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Modelling and dynamic simulation of the 2nd generation oxy fired power plant – oxidant fan failure case

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Abstract

In large and complex processes use of simulators will take place more and more in the future to avoid and learn about transients and unexpected situations. There are plenty of dynamic simulation tools in the markets but most of them have been developed and used for quite specific and limited application areas. At the moment there are just few simulation tools which are capable to handle dynamically in the same simulation case challenging process areas like combustion, distillation, chemistry and control of very large process areas. For this reason, in this study, there was a need to carry out co–simulation where two dynamic simulation tools Apros and Aspen Plus Dynamics were combined together by using Matlab Simulink as an interface. The co–simulation approach was a way to construct large dynamic process simulation environment, where typical operational transients and failure situations of an oxy fired power plant were possible to test and analyze.

Under EU 7th Framework Programme (FP7) the FLEXI BURN CFB project an oxy firing concept based on circulated fluidized bed (CFB) combustion and supercritical once-through (OTU) water steam cycle was developed and successfully demonstrated [1]. This project also generated a dynamic simulation model of the 1st generation oxy firing concept, as we call it. In the EU 7th Framework Program's project O2GEN (Optimization of Oxygen-based CFBC Technology with CO_2 capture), the 2nd generation concept of CFB based oxy firing was developed. The target of the project was, at first, to increase O_2 content in recirculated flue gas to see what kind of effect it has to the heat exchange and corrosion in the boiler. Secondly, the target was to carry out exergy analysis to increase the whole concept efficiency by decreasing energy consumption in the boiler, Air Separation Unit (ASU) and CO_2-purification unit (CPU). Based on these steady state analysis means the refined concept was then modelled for dynamic simulations which were carried out by using Apros and Aspen Plus Dynamics dynamic modelling tools in a co–simulation mode.

This paper deals with dynamic simulation of the 2nd generation 600 MW oxy fired CFB once trough boiler. In this paper we will present the dynamic model which includes oxy fired CFB boiler, turbine island, ASU and CPU with all needed equipment like heat exchangers, pipes, pumps, air and fuel feeding systems, distillation columns and sequestration vessels. Automation like measurements, controllers and actuators are included in the model. The simulation case selected for this paper presents an analysis what happens when one of the oxidant fans trips on boiler full load operation and how to handle this kind of failure by decreasing the boiler load to sufficient level of regarding the available oxidant feeding capacity. There were several items which were taken into account in the boiler, turbine island, ASU and CPU side when this kind of failure takes impact. The main findings in the failure analysis will be presented. Finally, discussion and future aspects of the simulation approach described will be given.

Keywords: CFB; ASU; CPU; CCS; dynamic simulation; modelling; co–simulation; oxy firing; Apros; Aspen Plus Dynamics; oxidant fan failure

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1. Introduction

This simulation study deals with dynamic simulation of the 2nd generation 600 MW oxy fired CFB once trough boiler with all needed additional process areas like steam turbine, air separation unit and CO_2 purification unit. The boiler design was developed by Amec Foster Wheeler and the ASU and CPU expertise by Air Liquide. Steady state exergy analysis and optimization was done by Silesian University of Technology (SUT) and Research Centre for Energy Resources and Consumption (Circe) and Endesa. Dynamic model construction and analysis of the ASU and CPU was made by SUT, and the boiler side modelling and co–simulation realisation by Technical Research Centre of Finland (VTT). During the concept evaluation there were many alternatives, how to for example optimize heat exchange between the process areas, what kind of control strategies should be used and how to locate different components and equipment into the process areas. In this paper the best solution found will be presented.

How to handle failure situations in large interactive process areas? This is an important question where engineers all over work trying to find answers. Simulation can give answers, also for projects in a concept level, not necessarily strictly exact but we can have understanding what might be the biggest problems and bottle necks in the processes. Fuel feeding with balance of feed water flow and oxygen feeding corrected with flue gas O_2-content controller are the main elements in the boiler process. Due to the slow response time of ASU there is a need for buffer vessel of oxygen to make sure the right oxygen amount is reached in the furnace. At the same time if flue gas quality is changing CPU has to respond for that to keep CO_2-content in the right level. In the following Figure 1 oxy fired boiler concept is illustrated.

