Next Generation Integrated Simulation Platform to Cover All Engineering Phases of CO_2 Power Cycle


Ian Boys — Simulation Software Architect at Schneider Electric*


Robert Fernandez — Manager, North American Technical Sales Consulting at Schneider Electric*


Livia Wiley — Product Marketing Manager at Schneider Electric*


Seiya Hirohama — Thermodynamic Product Manager, Schneider Electric*


Cal Depew — Simulation Product Director Schneider Electric*

*Schneider Electric Software, LLC, 26561 Rancho Parkway South, Lake Forest, CA, USA

1. Objectives

Actual and practical utilization of CO_2 Power Cycle requires completing all of the engineering steps indicated in Fig.1 based not only on steady-state but also dynamic simulation incorporating detailed mechanical information and control strategy. Conventional approaches require multiple software platforms and tedious manual integration procedures. A new single integrated simulation platform can serve all of the engineering phases with highly accurate, reliable and robust simulation capability, to save significant time and cost all through the plant life cycle.

- Basic Design: Steady-state material and heat balance is calculated for CO_2 Power Cycle under specified conditions such like load and temperature of heat source. Rough sizing of equipment is done based on simulation.
- Detail Design: After sizing and selecting equipment, steady-state simulation is done again to know "actual" operating conditions. Dynamic simulation is done for establishing and checking control logics. Operation manual can be checked utilizing dynamic simulation.
- Operation Analysis: By comparing actual operation with simulation, variable knowledge can be obtained such like real efficiency of each compressor or expander and heat exchangers.

Fig.1 Usage of process simulators in expected Engineering steps for CO_2 Power Cycle

2. Measure to Achieve Objectives

Establish a novel and integrated simulation platform utilizing the modern ease of use, multiple simulation modes, and custom modeling. Equip the platform with highly accurate Wager Equation of State (EOS) for CO_2.

3. Introducing SimCentral®

3-1 Platform

A new Simulation Platform was established using a newly-devised mathematical framework for solving huge sets of non-linear simultaneous equations based on multi-core CPU technology.
The platform has feature of multi-user collaboration of which concept is indicated in Fig.2.

- **Shared Simulation Repository**
- **Multi-client**
- **Cloud-ready**

Fig.2 Concept of multi-user collaboration

3-2 Incorporation of Wagner EOS

Wagner EOS [1] was incorporated into the platform to predict density, enthalpy, entropy and saturation line of CO_2. The simulation results were validated by checking exact matching with standalone calculation of GERG-2008 EOS on REFPROP[2].

3-2 Modeling of CO_2 Power Cycle

We successfully conducted steady state simulation to optimize the process configuration for a CO_2 recompression cycle studied by McClung et.al.[3] which had two compressors and a turbine as shown in Fig.3.

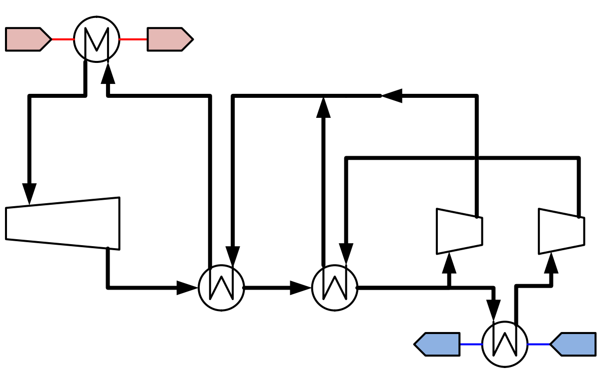

Fig.3 Simplified Process Flow Diagram of CO_2 Power Cycle process

Utilizing the equation solver, the circulating rate of CO_2 was readily determined in consistent "degree of freedom".
The simulation converted to dynamic simulation as shown in Fig.4, incorporating mechanical data such as response time of actuator and shaft inertia of the compressors and the turbine.

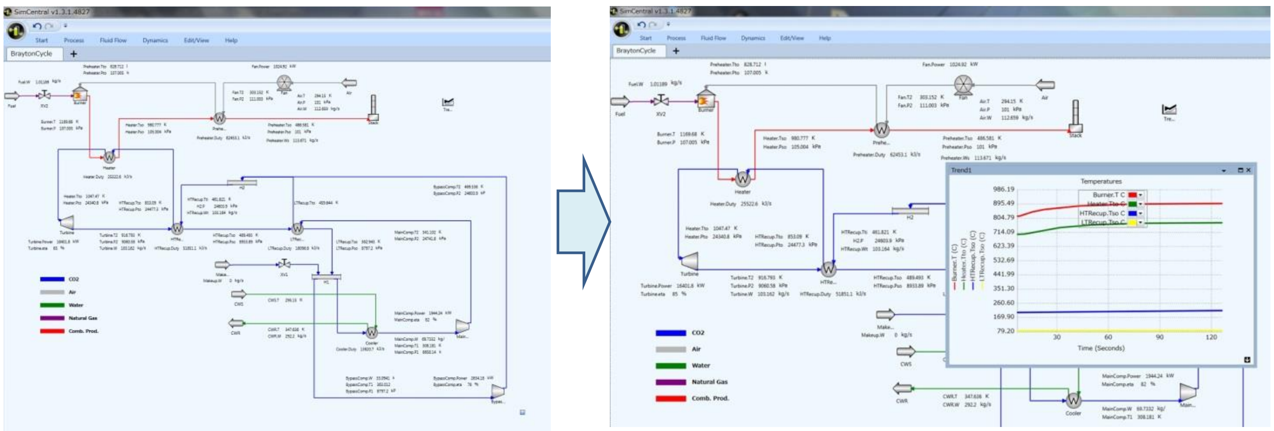

Fig.4 Snapshots of CO_2 Power Cycle Simulation

4. Conclusions

This work has established a single and integrated simulation platform which is rigorous, accurate, robust, and fast; and it can be applied to all the engineering phases of CO_2 Power Cycle.

Literature Cited

1) Span,R. and Wagner W.; "A New Equation of State for Carbon Dioxide Covering Fluid Region from Triple Point Temperature to 1100K at Pressure up to 800MPa", J.Phys.Chem.Ref.Data,25(6),1509-1596 (1996)

2) Kunz ,O. and W. Wagner; "The GERG-2008 Wide-Range Equation of State for Natural Gases and Other Mixtures: An Expansion of GERG-2004", J. Chem. Eng. Data, 57 (11), 3032–3091(2012)

3) Yoonhan Ahn, Jeong Ik Lee et al. "Review of Supercritical CO2 Power Cycle Technology and Current Status of Research and Development ", Nucl Eng Technolol 47, 647-661 (2015)