KARAKTERISTIKE TERMIČKIH SISTEMA ZA SIMULTANU PROIZVODNJU ELEKTRIČNE ENERGIJE, TOPLOTE I HLAĐENJA

CHARACTERISTICS OF THERMAL SYSTEMS FOR SIMULTANEOUS PRODUCTION OF ELECTRICITY, HEAT AND REFRIGERATION

Aleksandar GJERASIMOVSKI, Maja SHAREVSKA, Natasha GJERASIMOVSKA,

Monika SHAREVSKA, Vasko ŠAREVSKI

Faculty of Mechanical Engineering,

Ss. Cyril and Methodius University, Skopje, Republic of Macedonia

1. INTRODUCTION

- **SUBJECT OF THE PAPER**
  - **combined thermal systems for simultaneous production of electricity, heat and refrigeration with natural gas engine – electric generator and compressor and ejector refrigeration/heat pump and thermal vapor compression systems.**
  - **schematic diagrams of the combined thermal systems are given and thermal characteristics are estimated.**
- **RESEARCH METHODOLOGY**
- **SUMMARY OF PREVIOUS INVESTIGATION**
- **PURPOSE OF THE PAPER**

  The principle objectives of this paper are
  - **to propose novel alternative combined thermal systems for simultaneous production of electricity, heating, cooling, hot water, steam, etc., with natural gas engine – electric generator and compressor and/or ejector refrigeration / heat pump and thermal vapor compression systems**
  - **to present the performance characteristics of these systems and**
  - **to estimate the energetic, economic and environmental benefits of the implementation in various process industry sectors**

2. COMBINED THERMAL SYSTEMS FOR SIMULTANEOUS PRODUCTION OF ELECTRICITY, HEAT AND REFRIGERATION

- **Poly-generation systems with natural gas engines and electrical generator, for electrical energy generation, and turbo compressor and/or ejector thermal vapor compression (high temperature heat pumps) for steam generation and/or high temperature heat generation, and combined compressor – ejector refrigeration systems for low temperature refrigeration (freezing), cooling and/or chilling water generation.**
- **Original schematic diagrams of various thermal systems along with temperature conditions of the working fluids are given in Figures 1, 2 and 3.**
- **Basic thermal calculations, material and heat (energy) balances have been realized and results are given in the schematic diagrams.**
- **Gas engine – electrical generator: mechanical efficiency of the gas engine (32 – 35 % of HHV); electrical generator efficiency (95 – 97 %).**
- **The proposed poly-generation systems include ejector thermal vapor compression (Fig. 1) , centrifugal compressor thermal vapor compression (Fig. 2) and combined compressor – ejector thermal vapor compression (Fig. 3).**

2.1. Unconventional system for steam generation with gas engine prime mover – electrical generator for electricity generation and ejector thermal vapor compression (Fig. 1)

- **Heat energy in form of steam with defined pressure and temperature, depending on specific requirements of the technological processes, is generated using the waste heat from the combustion process in the gas engine (JC – jacket cooling; EG – exhaust gas) and ejector thermal vapor compression.**

- **High pressure and high temperature steam is generated in the heat exchangers EX2 (16 bar, 200 °C) and EX3 (5 bar, 150 °C)**

- **Steam with low parameters (0.7 bar, 90 °C), generated using low temperature waste heat from the jacket cooling of the gas engine is thermo-compressed up to 2.5 bar, 130 °C using ejector thermal vapor compression (EJ1, EJ2) with high pressure, high temperature steam as motive steam.**

