The high pressure turbine exhaust temperature is much higher in sliding pressure. Which results in less energy consumption in the reheater the condenser pressure is lower at part load than at full load. In the high pressure turbine, the isentropic performance drop is very significant at load spartial pressure at constant pressure, which can drop up to 60% for turbines with a government of a la, Figure 7. For turbines with two-stage steering, Figure 8. It is also verified that in both cases the drop in performance is practically linear for TFR values less than 70%.

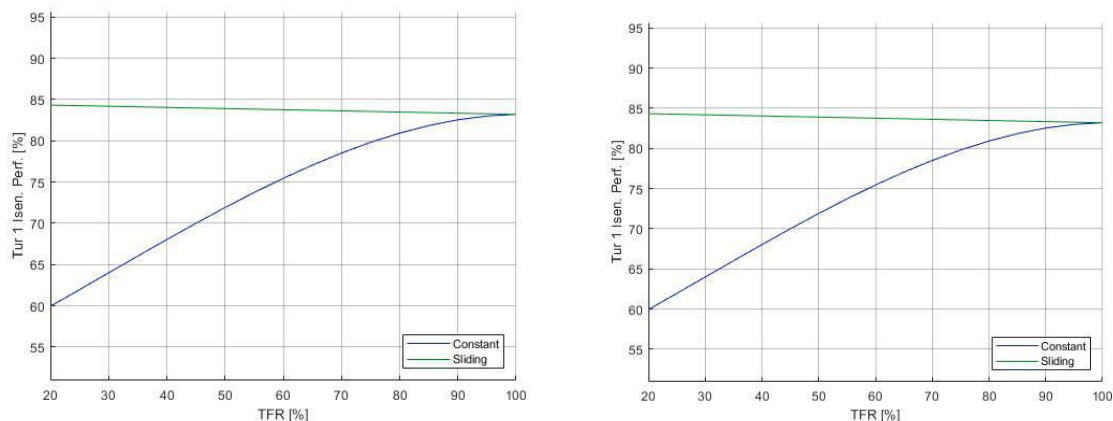


Figure 7: Isentropic performance at part load of the high pressure turbine

V. CONCLUSION

In this paper, the method of Spencer, Cotton and Cannon to predict the yield has Isentropic partial load operation of steam turbines. It has been detailed in detail the calculation process to use the method and a correction has been proposed to calculate the sliding pressure operation. The developed program allows the user to modify the value of the input parameters by means of through a simple user interface. It is possible to choose between different types of turbine, change the number of heaters in each section, or the pressures in each extraction. The results are shown in a cycle diagram and the operation of the devices can be studied in detail. Finally, the performance of the cycle has been studied and the results obtained have been analyzed. using the Spencer, Cotton and Cannon method for steam turbines.

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