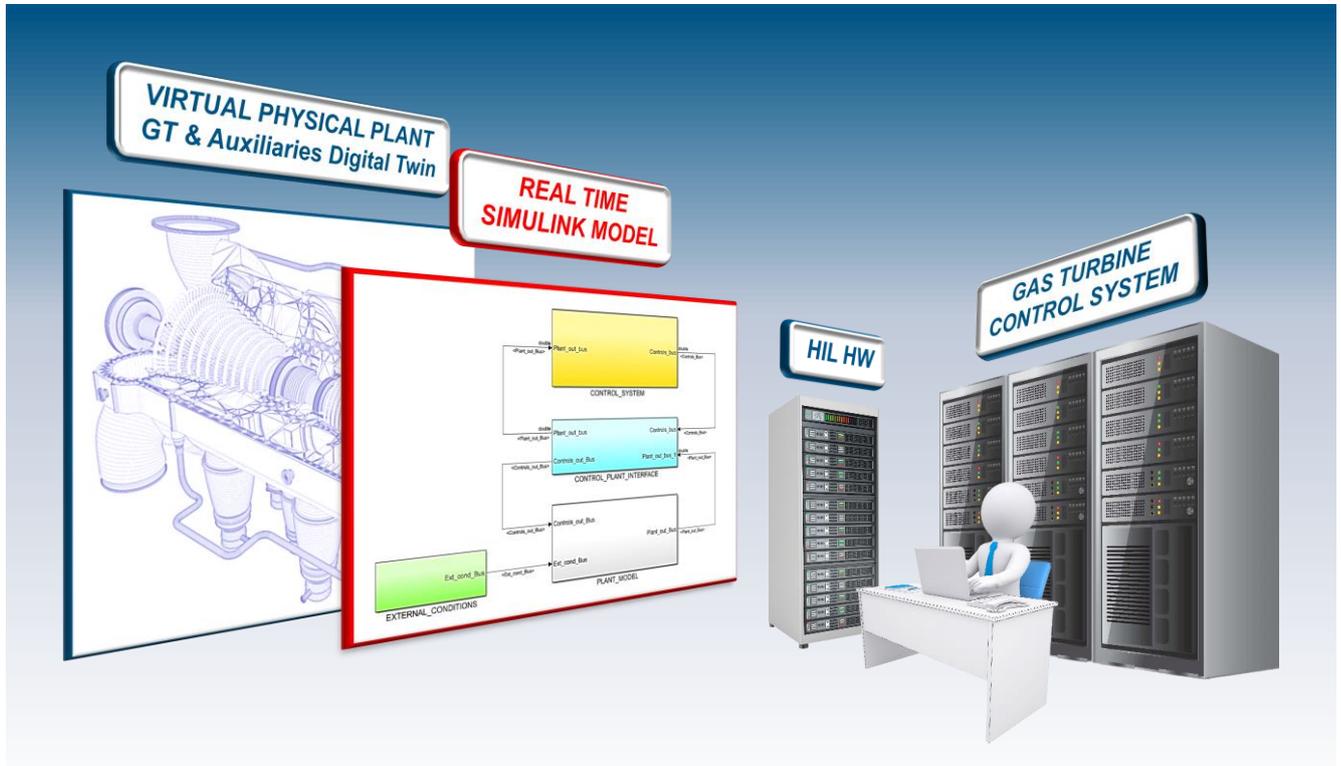# TGSim Plus™

A REAL-TIME DYNAMIC SIMULATOR OF GAS TURBINES

GT Control System validation and verification by HIL testing and simulated physical plant

OVERVIEW

TGSim Plus™ is a software application developed in the *MATLAB®/Simulink®* environment for the real-time dynamic simulation of a Gas Turbine (GT) power generation plant including gaseous and liquid flow Auxiliary systems (AUX).

TGSim Plus™ is an advanced engineering tool useful for the design and analysis of GT systems and for the verification of the control and diagnostic systems' reaction to emergency situations or fault conditions that could damage the machinery. It provides indications about performance, investigating the response of the plant to control actions in real time and allowing the identification of the most effective design and control settings to optimize transients and steady state operations.

TGSim Plus™ simulates the thermodynamic behaviour of the GT main process based on 0-D lumped elements such as compressor, combustor, expander, manifolds, valves and restrictions, including the variation of the compressor map with inlet guide vane angle (IGV), the bleed management and the model of a GT electric starter motor-generator.

PROGRAM DESCRIPTION

TGSim Plus™ runs under *The MathWorks™ MATLAB®/Simulink®* environment – a very powerful, qualified mathematical solver and systems simulation tool. The program includes a user-friendly graphic interface (GUI), based on buttons and menu driven commands.