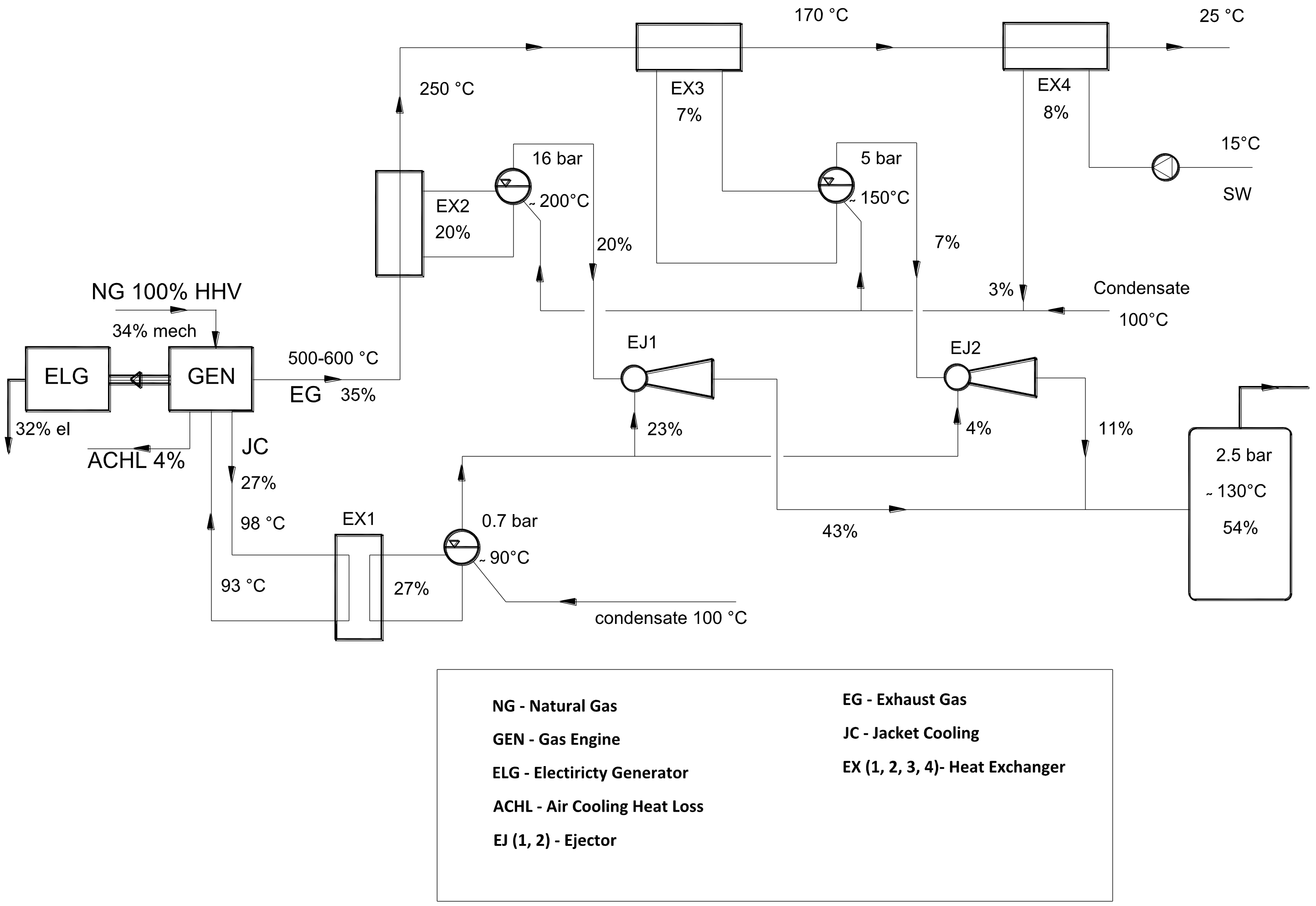

Figure 1 Unconventional system for steam generation with gas engine prime mover – electrical generator for electricity generation and ejector thermal vapor compression

2.2. Unconventional system for steam generation with gas engine prime mover – electrical generator for electricity generation and centrifugal thermal vapor compression

