How simulators help to manage a complex energy production environment

Elisabeth Burghart, Sajesh Nambiar and Thi Quynh Do

European energy production businesses are facing changes that are unprecedented in scale and scope. The drive to reach Net Zero by 2050 is leading to a rapid rise in use of renewable energy sources which, by their nature, are intermittent. At the same time, grid capacity is steadily growing, as nations try to phase out fossil fuels for heating and transportation.

Energy producers are faced with the challenge of meeting higher energy demand while fossil fuel production is being reduced as a matter of policy, doing this by balancing production from physically distributed and largely intermittent sources. At the same time, skilled human resources are starting to be in short supply, not just because a generation of experienced engineers is retiring, but because there is an urgent need to develop new types of skill to manage the growing complexity of the energy production landscape.

A great deal depends on the right management approach. As recent events have shown, any failure to ensure continuity of supply is economically damaging and can undermine confidence in policy. We need to make sure that reliable, proven solutions are in place now and can evolve to face future challenges without disruption to users.

So how can operators face this challenge successfully?

These strategic changes have led to a growing focus on digitalization and, above all, on the role of controls to manage, moment by moment, flows of energy from multiple sources to deliver steady, predictable output. That also highlights the importance of simulation: in helping to test a wide range of scenarios, accelerated training for new personnel and helping to build resilience and preparedness for unpredictable developments in energy production.

In this paper, we explore how simulators have become an essential part of energy production solutions, and we also show how the Siemens Energy Omnivise T3000 control solution, with integral simulation capability, can address today's key priorities, from training to operations. The challenge faced by energy producers is evolving fast: they require management systems with the flexibility and development potential needed to handle whatever the future brings.

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Introduction

The world's original energy production systems were designed and built for the **world we used to live in** and for societies and economies that have now changed out of all recognition. Even without Net Zero targets there would be an urgent need for energy production management to be made far more flexible, as a result of rapid, large-scale economic, social and technology changes. These developments are impacting energy production and distribution in the following ways:

– **Rise of renewables.** Intermittent generation techniques cannot be relied on to operate in a predictable manner. In addition, production is becoming distributed over a wide geographical area and new players are now involved at the heart of production.
– **Balancing local and national production.** We are seeing a steady growth in very local forms of power generation, from conventional generators to solar panels and small wind turbines, which are used both to meet the needs of small users (companies, localities…), and must be combined with large-scale production from national/regional producers.
– **Steady state generation becomes standby power.** We are rapidly moving away from a production environment based on a limited number of Combined Cycle plants with relatively predictable output. Many of these plants are still in existence, but their role has changed, from continuous operation to being called on to fill shortfalls of availability, which brings new problems in turn.
– **Steady state plants now operate routinely outside their design parameters.** Instead of a weekly start and ramp-up, they may now be called on to come online with little notice and at high speed, or face loss of revenue and financial penalties. This has a potentially important effect on wear and tear, emissions and reliability.
– **Plant efficiency is not enough.** What matters today is the wider industry context, which is extremely complex and often unpredictable. Your own plant may be managed with commendable efficiency, with optimized equipment and well-managed controls, but problems in the wider energy environment, which you cannot influence, can undermine all this good work.
– **Challenges to human skills.** This is not simply about the growing shortage of trained engineers but the need for personnel to work effectively in a more complex environment. Increasingly, our new generation of operators must go beyond their areas of core expertise and will be expected to operate more than just one type of

plant. As new technologies are developed and deployed, the skills gap may become more acute in the near future.

In this fast-developing, very complex landscape of energy production, the controls that manage and balance power flows are critically important- and simulation plays an increasingly important role within them.

The importance of simulators

We have already seen that digitalization is an essential factor in managing these changes, as emphasized in the EU's Digital Strategy and Action Plan for the Digitalization of the Energy Sector[1]. This is where simulators can help energy producers and distributors to meet their growing obligations and make complexity work for, rather than against successful operations.

What is a simulator?

A simulator creates a working virtual replica of a complex system, with a Human Machine Interface (HMI) that is as similar to the real system as possible. The simulator integrates different fidelity process models (the level of fidelity determines the accuracy of the simulation) and plant control logics to enable the simulation, evaluation, control logic fine-tuning and virtual commissioning of energy production and consumption processes.

How do simulators work?

Ideally, users should experience the same interactions and responses from the simulator as they would with the production system it represents. This is why simulators are air-gapped from the real system (with some being run on different servers) to ensure there is no chance of operators making changes to the production system- while believing they are still working with a simulation.

