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Part-load performance of a combined gas turbine - organic Rankine cycle for off-shore applications

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ABSTRACT

In off-shore platforms gas turbines are employed to provide the load required in processes such as crude oil separation, gas compression, seawater injection and oil and gas export. Off-shore gas turbines are designed to ensure high system performance, fuel flexibility and compactness. Furthermore, one or more redundant gas turbines are installed to improve the reliability during maintenance periods. In order to enhance the performance of the power generation system, an organic Rankine cycle can be utilized to recuperate the gas turbine exhaust heat. Benefits of this technology are the relatively high thermal efficiency in full and part-load, low weight, high compactness and little complexity. Furthermore, the organic Rankine cycle eliminates the problem of turbine blade erosion due to liquid droplet formation by utilizing a "dry" fluid as working fluid.

Fig 1. a) Draugen offshore platform, North Sea, Kristiansund, Norway. b) SGT-500 Siemens twin-spool industrial gas turbine.

On the Draugen off-shore oil and gas platform (see Fig. 1a) three SGT-500 gas turbines (see Fig. 1b) are installed. The normal load is normally shared between two engines working at about 50% of the nominal load. This operational strategy ensures that there is enough reserve power required during the oil export. Hence, the analysis of off-shore combined gas turbine – organic Rankine cycle requires an accurate part-load model.

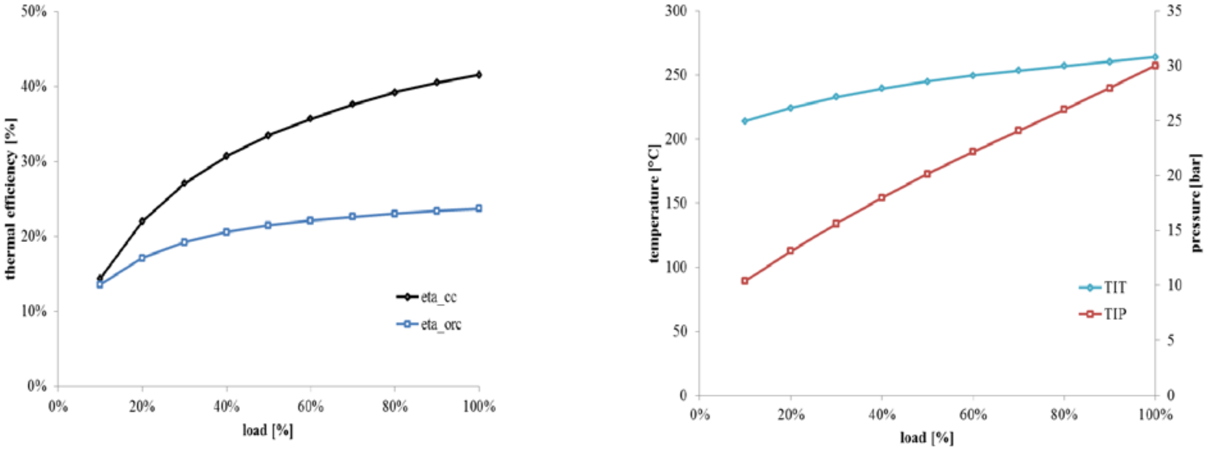

Fig 2. a) Combined cycle and organic Rankine cycle thermal efficiency versus combined cycle load. b) Organic Rankine cycle turbine inlet temperature and pressure versus combined cycle load.

The present work aims at deriving the off-design performance of the combined SGT-500 gas turbine - organic Rankine cycle. The part-load performance of the gas turbine is assessed by utilizing the data provided by the manufacturer. Namely, the mass flow, temperature and composition of the exhaust gases are given as a function of the load of the gas turbine and the ambient temperature. We evaluate the organic Rankine cycle at off-design by introducing specific equations for the pump, heat exchangers and expander. Cyclopentane is utilized as working fluid in the ORC. The simulations indicate that the thermal efficiency of combined SGT-500 - organic Rankine cycle drops down from 41.5% to 14.3% when the load is decreased from 100% to 10% (see Fig. 2a). The corresponding performance of the organic Rankine cycle lies between 23.6% and 13.5%. As show in Fig. 2b, the turbine inlet temperature of the organic Rankine cycle ranges from 263.8 °C to 213.7 °C and the turbine inlet pressure from 30.0 to 10.4 bar As a practical consequence, the methodology can be applied to simulate the real time operation of the combined gas turbine - organic Rankine cycle on the Draugen platform and to evaluate the fuel savings and the reduction of CO_2 and pollutants emission during the year.