The **TGSim Plus™** suite includes a set of customized libraries of ready-to-use basic components, which allows building a model by selecting and connecting the elementary blocks. This guarantees high use flexibility, allowing to increase the complexity of the model only as and when necessary, according to the behaviour details required and the model runtime constraints, by a stepwise approach.

TGSim Plus™ can manage two types of model: *online real-time models* for Hardware in the Loop (HIL) simulations, to be interfaced with the HIL platform, and *offline standalone models* for GT design and analysis, verification of control strategies, study simulations, or the validation of the physical system with reference data based on Simulated Control System procedures for the management of GT and AUX systems.
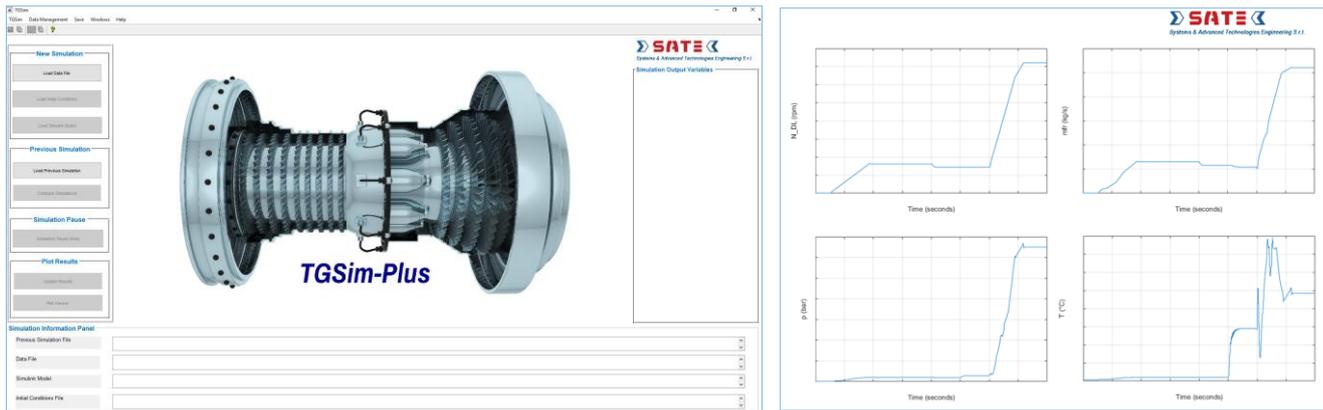
TGSim Plus™ GUI and example of model output plots

TGSim Plus™ implements the following relevant aspects:

- Thermodynamics of the compressor, featuring the interpolation of compressor maps – allowing to model the compressor either as a single-map compressor or as a multiple-map compressor, depending on the availability of performance maps as representative of the whole machine or of separate sets of stages; the computation of the operating point and the management of the mass flow rates extracted for bleeding and cooling.

- Thermodynamics of the combustion chamber, modelled as a two-zone combustor that simulates the combustion process considering the *stoichiometric combustion* of fuel – either gas, liquid or both – with dry air and the *mixing* of the stoichiometric combustion products with the excess inert air and the water vapour entering as humidity in the inlet air stream.

- Thermodynamics of the expander, including the interpolation of turbine maps, active torque calculation and cooling streams warm-up due to heat leakages from equipment mass along the bleed lines from compressor to expander.

- Operations of the electric motor-generator, considering in particular two mutually exclusive functional modes, activated as function of the GT operational phase: the *EM mode*, involving the Static Frequency Converter (SFC) and its internal control, driving the variable-speed electric motor, and the *EG mode*, involving the model of a synchronous type electrical generator, which simulates the load applied to the GT system before and after the connection to grid.

PROCEDURES OUTLINE

The user defines the simulation input data in an editable *MS Excel®* file, providing the settings for the *Simulink®* model.

For simulations performed in *online mode*, thus specific of an HIL architecture and application, the simulation results are visualised in the GUI provided by the HIL platform software.

For *offline* simulation results, instead, which include the time histories of all state variables and of the main operational and thermodynamic properties, *TGSim Plus™* allows displaying a variety of output plots that can also be printed or exported to other environments.

APPLICATIONS

TGSim Plus™ was developed as a software for the real-time dynamic simulation of a full GT power generation plant, including gaseous and liquid flow Auxiliary systems, to verify and validate the GT Control System (GTCS) for an international GT OEM, before its commissioning, by HIL simulations. The real-time model was integrated in a simulation suite that allows simulating steady state and operational transient conditions, such as start-up and shutdown operations, and load rejection, and was tested and delivered for a *DS1006* multiprocessor architecture by *dSPACE GmbH (DE)*.

TGSim Plus™ can run on any HIL platform compatible with *MATLAB®/ Simulink®* at milliseconds scale and may be used either in *online* or *offline mode* for the design of GT systems, the evaluation of their performance, the verification of the control system, and the validation of operation procedures and sequences.

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