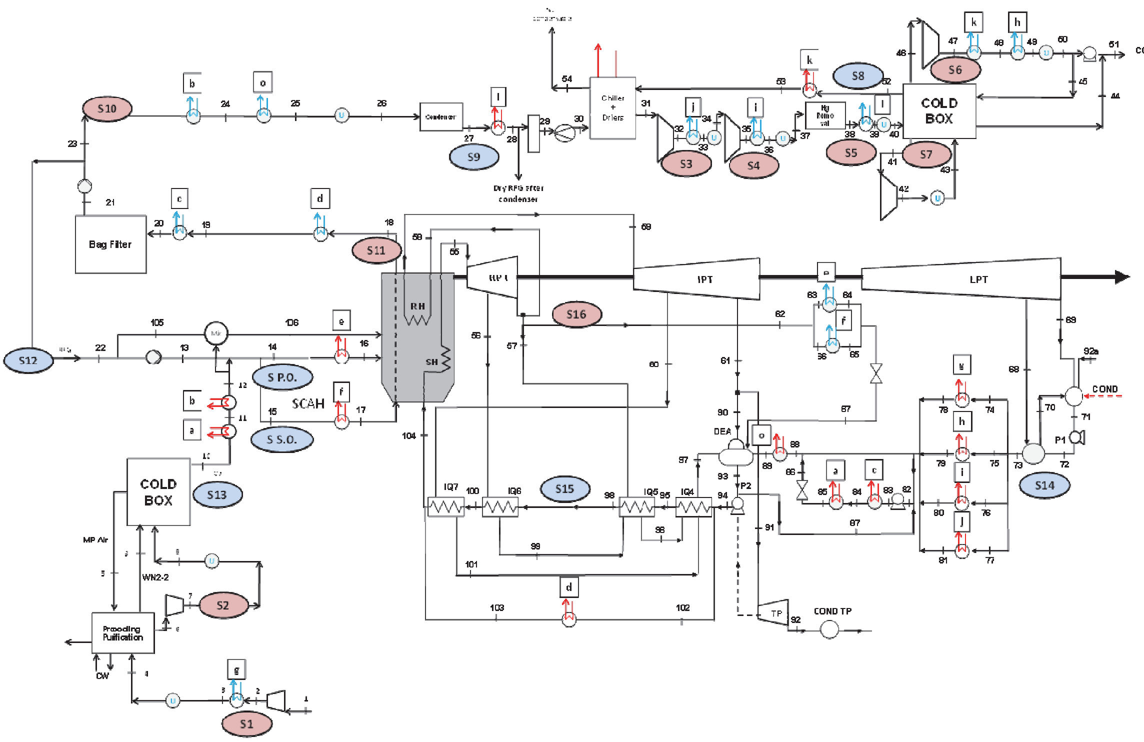

Figure 1. Structure of the oxy fired boiler, turbine island, ASU and CPU [6].

In Figure 1, on the left side, ASU is providing 96 mole-% oxygen feed for the boiler. The coal fired Circulated Fluidized Bed Boiler (CFB) can be seen in the middle. The turbine island is on the right side, and at the top, CPU is illustrated. There are several internal and external heat integration points defined between the process areas. The most remarkable points are the heat exchangers "g" from ASU and "h", "i" and "j" from the CPU to the boiler condensate water preheating. Oxygen preheating is carried out by using condensate water ("a"), indirect preheating with flue gases ("b") and tap steam ("e", "f").

Depending on the development history of different simulation tools, there are plenty of differences in solution methods, material properties, chemical reaction capabilities, ability to handle phases (solids, liquids, gases), and naturally, in the unit