SIEMENS energy

Omnivise T3000 Simulator

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A changing industry context

Market complexity

The energy generation environment is changing rapidly, and this is driving the need for new ways to plan, test, monitor and manage all forms of power generation. In developed countries, especially, growing use of renewables is also changing the ways in which established, conventionally powered plants are being used. Energy markets are becoming more complex, with a need for greater flexibility in how they operate. These rapid changes are happening at a time of growing skills shortages, as a generation of experienced engineers retire, and the industry struggles to replace them.

Large, centralised plants are extremely complex systems in themselves, and the commercial and technology environments in which they operate are also becoming more difficult to predict and manage. Though the move to distributed power generation is happening at different speeds in different markets, yet it is happening everywhere, step by step. A major side-effect of this development is that conventional plants, built for steady state operation, sometimes need to operate outside their original design parameters.

To manage this new reality, skilled engineers are being challenged to move beyond their established areas of expertise. We believe it is not enough for them to understand their own plants in detail, they also need to understand the wider market context – which adds further complexity to the work of control centre personnel. For example, operators may be required to handle more than one type of plant, due to the shortage of skilled personnel. It is quite normal for the same engineering teams, for example, to be responsible for combined cycle, biomass and wind generation plants, all at the same time.

In dealing with these complex requirements, the Instrumentation and Controls (I&C) solution in use has a central role. It gives operators a detailed Human Machine Interface (HMI) that shows exactly what is happening in any given plant. An effective modern control solution should support automation, enable fast intervention when required and, above all, show clearly the status of all operational systems. In practice, this means that if operators can manage the I&C system, they can also manage the plant, itself.

In this context, simulation is becoming more important than ever, for testing options, trying out different configurations, and identifying potential issues in advance, while defining workarounds and solutions – all in a virtual environment. This is the key to operational efficiency and energy security, as the energy landscape continues to evolve.

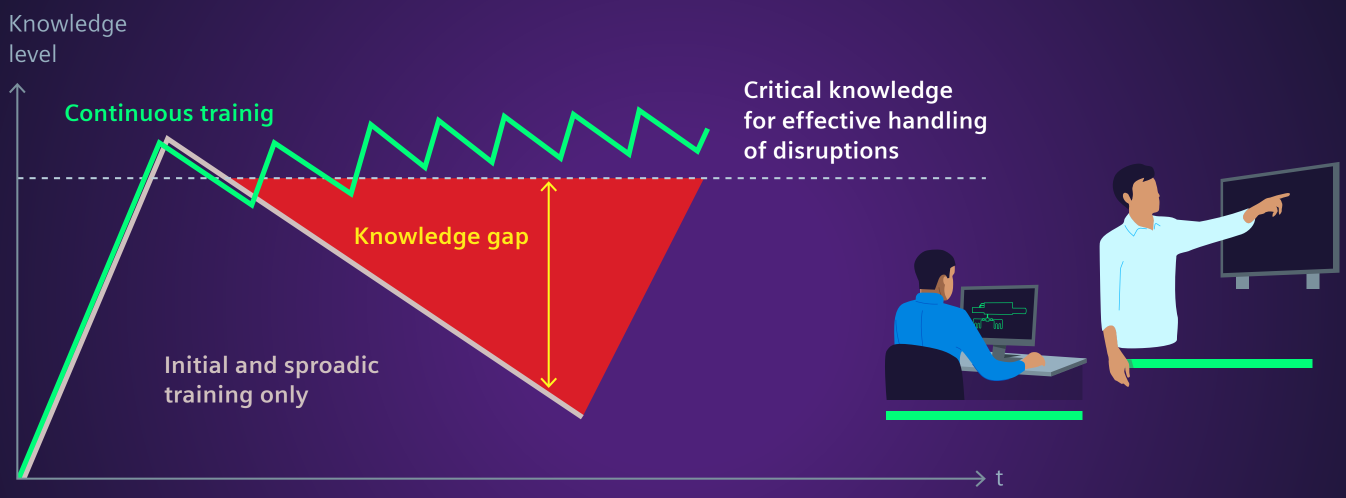
A new approach to training

Perhaps the single most urgent issue driving use of simulation is the need to replace skilled staff as they retire. Power generation businesses not only have to recruit new engineers on a one-to-one basis, they must also help new employees rapidly gain a wider range of new and different skills, while keeping operational costs under control.

One additional concern is the need to train engineers without giving them the same opportunities (as in the past) to work alongside more experienced personnel. These days, a new engineer is likely to go through a relatively short training period and then be expected to work as an operator at once – and that can be very challenging for them. This explains why simulation solutions are now so important to all power generation companies.

In practice, the intensity of the work required cannot always be covered by "on the job training". Operators must be trained offline, and the best tool for achieving this is through simulators. That's because simulation platforms enable rapid training, not just on systems that are operating normally, but also on systems under stress, unusual pressure or threat of imminent failure.

In an increasingly complex industry, dealing with skills shortages and an accelerating speed of change, training under realistic conditions is now more important and urgent than ever.



Continuous training approaches are needed to make sure operators react correctly in case of difficulties.

A new role for simulators

Why effective simulation matters

Simulation enables teams and individuals to try out a comprehensive range of scenarios, from everyday steady running to the most unusual and rare cases of system failure. Above all, simulators can resolve some of the most urgent and compelling issues that concern management today, where skills development is concerned. They provide training without risk, enabling engineers to become familiar with the systems they will soon be operating for real, but to do so without any possibility of causing harm, inconvenience or other hazard to the business or themselves.