- **Heat energy in form of steam with defined pressure and temperature, depending on specific requirements of the technological processes, is generated using the waste heat from the combustion process in the gas engine (JC – jacket cooling; EG – exhaust gas) and thermal vapor compression by single stage centrifugal compressors.**

- **High pressure and high temperature steam is generated in the heat exchangers EX2 (16 bar, 200 °C) and EX3 (5 bar, 150 °C)**

- **Low pressure steam (0.7 bar, 90 °C), generated using low temperature waste heat from the jacket cooling of the gas engine and medium pressure steam, generated in heat exchanger EX4 (1,5 bar, 110 °C) is compressed by centrifugal compressors (TC1, TC2, TC3) to different pressures (5 bar, 150 °C; 16 bar, 200 °C) defined by the working conditions. Part of generated electrical power is consumed by the centrifugal compressors.**

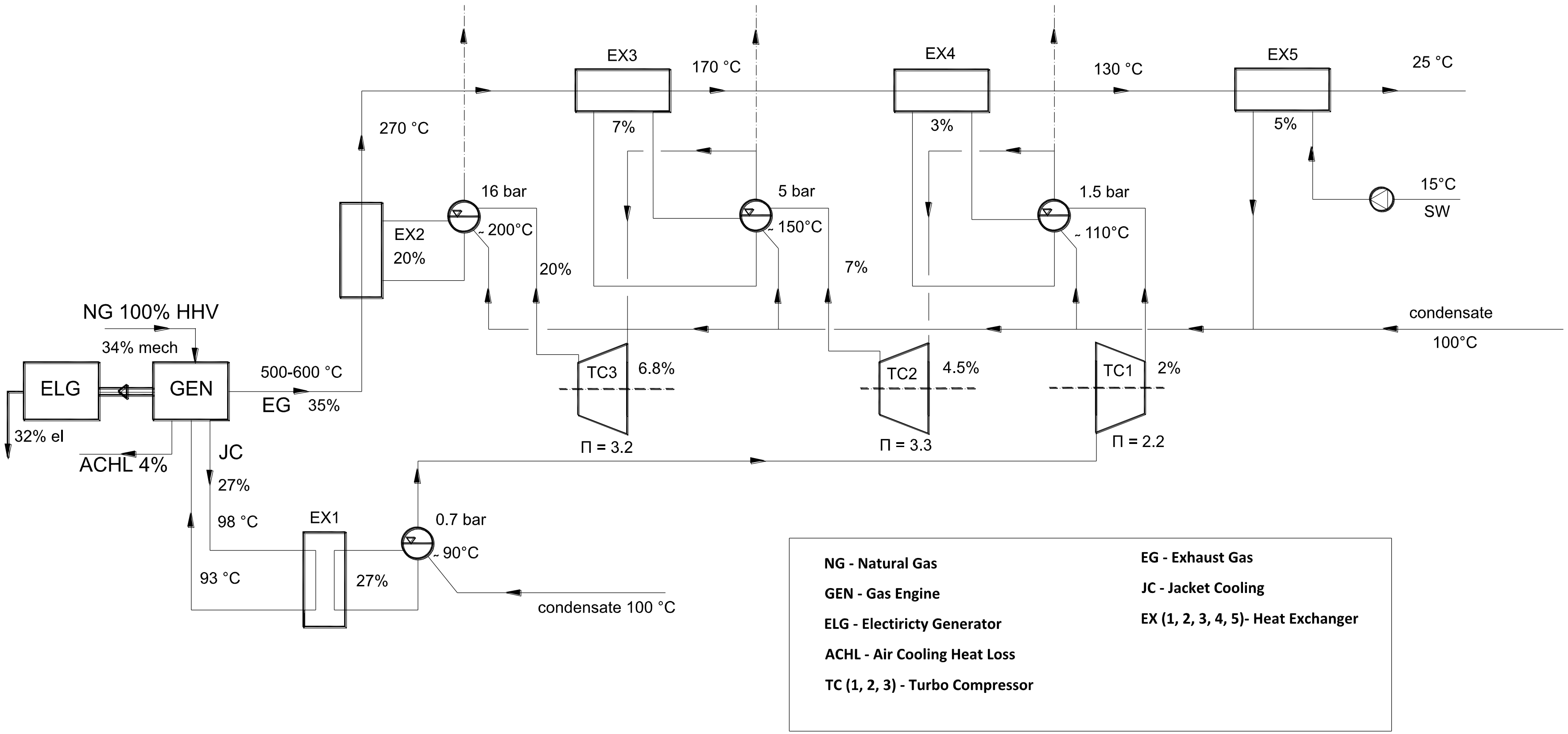

Figure 2 Unconventional system for steam generation with gas engine prime mover – electrical generator for electricity generation and centrifugal compressor thermal vapor compression

2.3. Combined poly-generation system with gas engine prime mover – electrical generator for electricity generation, steam, heat energy and refrigeration

- Heat energy in form of steam with defined pressure and temperature, depending on specific requirements of the technological processes, is generated using the waste heat from the combustion process in the gas engine (JC – jacket cooling; EG – exhaust gas) and thermal vapor compression by ejectors and single stage centrifugal compressors.
