Exergetic Pinch Evaluation of a Steam Power Plant Heat Exchanger Network

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1. Background:

• Power generation companies are looking for ways to do what was once perceived impossible which is complying with stricter environmental regulations while operating profitable, reliable, more productive plants [1].

• A lot of recoverable energy is lost in the form of heat in power plant **heat exchanger networks (HEN)** and any effort to recover or minimize these heat losses will increase the overall plant efficiency.

• **Pinch analysis** is a method used for minimizing the energy consumption of plants by thermodynamically determining the required minimum energy consumption and achieving them by optimizing heat recovery systems and process operating conditions.

• **Exergy analysis** on the other hand aid in identifying the location, sources and magnitudes of true thermodynamic inefficiencies in a system.

2. Description of the Egbin TPP Rankine Cycle:

• The HEN of the Egbin thermal power plant (TPP) was considered in this study. The plant is a self-contained dual fired (gas and oil) steam electric generating station, comprising six identical 220 MW steam turbine-generators giving a total installed capacity of 1320 MW. A schematic of processes ina typical unit is shown in Fig.1 (bold lines representing cold streams and the light lines representing cold streams).

• Steam is generated in a boiler (the steam generator) and flows through the high pressure (HP) turbine back to the steam generator for reheating, then through the intermediate pressure (IP) turbine to the low pressure (LP) turbine, and from the exhaust of the LP turbine to the condenser for condensation.

• The steam is cooled in the condenser cause its condensation, and the condensate is pumped. from the condenser outlet through feedwater heaters for heat exchange with the steam extractions from the HP, IP and LP turbines, raising the temperature of the condensate. Finally the condensate at the exit of the last HP feedwater heater is sent to the steam generator for re-conversion to steam.