The ability to run simulations from any device, anywhere adds new options for skills development and management of complex systems. The focus should not just be on "what may go wrong", as simulation makes it possible to work on the potential for optimization in different kinds of operational situations.

This matters because:

- Faults need to be eliminated in advance wherever possible, as the cost of faults increases by a factor of 10 from stage to stage of development.
- It is 6 times more costly to fix a bug identified in operational systems than to eliminate it at design stage.
- The number of skilled workers aged 55 or over has increased in the EU from 12% to 20% according to the latest Eurostat figures, which cover the 15 years between 2004 and 2019.[1] The potential loss of skills through retirement is a major issue, which makes timely, effective training an urgent necessity.

In an industry that is subject to rapid change, shortfalls in engineering skills, and the need to develop more flexible operational options, simulators are a necessary requirement. So how do we build and operate simulation solutions that can be trusted to deliver the training and test test support required today and into the future? Let's start with digital twins.

The role of digital twins

A digital twin is designed to be a detailed, accurate virtual replica of a real system, working in parallel and able to replicate the same operating conditions, and this concept is now well understood. It is in use across many different industries, ranging from power generation, which is the area that concerns us, to aircraft controls, smart cities, road and rail networks: wherever many different variables coexist and influence each other inside a single system.

In power generation, the most important use of digital twins is for process models: tracking and identifying/diagnosing the ways in which a specific process operates under different conditions, with varying inputs and influencing factors. They can also be used for thermodynamic models (covering factors like physical performance – heat, pressure, energy, etc.).

We should note that process models are not homogenous and consist of components and other areas that are modelled differently. The main categories are physical based, functional, assumed conditions and fixed static values.

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[1] Ageing Europe – looking at the lives of older people in the EU, Eurostat, 2020

Types of digital twins

There are different types of digital twin which are used for different purposes in the power generation industry. One type is connected to real time data flows, staying dynamically updated to reflect the true status of an operational system. By contrast, non real-time, static digital twins can be used to optimize operational performance by identifying the best operational points, while predicting the effects of aging.

The non real-time approach is now being used to build simulators that are kept physically separate from operational assets, so they can be used for testing and training. This enables us to use a digital twin to create a virtual environment that accurately reflects operational reality, but does not use real time data flows and is not connected to the production systems.

This is the key to building an effective training simulator. It has much in common with digital twins in terms of realism and accuracy, but strict physical separation of the training environment from operations means that all forms of training can be carried out without risk to the business.

Building an effective simulation solution

Given the speed of change in the power generation industry, it is vitally important for the industry to have the means of testing, trying out and proving all techniques in virtual systems before committing to real world applications, and only simulation can provide this option.
To become a normal, regular part of the engineer's toolkit, however, simulation needs to be affordable, easy to access and intuitive to use.

This has not always been the case, so what is changing now?

In the past, simulation solutions were normally hybrids, built from modules provided by a range of external partners. This is because component and assembly providers originally developed simulation modules that covered only their own components, which made the process for sourcing and building simulation solutions complex and costly.

At one point it was quite common, for example, to require several different servers to run the solution, one for each vendor application involved. In turn, that led to the need for dedicated expert teams to maintain the solution, a complex programme of upgrades, and the need to train operators on each application separately. This had the unfortunate effect of raising costs, placing restrictions on use, and generally making the simulator appear to be a specialised, high-cost resource, rather than a normal, everyday business tool.

The industry has now advanced beyond this point, with simulators that include different model categories, enabling a single system to replicate the entire production environment.

Despite this advance, however, a great deal of complexity remains in the form of multiple software packages, interfaces and – sometimes – more than one server to enable all options to be covered.

The fragmented, piecemeal approach described above is not a practical solution for most power generation companies. Siemens Energy has therefore developed a simpler, more integrated and, above all, practical method.

