Towards the digitalization of a biomass pellet production plant

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ONE SENTENCE SUMMARY

This project aims to advance the digitization of the biomass sector industry. To do this, we have developed a digital twin of the process of a pellet production plant with an innovative approach that combines Computational Fluid Dynamics techniques, Reduced Physics models and Model-Based System Engineering methods.

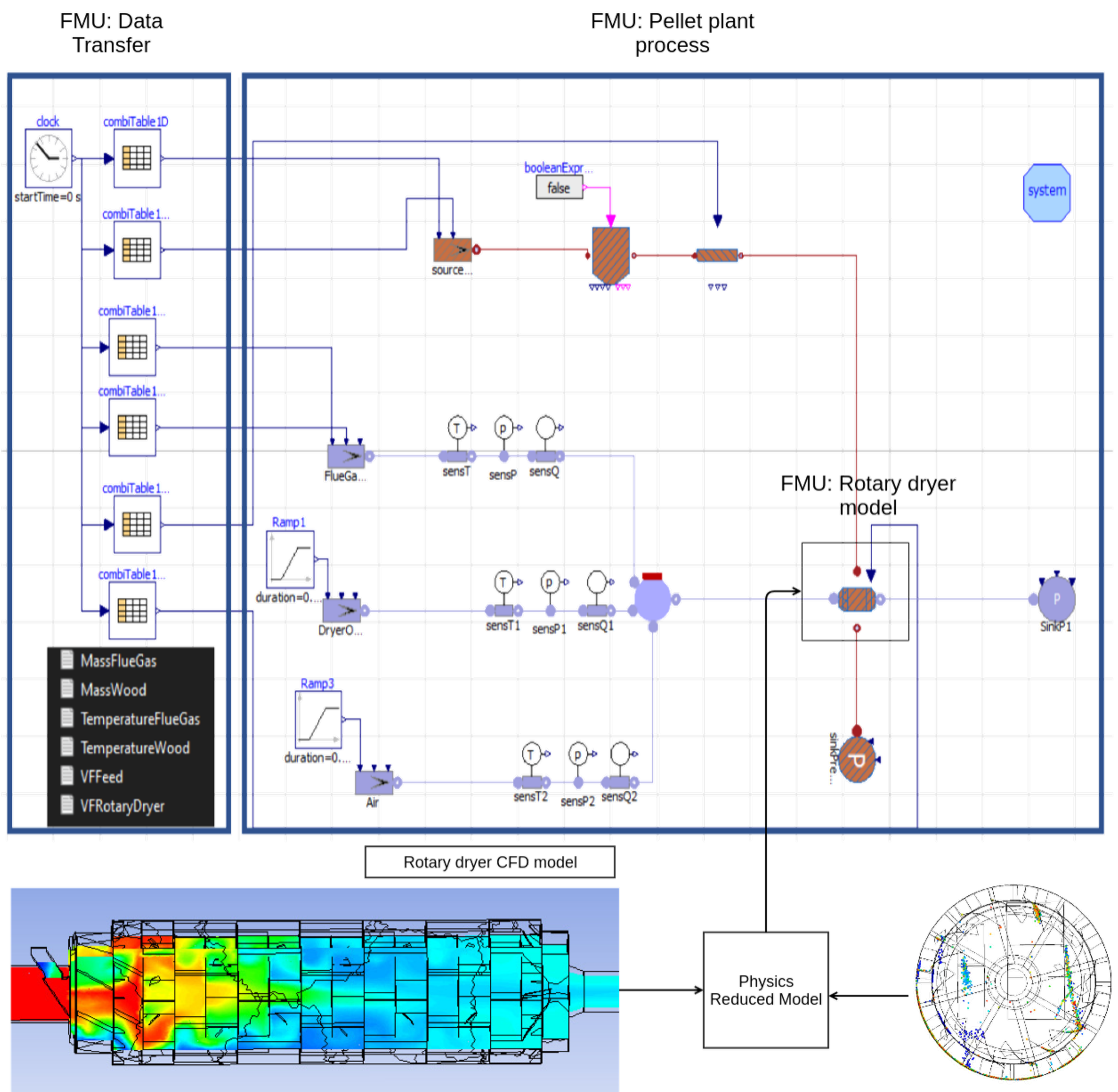
WHY?