- Steam with low parameters (0.7 bar, 90 °C) generated using low temperature waste heat from the jacket cooling is compressed by centrifugal compressor (TC1), to medium pressures (1,5 bar, 110 °C).
- High pressure and high temperature steam generated in the heat exchanger EX2 (16 bar, 200 °C) is used for ejector (EJ) thermal vapor compression from 1.5 bar to 5.0 bar.
- In the heat exchanger EX3 steam with parameters (5 bar, 150 °C) is generated. Medium pressure steam is generated in heat exchanger EX4 (1,5 bar, 110 °C).
- Refrigeration capacities of the refrigeration/heat pump system (R717/R718) are: 15%HHV at – 5°C and 15%HHV at – 40°C.
- Electrical power consumption of the ammonia screw compressors is 9% HHV and 3% HHV. The condenser capacity is 2x21% HHV, and condensing temperature is 45 °C.
- The heat from the refrigeration process is used in the condenser to produce technological hot water which is heated from 15 °C to 40 °C. Additional heating up to 70 °C is realized by two-stage R718 centrifugal heat pump subsystem. Electrical power consumption of the water centrifugal compressors is 2x2% HHV.
- Sanitary hot water is also produced in the heat exchanger EX5 – 5% HHV. Technological hot water capacity is 46% HHV.
- Cooling storage (CS - BLW) and heating storage (TS) are proposed.