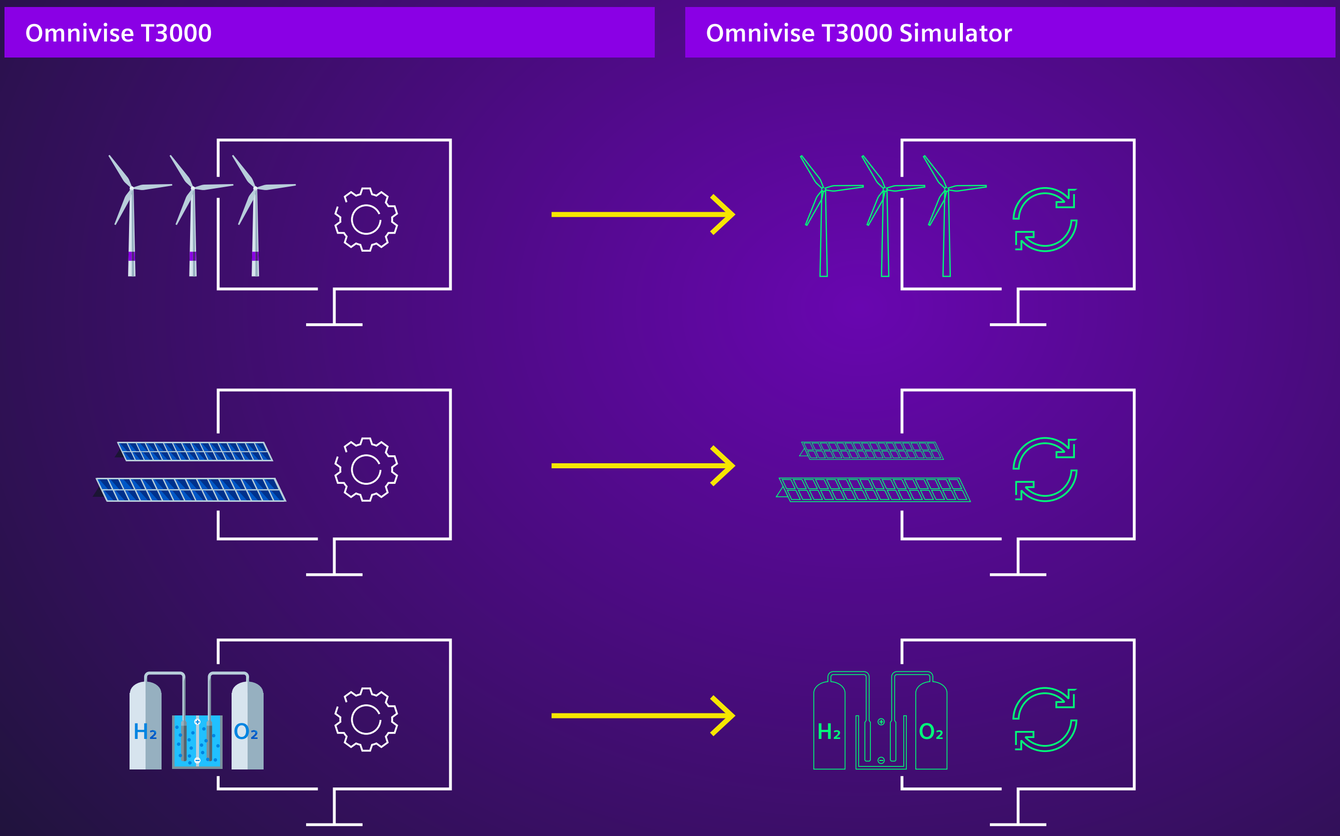
Omnivise T3000 Simulator

Towards a faster, more streamlined approach

In designing the Omnivise T3000 Distributed Control System (DCS), Siemens Energy took the decision to break away completely from the problems that limited the value of conventional simulators by making simulation a built-in, fully embedded component of the control system.

In other words, simulation functionality now comes as standard. The simulator is entirely composed of internally sourced elements (everything from a single source), making it simpler, lower risk and more cost effective to use. As the simulator is based on the same T3000 application software as that used in the real plant, any changes made on the operational system can be transferred to the simulator by taking a backup from the plant and importing it to the simulator. In this way the simulator and operational systems can very easily be kept aligned.

In the T3000 Simulator, the user interface is identical, while the system responses and the routines followed by the engineers are also the same. The T3000 Simulator can run in a virtual environment on any kind of hardware, including a laptop. In an industry, where remote teams are tasked with managing fleets of production assets on multiple sites, the ability to train, model and test via virtual teaming is a huge long-term advantage.



Key components of the Omnivise T3000 Simulator

Now let's look beneath the surface of the T3000 Simulator to understand its main components and points of difference when compared with previous solutions.

The Simulator includes the following key characteristics:

Process models. Every simulation environment is based on processes and process flows. This requires the developers to identify all elements that contribute to a specific process, provide the equations that define how each element within each process model relates to every other element, and ensure realistic responses to every change.

To give one example, for heat exchangers it is necessary to model what happens when heat transfer changes at different load conditions and how multiple heat exchangers influence each other. Or in mixed generation, how disturbances in renewable energy production affect the overall working of a conventional plant. This requires calibration testing and proof of assumptions before the virtualized process models can be used.

Easy updating. Mathematics is the basis for any simulator, as mathematical calculations define how each component in the virtual environment responds. As changes of configuration or updating of components take place in the operational system, similar changes must be made to the virtual system that mirrors it (the simulator). Since the simulator is also located within the same T3000 software as the operational system, it becomes much easier to update compared to conventional simulators, where multiple systems may be involved. This ensures that the simulator will always replicate the operational environment as closely as possible.