Operators normally use simulators for training, testing and scenario planning. They are vitally important to the task of training new personnel at speed, making it possible for them to gain a realistic feeling for how the production system works, to learn skills and try them out- with no risk of causing damage or interruption to normal working. In addition, simulators make it possible to test responses to a huge variety of inputs. Operators can push the virtual system beyond normal operational limits to evaluate responses, and operators can also test scenario and "what-if?" events, thereby combining operational security with a completely realistic- but virtual- experience.

In summary: Simulators offer the opportunity to test situations, even those where incorrect behavior could lead to significant damage. If something goes wrong with a simulator, you simply restart. In power generation, the simulator simulates the power plant's process and automation functions. In short, the T3000 Simulator simulates what the T3000 control system controls.

Using Digital Twins

The use of Digital Twins is becoming more important across the energy industry, as it is for many other sectors that require interaction between complex systems. Digital Twins use simulation techniques but have a somewhat different purpose. Here the goal is to build a complete virtual model of the wider system, with all components represented in a realistic manner.

Models used for building a Digital Twin can vary in their level of fidelity to real operations, so the virtual model can range from a basic representation of the entire system landscape, ready for pre-operation testing and refinement (this is essentially a Development Tool), through to a continuously functioning model that is updated in real-time by live data flows from the production platforms.

Most Energy businesses use Digital Twins to model design options, testing scenarios and sometimes pushing past limits to test the design "to destruction", in the virtual environment. Incorporating the digital twin concept early in a project can yield significant long-term benefits for different stakeholders, including retention of know-how, real-time monitoring and predictive analytics, ultimately leading to enhanced efficiency, reliability and sustainability.

Real use cases, real insights

End-to-End benefits

Figure 2 below shows how effective use of simulation can enhance performance at three key stages: during development and installation of the system itself (commissioning); for personnel qualification and familiarization (training); and for managing changes and enhancements in the fully operational production system (optimization). The same simulation platform is used in each case, but the tasks, objectives and outcomes are managed in specific ways. Let's take a closer look at each.

Commissioning

It is fair to assume that virtualized platforms, such as Digital Twins, will be used as integral parts of the design and development process leading to finalization of the generation environment itself. The simulator can then be used extensively in pre-production to test and validate the platform, in advance and under operational conditions, to ensure it is running as expected, while also evaluating each different function- all before go-live.

Staff can now test control logic and do virtual commissioning checks for master controls and sequences to validate whether the

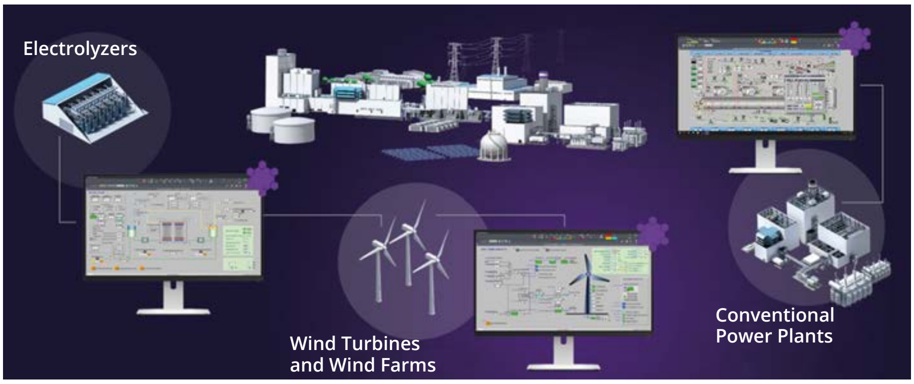

Fig. 1. Top level view of the T3000 Simulator platform designed by Siemens Energy.

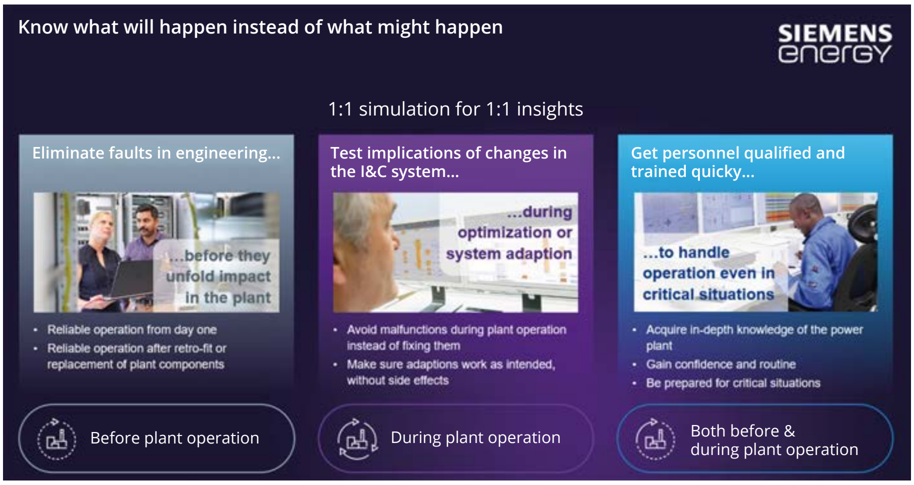

Fig. 2. Use of simulation for end-to-end benefits, from design to operation to training.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0552&qid=1666369684560