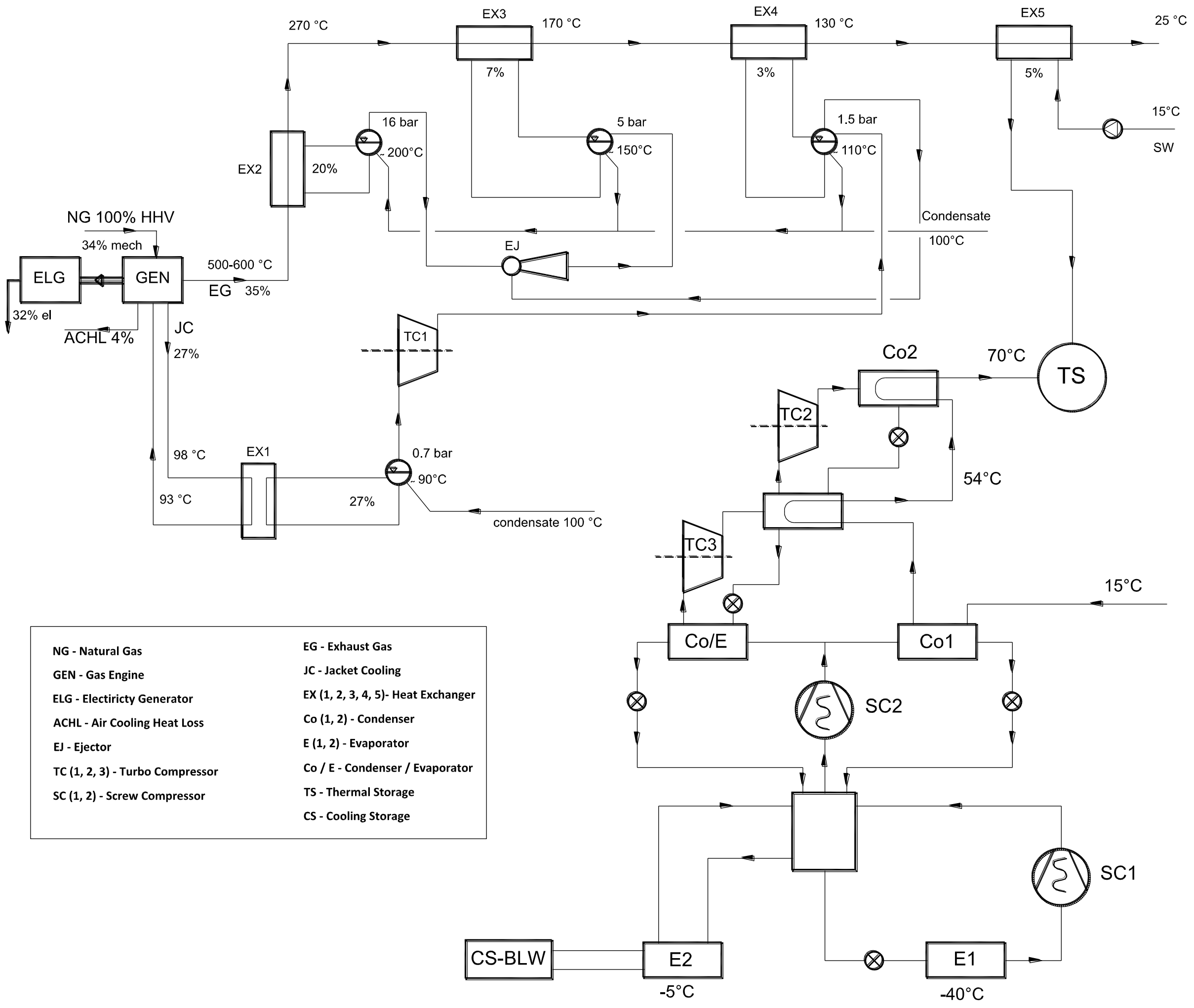

Figure 3 Combined poly-generation system with gas engine prime mover – electrical generator for electricity generation, steam, heat energy and refrigeration

3. CONCLUSIONS

- **Original combined thermal systems for simultaneous production of electricity, heat and refrigeration with natural gas engine – electric generator and compressor and/or ejector refrigeration / heat pump and thermal vapor compression systems are presented.**
- **Schematic diagrams of the combined thermal systems are given and thermal characteristics are estimated.**
- **The concept of dispersed production and consumption of energy (electricity, heating, cooling, hot water, steam, etc.) is applied and can be optimally implemented in various process industry sectors: chemical and pharmaceutical industry, paper industry, food industry, dairy industry, meat industry, textile industry etc.**
- **Comparison with conventional systems for electricity supply, separate production of heat energy and refrigeration energy shows that the expenses for electrical energy and fuel consumption are significantly higher in the conventional systems.**
- **Application of the combined thermal systems for simultaneous production of electricity, heat and refrigeration in process industry sector lead to technical, economic and environmental benefits. High energy efficiency of the proposed thermal systems and significant decrease of fuel consumption result in local ecological benefits, reduction of CO_2 emissions and give contribution in decrease of global warming.**