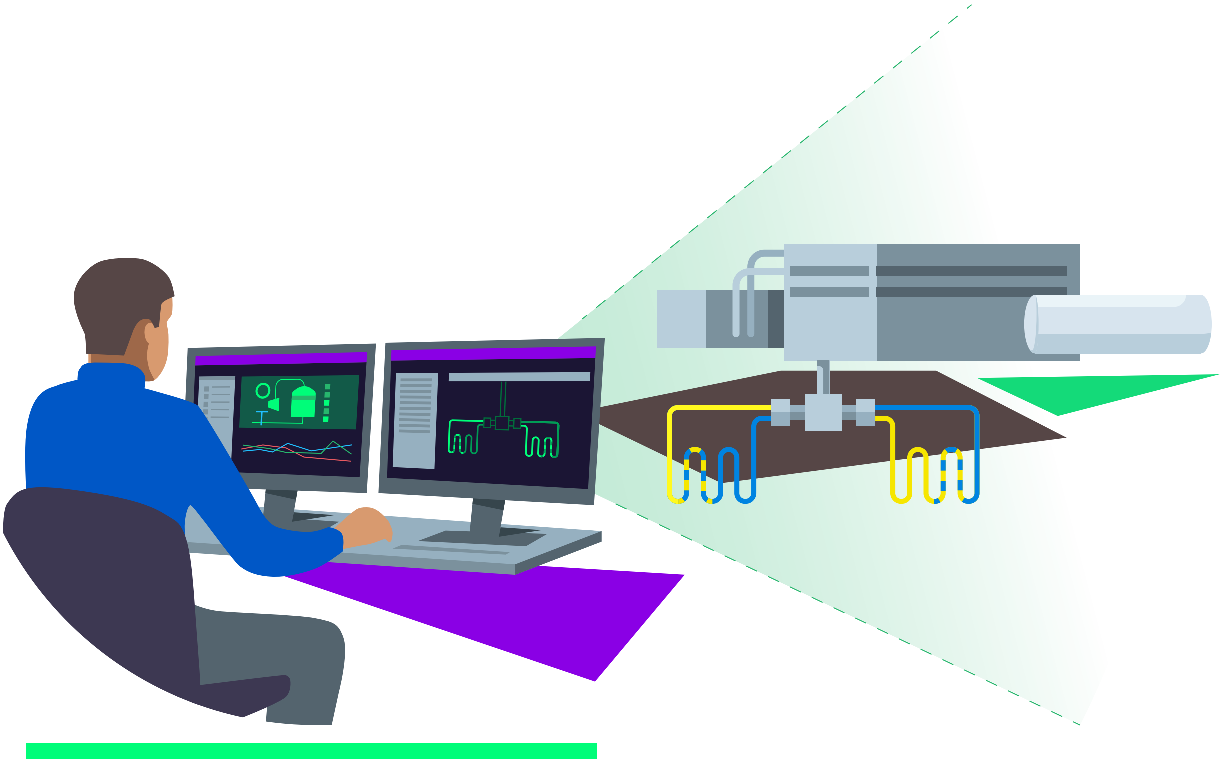
To make the simulator work effectively, we must be completely certain that altering one parameter in the simulator will have the same (or very similar) effect on the simulated environment, as altering the same parameter in the real system will have on the operational environment.

Accurate data flows. We have already seen how simulators can be made more accurate by use of true data from the operational environment, and by the rigour imposed on definitions of process models. The virtual environment must work according to the same laws of physics that govern all forms of power generation. That includes conservation of energy and mass, and accurate, trustworthy responses to all physical changes. T3000 provides functionality that enables simulation to be carried out inside the T3000 control system. In practice, however, for an operator training the simulator will be set up on its own platform to ensure there is no risk to the operational systems. For this reason, the simulator should be air-gapped from the physical production environment and will run on a separate device, which may be a server but can also be a laptop.

For engineering test validation however, the Distributed Control System (DCS) of the operational platform may be used for carrying out simulations, provided this is done before it becomes operational. Our goal is to ensure that engineering and plant data is used to measure and test operation of the virtual system, ensuring it remains accurate at all times. This is a specialized and complex task.

User Interface. We have already made it clear that the simulator should be kept physically separate from the production controls. Why? Because it is the task of the user interface to be completely identical to the real T3000 system. It is not simply a model: The HMI is identical in visualisation, behaviour and methods of interaction, to the point where engineers or operators may not be able to tell whether they are interacting with the simulator or the operational system. As Omnivise T3000 Simulators are an integral part of T3000 itself, with software maintained and updated as part of overall DCS updates, this similarity is a core feature of the solution.

The relevance and effectiveness of the T3000 Simulator is best demonstrated through reference to real operations, so now let's explore how we set it up and put it to work.



T3000 Simulator structure and setup

Setup of the system

Built-in simulation functionality, within Omnivise T3000, enables rapid set-up, as no new hardware is needed (everything can run on the T3000 Application Host). Engineering Testing is carried out on the real T3000 system, while an "air-gapped", physically separate platform (such as a laptop) is used for operator training to avoid risk to operations.

Scale and scope. The T3000 Simulator can be used with many different plant types, from combined cycle to gas, from hydro to coal-fired, and for renewable options and hybrid solutions of every kind. This solution was always designed to be as future-proofed as possible. Asset scale is also not an issue. The simulator can match and model the functionality of the wider T3000 solution, itself.

Architecture. The simulator mirrors the structure of T3000 itself and is based on four layers, as shown in figure 1 below.

The component layers are:

- T3000 Clients, enabling access and the same user interface from the most basic terminal, with no special requirements for memory or speed.
- Server layer, with automation controllers present as virtual controllers running inside the T3000 Application Host.
- Input/Output modules to deal with the flow of data from and to the generation asset(s) and is also modelled inside T3000 Simulator as mirror proxies inside the T3000 Application Host.
- Process layer, which manages the process flow calculations and feeds back system responses to the operator. This is also present within the T3000 Application Host.

