# Superstructure optimization of supercritical $CO_2$ Brayton cycle by MINLP approach

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Supercritical $CO_2$ (SC-$CO_2$) Brayton cycles have emerged as a promising solution for high-efficiency power production in fossil-thermal, nuclear and solar-thermal applications. To explore its industrial feasibility, studies have been devoted to maximize the cycle efficiency for some well-known Brayton cycles. However, cycle layout improvement is a potential solution in enforcing the Brayton cycle efficiency. Searching a competitive layout among many different cycles or even creating new layouts is thus necessary.
On the other hand, an industrial-scale problem usually has additional constraints arising in practice (e.g., new restriction on some variables), or even modified objective function (e.g., new cost function developed). It occurs that most of performed assessments will need to be reviewed from time to time.

In this study, a framework of **superstructure optimization** of SC-$CO_2$ Brayton cycle is described. In a superstructure, all equipment that can be potentially selected (in the final flowsheet) as well as equipment interconnections are represented. This methodology permits to review **automatically** a large quantity of cycle layouts within a defined superstructure. By using the mixed non-linear (MINLP) optimization, a global optimal layout of Brayton cycle –or at least competitive solutions– along with optimized process specifications can be found.
The process synthesis performed in this framework can be described as two levels. Firstly, the superstructure generation and interconnection identification (integer decision variables identification) are carried out. Then by employing an optimizer linked with a chosen process simulator, both continuous (e.g. process specifications) variables and discrete integer variables (decision variables) are optimized.

In this paper, a commercial process software *ProsimPlus* is linked with an ACO (Ant Colony Optimization), *MIDACO* [1], which is suitable to handle such a non-linear and non-convex problem. A very first test-of-proof superstructure represents only 6 different layouts of SC-$CO_2$ Brayton cycle defined by 3 discrete integer variables. 7 continuous variables and 4 inequality constraints are considered in the superstructure optimization. Results point out that the most competitive configuration is recompression-reheating cycle with an efficiency of 50.8% under consideration of coal-fired plant situation (30MPa/620°C). This initial superstructure allows to validate the methodology.

A second built superstructure represents **over 100** layouts of SC-$CO_2$ Brayton cycle. A total of 19 variables are optimized among which 5 are discrete integer variables. 7 inequality constraints and one equality constraint are considered. The best known efficiency is found to be as high as 55.8% in a double recompression-preheating-reheating layout.

The optimization framework presented in this paper focus on maximizing the cycle efficiency, however, design trade-offs between thermodynamics and economics have to be taken into account in a practical energy systems decision making. The ongoing study carries on the development of associated techno-economic cost functions. Thus, in a close future, the framework will be extended to the levelized cost of electricity (LCOE) optimization.

[1] M. Schlueter. Nonlinear mixed integer based Optimization Technique for Space Applications. PhD thesis, University of Birmingham, 2012.