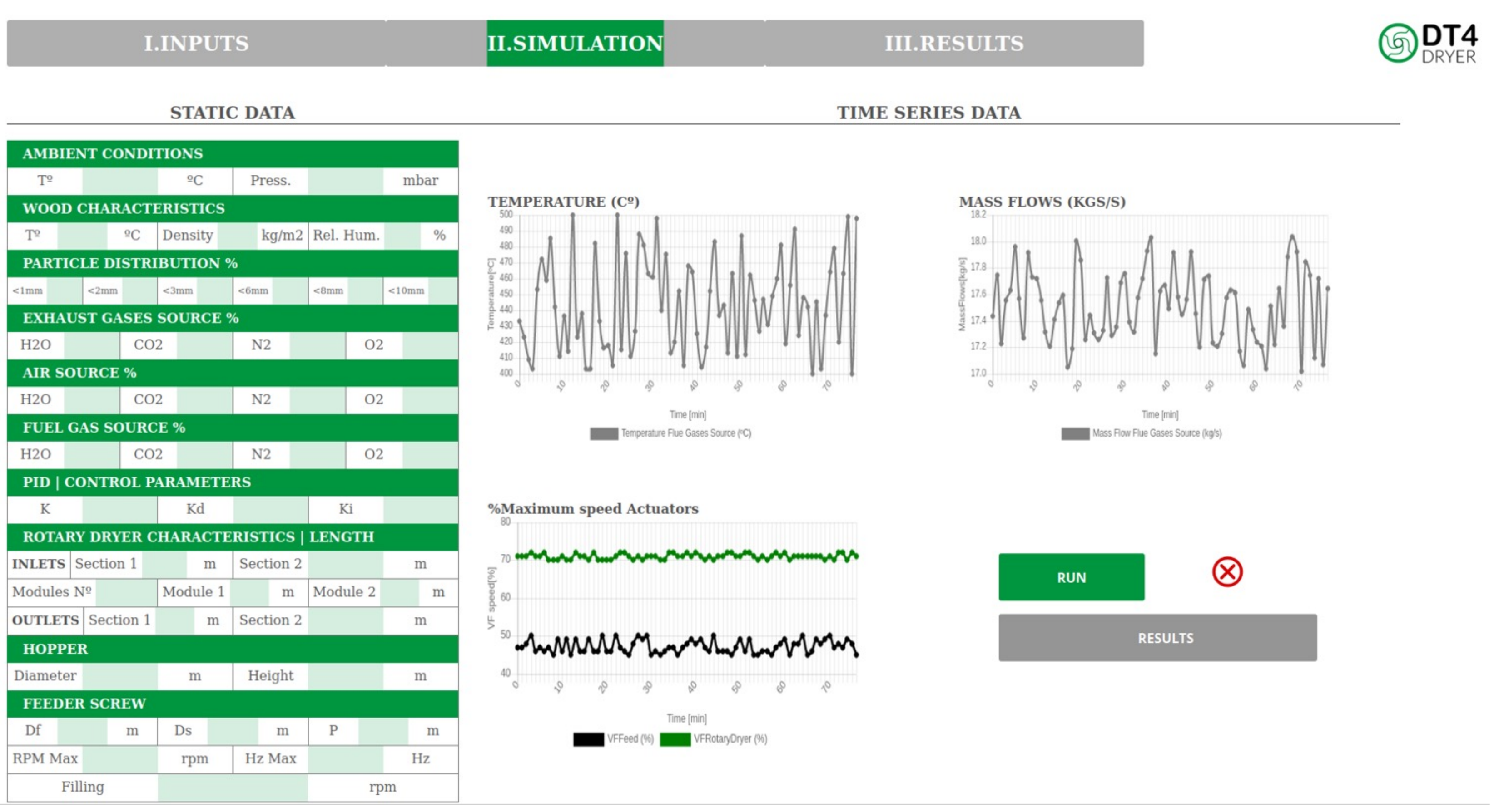
DT4DRYER's objective is to virtualise a fundamental process in the manufacture of biomass pellets, such as the drying of the raw biomass material. In this process, the humidity of the particulate matter is reduced through the direct contact of the biomass particles with combustion gases (from fossil or renewable fuels).