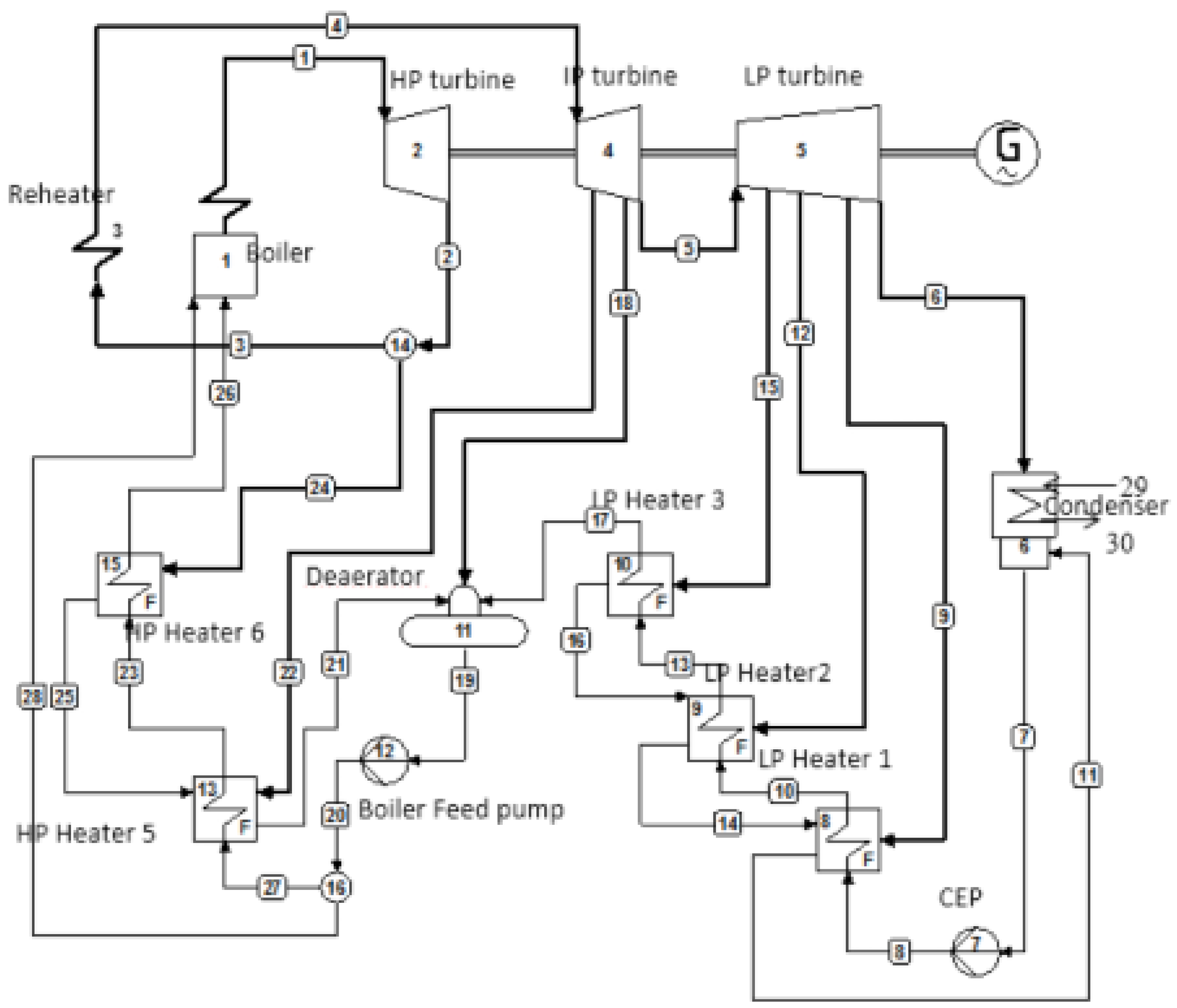

Fig. 1: Schematic of the Egbin TPP

3. Analysis

3.1 The Pinch Analysis: The pinch analysis steps are as follows: * Data extraction from heat exchanger network flow sheet. * Creation of a problem table. * Formation of heat cascade from the problem table. * Construction of composite curves (CC) and shifted composite curves (SCC) for hot and cold steams, and a grand composite curve (GCC). * The CC, SCC and GCC are plots of stream heat flow rates against stream temperatures.

• The horizontal offset between cold stream and hot stream curves in the CC and SCC indicates the quantity of heat recovery that is possible between the streams at any given temperature, and the point of closest approach (least horizontal offset) between the curves is known as the **pinch point**.

• The GCC is obtained from the SCC by plotting the differences in the heat loads of hot and cold composite curves against their temperatures. Thus the GCC is a graphical depiction of the quantities of heating that can be provided by hot streams above the pinch point and the amount of cooling that can be achieved using cold streams below the point. At the pinch point, the cold curve touches the hot stream curve in the SCC, and hence the GCC touches the vertical (temperature) axis at the pinch point. Conceptually, this means that there can be no transfer of heat between hot and cold streams at the pinch point.

3.2 The Exergy Analysis: Disregarding kinetic and potential energy changes, the flow exergy of a fluid in a system at any cycle state is given by

$$\dot{E}x = \dot{m}[(h-h_o)-T_o(s-s_o)] \quad (1)$$

Where Ex = flow exergy, $\dot{m}$ = mass flowrate, h (kJ/kg) = specific enthalpy, h_o = specific enthalpy of the environment, T_o (K) = ambient temperature, s and s_o (kJ/kg°K) = entropies at system and ambient conditions. The difference in the sums of exergies entering the component and the exergies leaving any component is equal to the sum of exergy destruction within the system and exergy losses to surroundings, i.e.,

$$\sum \dot{E}x_i - \sum \dot{E}x_{out} = \dot{E}x_d + \dot{E}x_l \quad (2)$$

Where the sums represent the exergies entering and leaving the system. The external losses Ex_l were consider negligible. Exergy balances was done for the different HEN components shown in Fig.1. Each node was treated as a control volume and their respective properties corresponding to the state specified in Fig 1.