control scheme, or even the entire new generation unit, is working as designed. Plant operating limits can be checked at this stage, with reliable outcomes based on rigorous integration of process model and control logics in the simulator.

Virtual commissioning, making efficient use of simulators, helps prevent operational deviations and failures during the **physical commissioning** phase, thereby mitigating the risk of plant trips and malfunctions caused by engineering errors in control logic from the very beginning. Ultimately this accelerates acceptance and approval of the facilities.

Training

Training operators is one of the most urgent problems facing energy producers today, not just because of the need for a larger number of skilled personnel but also for the changing skill profiles required. Simulators offer a risk-free solution for learning and becoming familiar with control systems and plants by providing a safe and controlled environment, free from the risks associated with learning on a real production platform. This approach is already used in other high-risk environments, such as pilot training.

Figure 3 above shows some of the typical malfunction scenarios that are built into a simulator for rapid access by trainee engineers. An effective simulation solution will include an internal model library with a high level of fidelity (to provide a truly realistic experience), integration with control logics and a sensitive, interactive HMI. This means the trainee engineer has the real sense of working on a production platform, with extremely realistic responses to each input.

Engineers can become familiar with the process, control system and plant, understanding process behavior, gaining comprehensive knowledge of facilities, developing routines, and preparing for critical situations, all without putting the plant, energy delivery to the grid or their own safety at risk. Additionally, the simulator gives operators the chance to learn critical or practice infrequent tasks, such as starting up or shutting down a plant and managing critical operating conditions with simulated malfunctions.

This approach to training is more important than ever because operators may well own and manage asset fleets, that include plants based on different technologies (wind, combined cycle, hydro, other…) and it is no longer possible for operators to familiarize themselves with one plant through experience. The modern production landscape is inherently complex- and operators need training that reflects this new reality.

Optimization

Finally, operators will need to deal with changes to the control landscape, due to new functionality, replacement or upgrade of components and potentially integration of entirely new assets. Controls manage the interaction of systems and assets: if one of those assets changes then it impacts on the entire control process. The simulator makes it easier to carry out these necessary and planned changes smoothly and with precision, knowing in advance what the outcomes should be. It then becomes possible to test options that will enhance performance and optimize operations, with fine-tuning now an easier task than before.

Once again, by testing options through simulation in advance, risk is greatly reduced in these processes, and the organization can navigate through points of transition with confidence and precision. Figure 4 below shows how the simulator HMI can be used to model process parameters at points of change and optimization. This makes it possible to implement physical changes **only once the new processes can be seen to operate smoothly and normally in the simulator.** This is an important factor in reducing operational risk.

Use of simulation in Omnivise T3000

Simulators are moving from being desirable control system "add-ons" to becoming integral components within core solution design. Siemens Energy believes it is essential for simulators to be at the heart of an effective control solution- and that is the approach taken in developing the latest generation of Omnivise T3000 controls. This design strategy addresses one of the main obstacles to effective use of simulators in complex systems, which is the need to incorporate modules from multiple suppliers to reflect the reality of production platforms: that they normally include components and packages from many different vendors and integrators. This means a simulator must be custom-built from individual elements, integrated, tested and validated before it can be used.

Siemens Energy decided to make the Omnivise T3000 Simulator integral to the solution design, so there is no need for external modules or complex integration work. The simulator is ready for operation as soon as the control solution, itself, is installed. This

Fig. 3. Examples of predefined important plant malfunction scenarios for training.