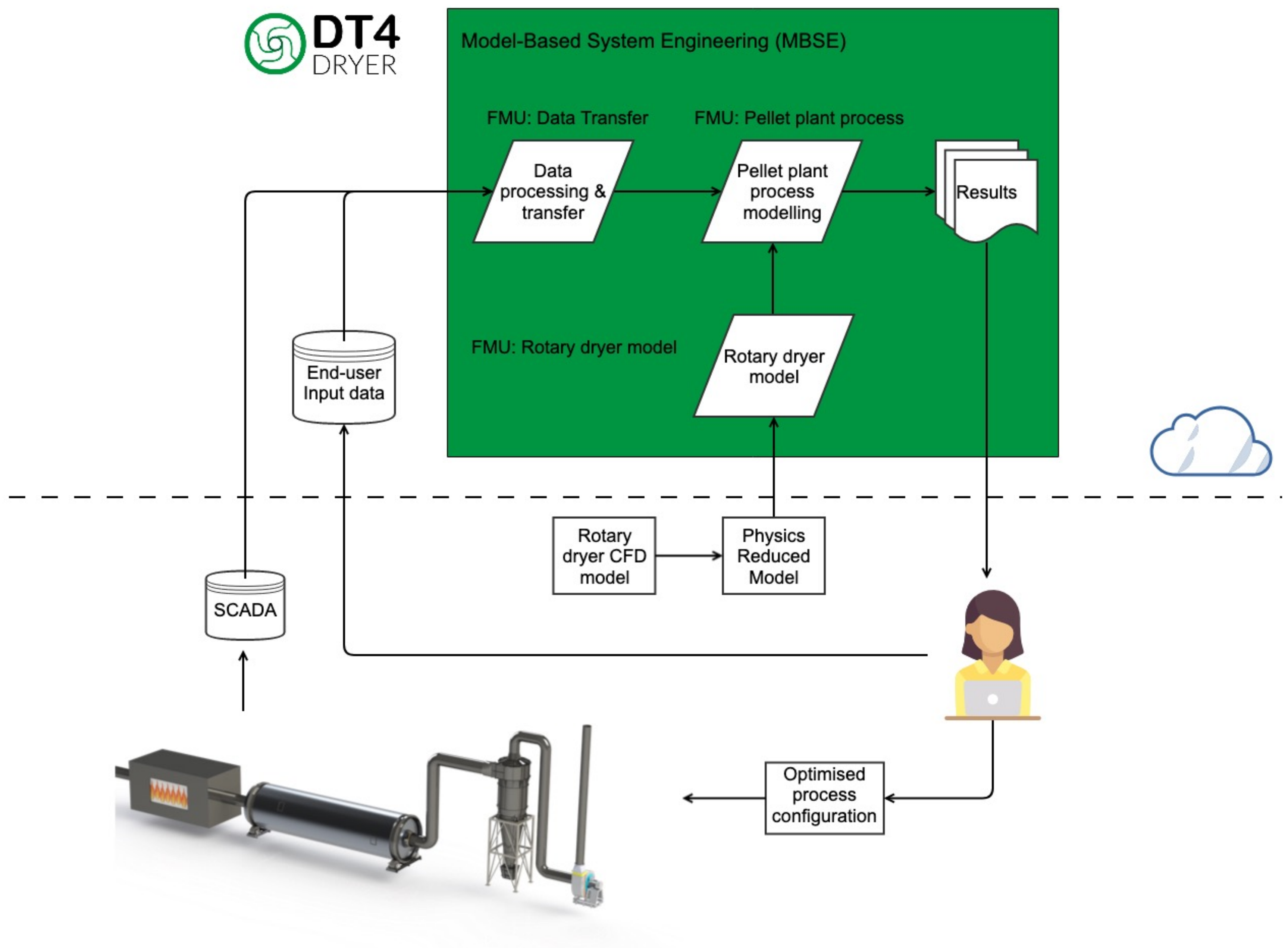
The following equipment is involved in this process: a boiler (fossil or renewable fuels), a mixing chamber (where the combustion gases are mixed with recirculated gases or ambient air) to obtain a gas stream with the right temperature for drying, a biomass feeding system (in general, consisting of a screw and a hopper), a rotary dryer, where biomass particles and combustion gases are mixed, favoured by rotation and the blades incorporated in this equipment, and auxiliary elements such as fans, motors and sensors.