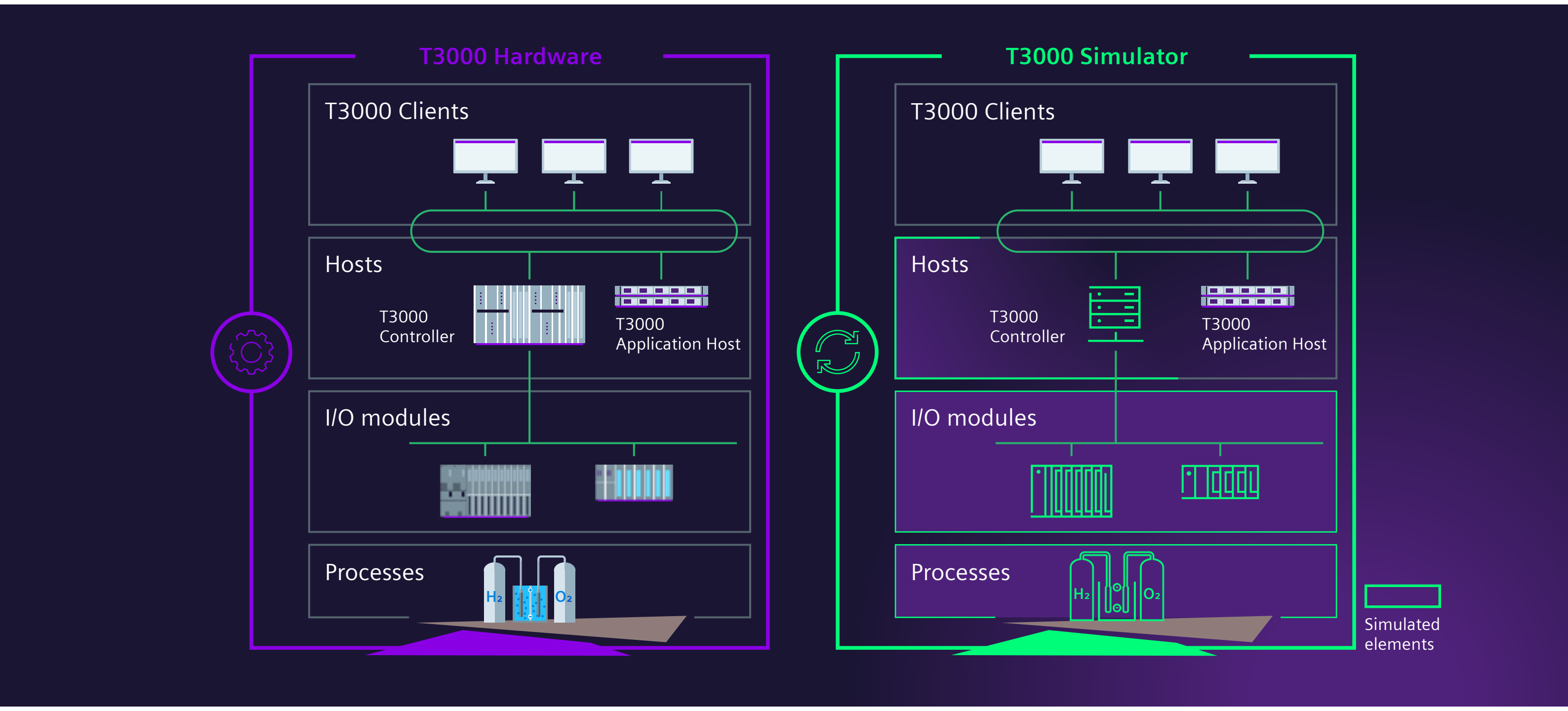


Figure 1: Simplified view of the simulator architecture

Functionality. The physical production assets are managed through data flows coming from IO modules and intelligent field devices, which interface with the controls via Input/Output modules.
The engineered backup is taken from the operational system and imported into the simulator server.

- A tie-back is then created, using proprietary blocks we call Mirror Proxies.
- These are linked to the Hardware Proxy, which represents the IO modules.
- And are also linked to the Partner Functions, which simulate the different types of field device, such as motors, valves and other hardware.

The T3000 Simulator uses the controls backup and integrated process model of the real operational system, which can be customized to ensure complete data consistency, eliminating the need for external software. In addition, it is possible to establish a connection to external process modelling software to ensure maximum flexibility and even higher levels of detail, while also future-proofing the solution.

Human Machine Interface (HMI)
As far as trainees and operators are concerned, the simulated process appears identical to the same process within the physical operational environment, as long as all virtual components (Mirror Proxies, Partner Functions and Process Models) are correctly updated to reflect changes within the physical environment.

This means that operator training on the Simulator can always work within an up-to-date, accurate representation of the physical system, which simplifies and accelerates the process of moving from the virtual to the real operational environment.

Levels of complexity

The T3000 Simulator can be designed to reflect the customer’s exact requirements, ranging from low to high fidelity, as desired. We should be careful, however, not to confuse fidelity with accuracy.

- Fidelity is the term used to define the levels of exactness with which a real operational system is reproduced in the simulation.
- Accuracy of a model is defined by whether parts of a process model are based on assumed conditions; simplified or functional modelling; or a physically based model (which provides maximum accuracy).

At least three different levels of fidelity are available when it comes to building and commissioning a virtual, simulation solution.

Low fidelity

Low fidelity systems provide basic “tiebacks” (in which the operator sees output from individual components and assemblies based on specific inputs).

This model is appropriate in some cases, for example, when modelling a grid system, where very detailed working of the individual power generation components is not required. It provides a basic simulation solution with some droop characteristics.