3.3 Combined pinch and exergy analysis (Inevitable and avoidable exergy losses): The combinee pinch and exergy analysis takes the advantages of the individual strengths of pinch and exergy analyses, so that complex processes can be easily represented with diagrams and promising modifications quickly identified. The exergy composite curve (ECC) and the exergy grand composite curve (EGCC) are the curves developed for (CPEA). The ECC and EGCC are produced by converting the temperature axis of Composite curves (CC) and Grand composite curves (GCC) to Carnot factor which is expressed in Eq. (3)

$$\eta_c = 1 - \frac{T_o}{T} \quad (3)$$

4. Results:

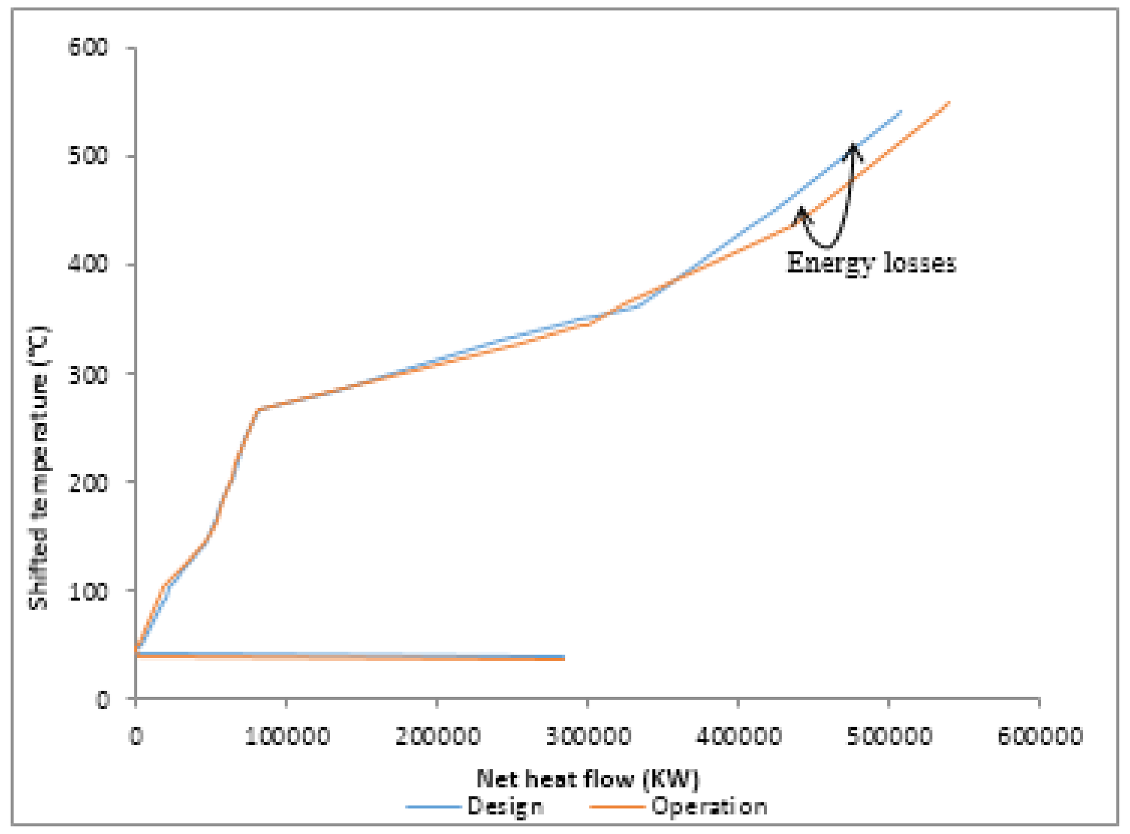

Fig. 2: Grand composite curves for the HEN under plant design and operation condition