The optimal operation of this process depends on numerous variables such as the composition of inlet gases, moisture content of the particles, the mass flow rate of gases and biomass particles, the speed of rotation of the rotary dryer, the ambient humidity, pressure and temperature, the distribution of the particle's sizes or the mixture of gas streams.

Currently, the operation of this process is basically manual and based mainly on the operator's experience. The virtualisation of this process will allow the operator to obtain an optimal configuration of the process (maximum production with lowest energy consumption) for each situation. In addition, the digital twin will allow better training of the operators and early detection of failures (for example, through relevant discrepancies between real and virtual equipment). Finally, data analysis and simulation results will provide new insights to manufacturing companies to improve the design of this process.







OUR APPROACH

The information flow of the virtualised system is shown in the figure above. SCADA data from the plant (real-time or historical) is combined with data from the operator to configure the case to be simulated (for example, the system's operation with a different biomass moisture content). These data (static and time-series data) are entered into the developed model (using Model-Based System Engineering methods) to co-simulate the system. This model has been built using FMUs (Functional Mock-up Units) that allow defining the characteristics of the equipment to be simulated in a standard way, facilitating co-simulation. The elaborated model consists of three different connected FMUs: one for the processing and transfer of input data to configure the simulation operating conditions, another FMU corresponding to the simulation of each element of the system, and another FMU, integrated into the latter for the simulation of the rotary dryer, the essential equipment in this process. These functions are developed under the Modelica language using the platform OpenModelica.

The rotary dryer is a piece of equipment with very complex physics. The fluid flow is transitory and multiphase, being the movement of the particles completely decoupled from the motion of the gas. Furthermore, there are phenomena such as rotation, heat transfer (convection and radiation) and mass transfer (evaporation). Therefore, this installation's detailed modelling (with Computational Fluid Dynamics (CFD) techniques) is complicated and requires considerable computational resources and calculation time (around ten weeks).

Integrating a detailed CFD model into a co-simulation model that requires real-time calculations is not feasible. Therefore, we have developed a Reduced Physics Model of the rotary dryer using the results of a CFD simulation. This new model is solved in quasi real-time.

Thanks to this, we can incorporate a detailed model of the rotary dryer in the MBSE model. This approach to simulating the rotary dryer performance in a co-simulation model is one of the most innovative elements of this work.

RESULTS

We have created a unique tool that supports the operator of a pellet production plant in decision making. This tool is a virtual representation of the pellet drying process, incorporating the detailed physics involved. The operator can optimize and plan the pellet drying process before, for example, changes in the biomass conditions (size distribution, humidity, temperature), which is very dependent on local weather, or changes in production planning (for example, an increase of the pellet demand). This tool can also support the training of plant operators and the early detection of faults.

As a result, this tool will contribute to greater flexibility and resilience of pellet production plants improving their energy efficiency.

DT4 DRYER — EUBCE — DIGITBRAIN

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