Medium fidelity

Medium fidelity systems build on the base level and use real data as well as empirical modelling to ensure that outputs include conservation of mass and energy, going beyond synthetic or theoretical calculations to provide a more reliable picture of the real system in operation.

This type of solution is ideally suited to auxiliary areas, which do not affect the main heat balance. Examples include lubrication oil system or vibration analysis, where it is possible to use a simple approach to show what happens when pumps are operated.

High fidelity

High fidelity systems represent the most effective and trustworthy level of digital twin technology.
The models used faithfully represent mass and heat balance, and are suited to representing heat exchangers inside the main boiler, main pumps and valves, or turbines and other complex components.

In almost every sense, this kind of system is representing in detail the real plant, virtualized. It models process streams end to end and responds accurately to automated system and process changes/inputs.
As you would expect, such a solution will require much more upfront process design work and is more costly to maintain.

Current use cases

Omnivise T3000 simulators are being used right now at very different types of power plants for training and testing.

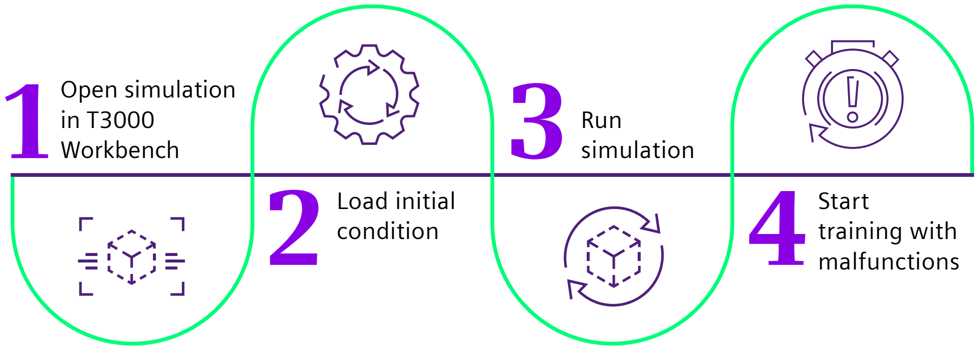
Schweinfurt local utility

At Schweinfurt, the local utility GKS, which was created to provide power to industrial users, while at the same time disposing of waste through incineration, uses a T3000 Simulator. It is backed by detailed process models from another partner, to train engineers while testing plant configuration and optimising performance. GKS staff can now test different scenarios, optimize processes, and control the plants safely. Simulation allows staff to effectively prepare for what-if scenarios involving the plants.

Omnivise T3000 Simulator in operation

Once set up is complete, operators can proceed to using the simulator for every potential purpose. This includes training operators and engineers (individuals or teams, on a single site or remotely based), testing operational assumptions and parameters, or simulation of specific states to see how the assets will respond (for example, to simulated faults and malfunctions).

In simple terms, we have a four-step approach, as shown in the figure below:



Let’s take a closer look at these stages

Open the simulation in T3000 Workbench. Users, both instructors and trainees, can select simulation projects via preconfigured screens or select an existing project via “Project View/ Plant Hierarchy”. The user interface is the real T3000 system: it is not a model or copy but the real system itself. Figure 3 shows the layout Plant Display for a combined cycle gas turbine in schematic form, with a drop down that enables the operator to select the HMI they require to operate the plant inside the Simulator, as shown in the image. The process model stays the same, but the view can vary as required.

Load initial condition. The instructor loads an initial condition (which is a training scenario). Loading the initial conditions primes the Simulator with the correct process conditions and values, according to the selected initial conditions, such as Cold Startup, Warm Startup or other option.

Run the simulation. The operator/ instructor can now select the view they wish to test or use for training, and then adapt the parameters as required.
They can adjust load test variables, which will lead to changes in the selected view. After the initial condition is loaded, the instructor can select RUN, which will begin the simulation from the selected initial condition.

Start training. One of the most common options is to introduce a malfunction and show the impact this has on the wider system over time. The instructor can introduce a malfunction at any time, causing the T3000 Simulator to behave in the same way as the real operational system under similar circumstances. Trainees then need to find ways to respond effectively, enabling them to work through increasingly serious and dramatic scenarios, with a sense of great realism but without any risk to operations.

