POWER CONVERSION SYSTEMS BASED ON BRAYTON CYCLES FOR FUSION REACTORS

J.I. Linares[1], L.E. Herranz[2], B.Y. Moratilla[1], I.P. Serrano[1]

[1] *Rafael Mariño Chair on New Energy Technologies*
Comillas Pontifical University – Alberto Aguilera, 25, 28015 Madrid, Spain
[2] *Unit of Nuclear Safety Research*
CIEMAT – Avda. Complutense, 28040 Madrid, Spain

Corresponding author: linares@upcomillas.es

Based on the ITER program, a domestic R&D program called TECNO_FUS [1] was launched in Spain in 2009 to support technological developments related to a specific concept of dual-coolant (He/Pb-Li) breeding blanket (TBM, Tritium Blanket Module). The dual-coolant blanket is one of the advanced concepts to be pursued within the European long-term power plant conceptual study. Its main characteristics being: the self-cooled breeding zones based on using Pb-Li eutectics both as a breeder and as a coolant, the He-cooled low activated ferritic/martensitic steel structures and the SiCf/SiC made flow channel inserts, serving as electrical and thermal insulators [2].

The thermal energy produced through the fusion reaction in the plasma gets eventually deposited on two locations in a fusion power plant: the breeding blanket module and the divertor. A fraction of around 80% is absorbed by the TBM coolant (He and Pb-15.7Li) [3], whereas the He cooling the divertor takes up the thermal energy leftover (~20%). Presently, He is responsible for about 40% of the total heat removed (blanket and divertor sources included), the other 60% being absorbed by the eutectic. In addition to the unequal distribution of energy absorption, the energy is absorbed at different thermal levels. This fact becomes a key condition for potential power cycles.

Based on previous experience on power cycles for innovative fission reactors [4,5], He and CO_2 Brayton cycles have been adapted to the aforementioned fusion energy sources and their performance investigated in this paper. In addition, super-critical Organic Rankine Cycles (ORC) have been considered as a way to recover a fraction of the exhaust exergy from the He power cycle (i.e., combined cycles), whereas more conventional steam Rankine cycles including re-heating have been used in CO_2 cycle. The good number of power cycle configurations explored yielded to a broad range of thermal efficiencies, from low 30's to high 40's. By using He, efficiency ranges from 32%, in classical configurations, to 38% when an ORC is implemented. Dual-cycle arrangements in which steam is responsible for structural blanket cooling and He takes over the other thermal sources, can reach up to 42%. And, finally, the reference CO_2 recompression cycle efficiency (~41%) can be stretched to 46% when a Rankine cycle takes advantage of the exhaust exergy.

[1] J. Sánchez et al., 23th Symposium on Fusion Engineering, San Diego, USA, May 31-June 5, 2009.
[2] P. Norajitra, L. Bühler, et al., Fusion Engineering and Design, 69, 2003, 669-673.
[3] E. Mas de les Valls, L. A. Sedano, et al., Journal of nuclear materials, 376, 2008, 353-357.
[4] L.E. Herranz, J.I. Linares, B.Y. Moratilla, Applied Thermal Engineering, 29, 2009, 1759-1765.
[5] M. Saez, D. Haubensack, A. Gerber, F. David, ICAPP '08, Anaheim, USA, June 8-12, 2008.