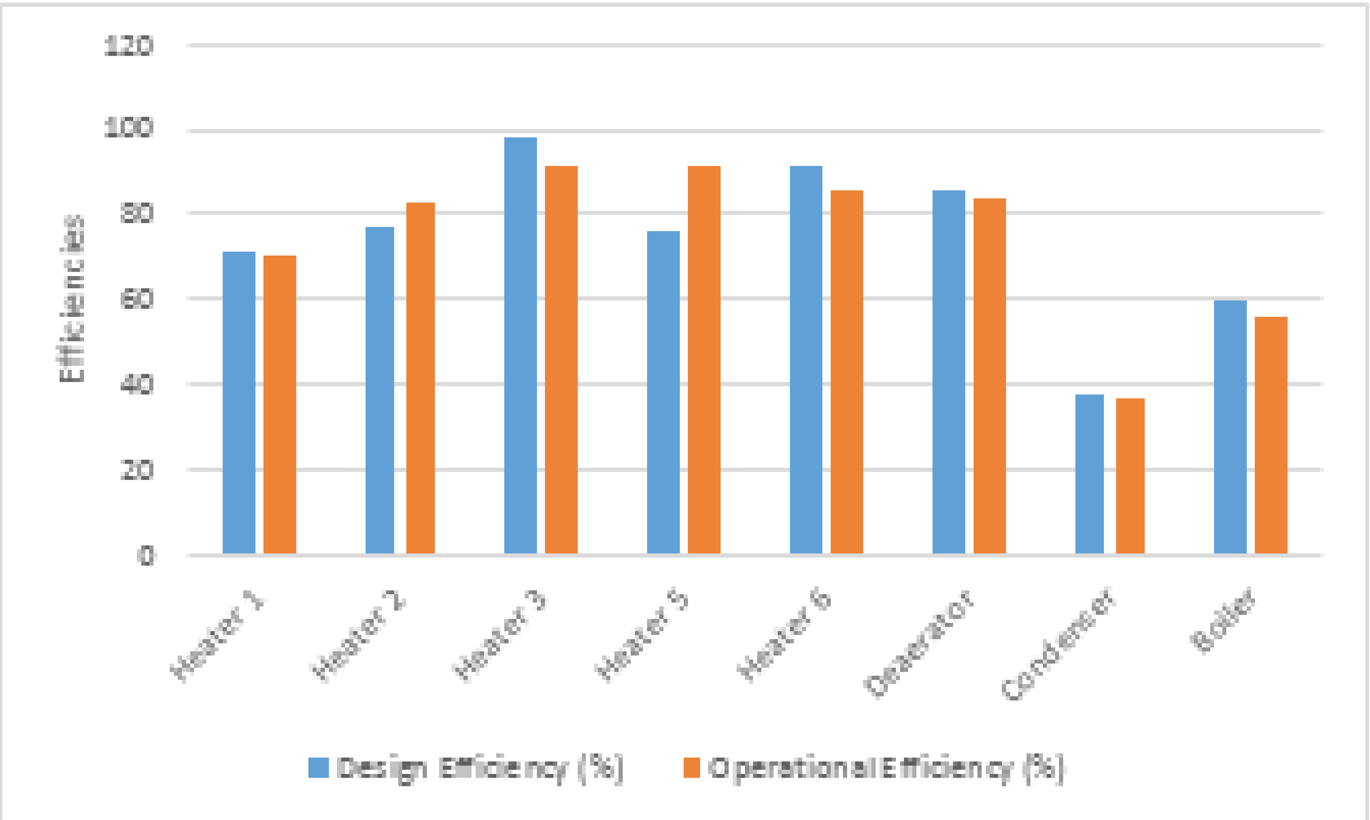

Fig. 3: Exergy efficiencies of major HEN components under plant design and operation conditions