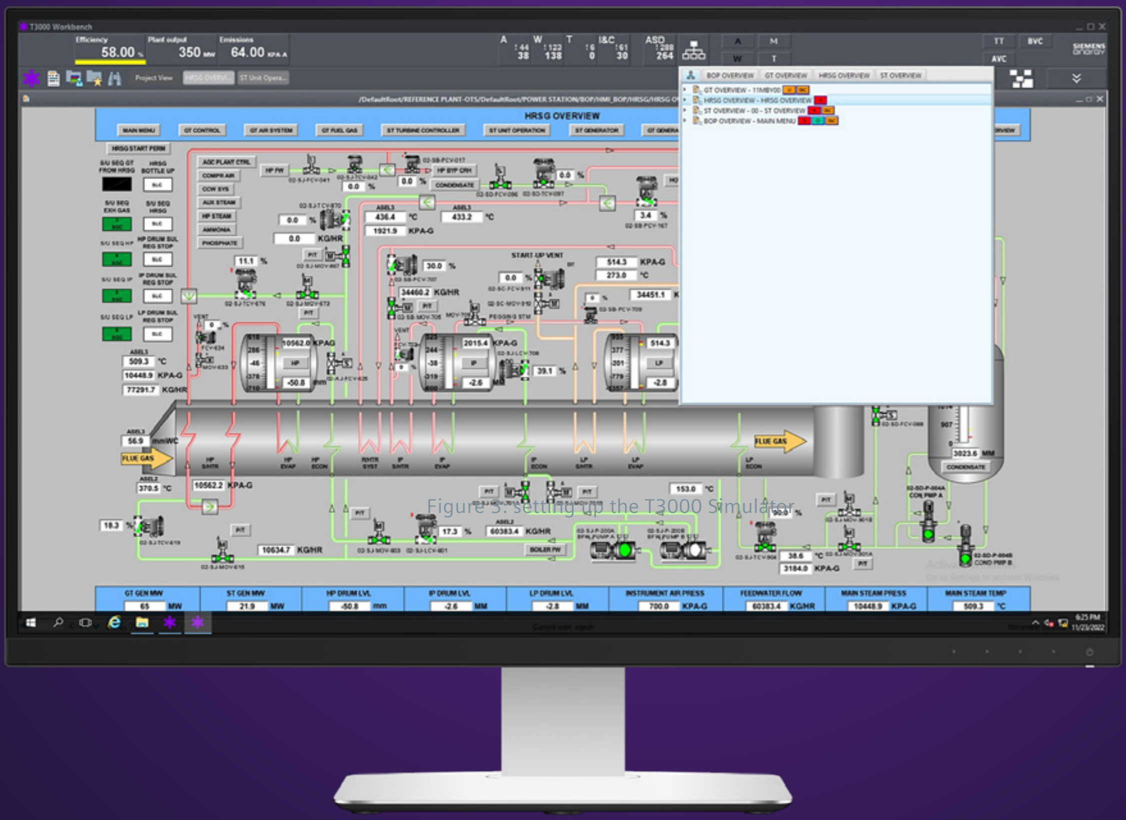
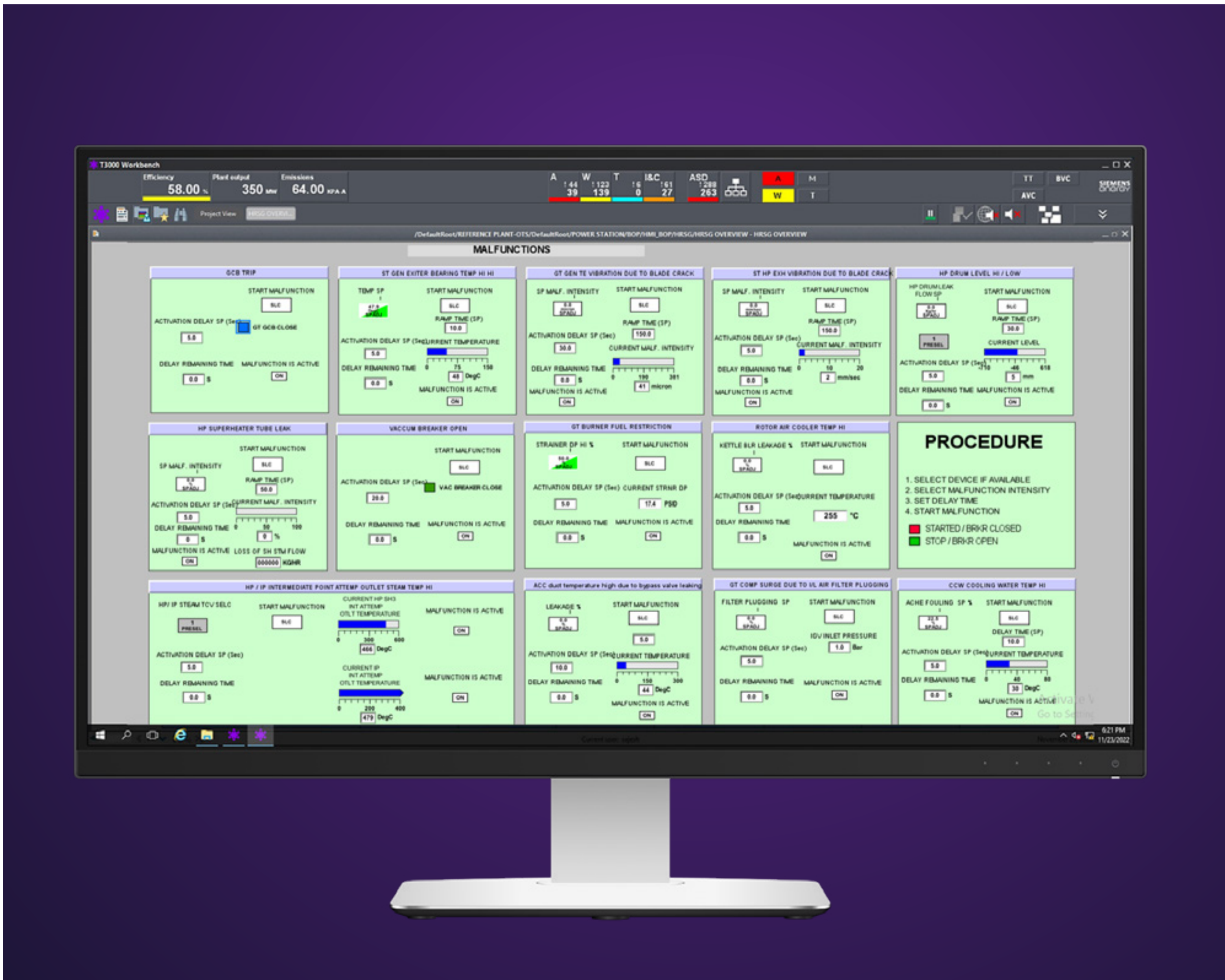


Figure 2: setting up the T3000 Simulator

Figure four below is a real snapshot of the operator screen during the running of a simulation. It shows the impact of steam leakage in the system, a problem that will become increasingly damaging over a period of minutes and potentially hours. For training purposes, an operator will be presented with this malfunction, which plays out on the screen as a representation of the virtual system.

No matter what their level of experience, engineers will need to be tested on these potential scenarios to ensure they know the correct actions to take. The operator's own input will be integrated with automated responses built into the system, enabling the response to be highly realistic.



1. SELECT DEVICE IF AVAILABLE
2. SELECT MALFUNCTION INTENSITY
3. SET DELAY TIME
4. START MALFUNCTION

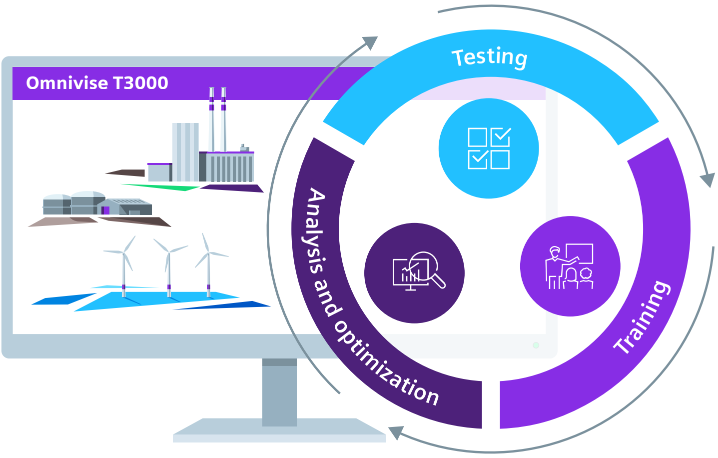
🟥 STARTED / BRKR CLOSED
🟩 STOP / BRKR OPEN

Figure 3: Malfunction training

Omnivise T3000 Simulator: the benefits checklist

The power generation industry is facing major challenges due to an unusual convergence of several different factors. These include:

- Changes in generation technology, with the rise of intermittent power sources.
- Grids which are more distributed.
- The need for more frequent ramping up and down of conventional power plants to cover for intermittent sources.
- Mass retirement of a skilled workforce.



Any one of these changes would be enough to drive instability in the market, while for all of these to happen at the same time is a major challenge for the industry. We can be certain of one thing, which is the ability to test, refine, update, test again, train, optimize, review, accurately, without additional hardware and without risk to operations is now a basic requirement.

Because it is an integral part of the T3000 system, the Omnivise T3000 Simulator offers transformational benefits to power generation businesses, and is a crucial component in keeping them competitive, efficient, compliant and relevant in a changing world. It delivers:

Simulation as standard. No specialized hardware is required for the simulation. It can run on the T3000 Application Host, with a virtual machine, even on a laptop.

Realism through use of mirror proxies. A tie back is generated using mirror proxies. The process model is connected to these mirror proxies via partner functions, providing a realistic experience while leaving the engineering untouched.

Field devices. In the simulation, these are represented by Partner Function Blocks.

Functional testing. The process model that the operator wishes to examine can now be tested, using functionality that replicates the physical operation of that specific process.

Benefits for engineering tests. Testing now becomes routine, with engineering tests, normally using tie-back simulation, ensuring that the engineering of the real plant is correct and interacts with the process models as desired.

Benefits for operator training. Training becomes faster and more effective, enabling engineers to reach higher levels of competence. Costs are limited and controlled, while operators can experiment and learn without risk.

General benefits. For engineers undergoing training, or for operational engineers reviewing an operational scenario and identifying potential areas for optimization, the experience is the same. Working with the T3000 Simulator User Interface is indistinguishable from working with the physical real T3000 system.

> **By making a simulator that exactly replicates the physical status and actions of the plant in operation, operators can train without risk or hazards, gaining real hands-on experience without the worry that comes with training in a real plant environment.**

At a time of change, with the operational landscape moving forward in sometimes unpredictable ways, the ability to review different scenarios and drive continuous improvement is simply vital.

T3000 Simulator summary

The Omnivise T3000 Simulator delivers all these benefits in a single package. They reduce the risk and cost of testing, accelerate installation and uptake, and improve the quality of operator training at a time of enormous change in the power generation industry.

Integrated with T3000 DCS, Simulator comes “as standard”.

Engineering and testing takes place in the same environment, using the T3000 Application Host Workbench without changing tools. Users can move between engineering and testing while using the same engineering environment.

Instructor station is fully integrated with the solution.

Device level simulation is generated automatically, with very rapid simulation setup.

The solution can use scalable process models, including low, medium and high fidelity, with varying levels of accuracy, as required.

The T3000 Simulator offers different options for virtualization, including T3000 Application Host, cloud-based and mobile devices.

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