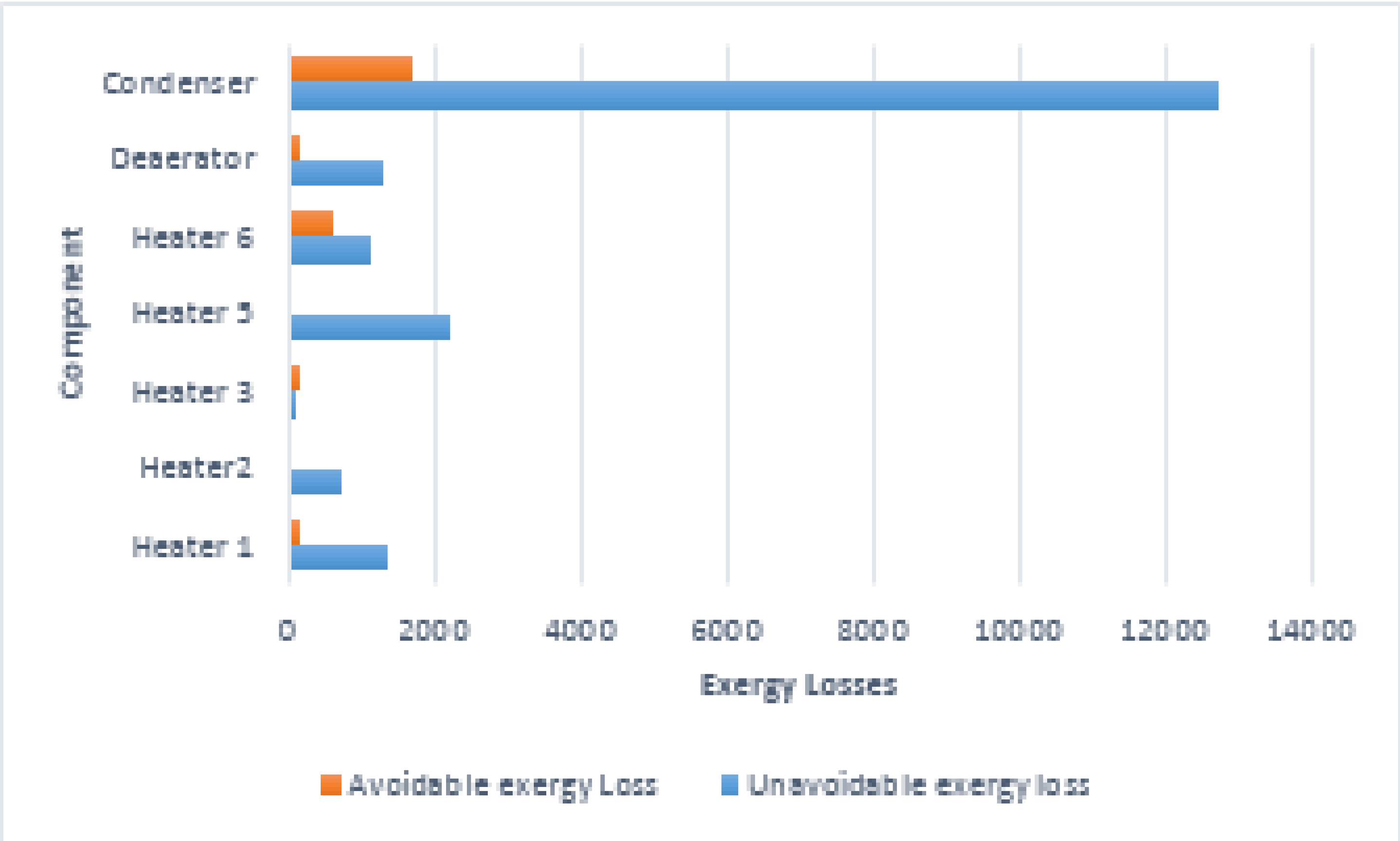

Fig. 4: Inevitable and avoidable exergy losses of major HEN components

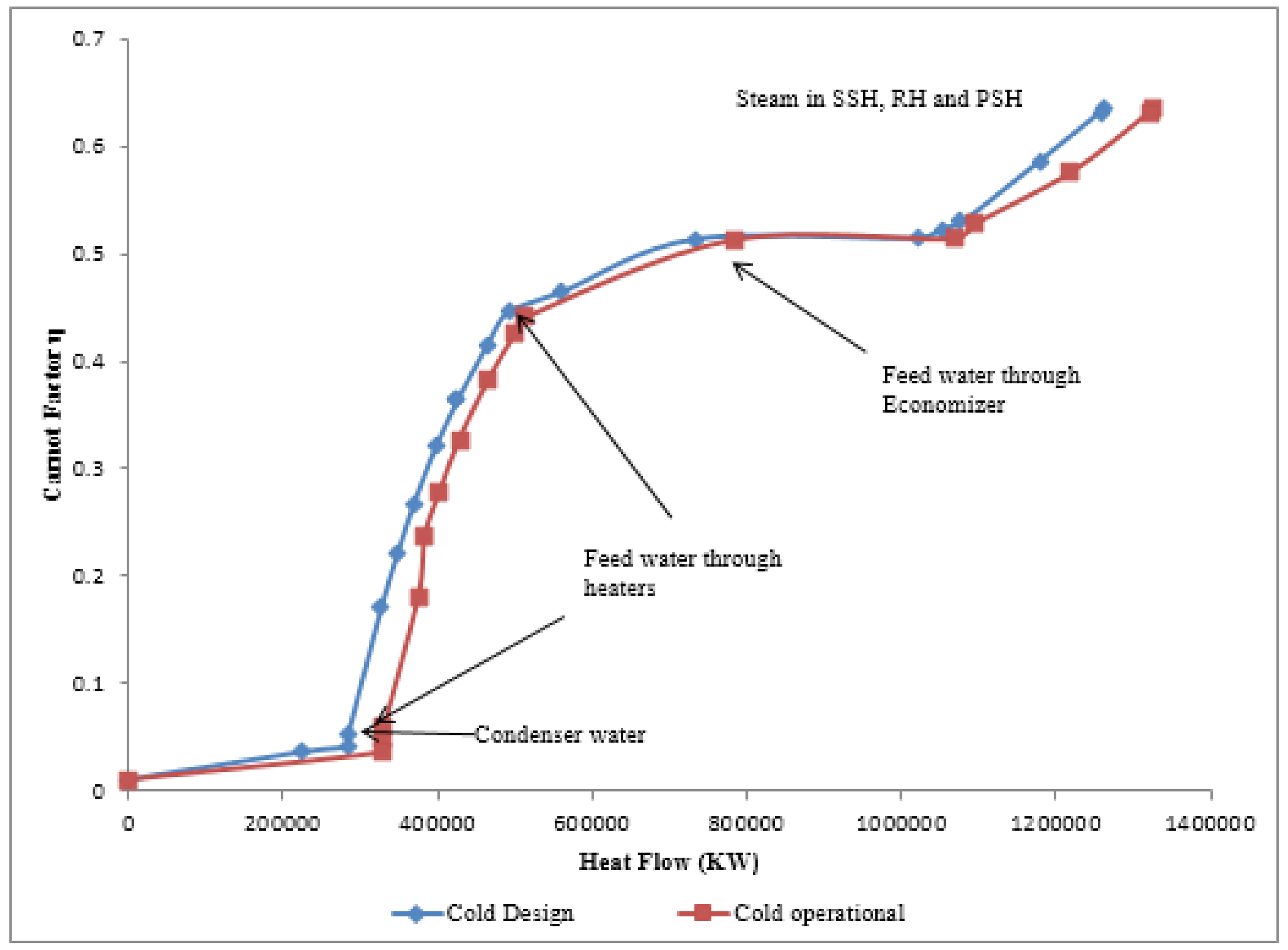

Fig. 5: Exergy grand composite curves for the HEN under plant design and operation conditions