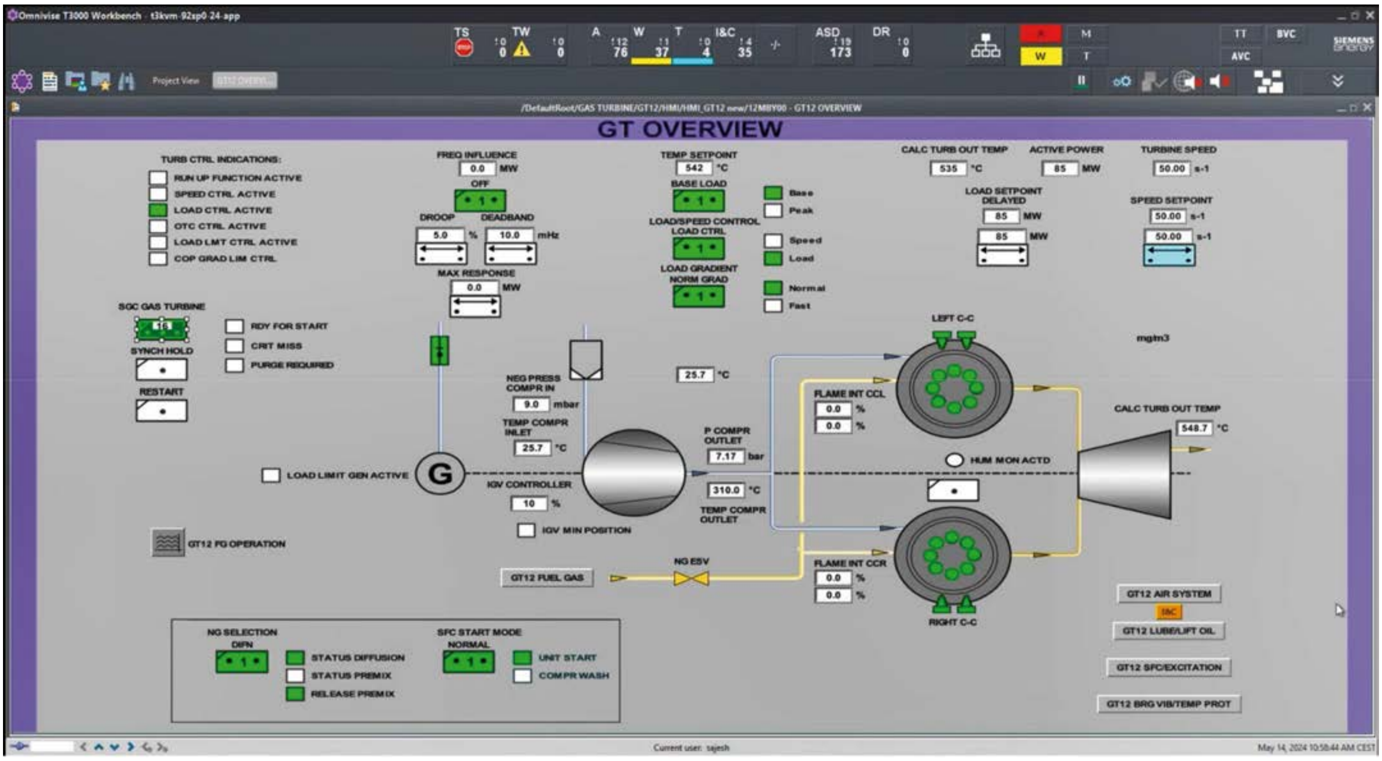

Fig. 4. Representation of a gas turbine HMI with key process parameters incoporated inside of process models.

means operators can begin to extract maximum value from their investment, while reducing their risks and accelerating time to operations, right from the start.

A key feature of the Omnivise T3000 Simulator is that it enables to different fidelity levels in internal process models that accurately reflect the essential chemical and physical behaviors of actual process units and equipment, where internal process models of both high and medium level fidelity can be connected.

These process models are modular and classified into three fidelity levels:

- Low-fidelity systems offer basic "tie-backs," enabling operators to observe the outputs of individual components and assemblies based on specific inputs.
- Medium fidelity models integrate real data and empirical modeling, providing a more precise depiction of the actual system in operation.
- The highest accuracy is achieved with high-fidelity models, which offer a complete virtual replica of the real plant in detail.

Thanks to this modular design, scale-up and extensibility can be achieved quickly and without disruption, while it can additionally seamlessly connect with external process models for data exchange. The Omnivise T3000 Simulator includes additional elements such as valves, actuators and heat exchangers etc., providing a richer quantitative and qualitative reflection of steady states, unexpected scenarios, malfunctions and the dynamic behaviors of real plants. This means the operator can be trained and benchmarked on what is, in effect, the real plant, **as the platform is the real Omnivise T3000 DCS**, so features, usability and user experience are identical.

Making the simulator a function of the control system

It is now clear to every operator that use of simulators is both logical and potentially valuable for their activities, yet there have been significant obstacles to adoption in the past. That's because traditional simulation systems often depend on specialized software and hardware, which makes extra investments necessary, together with more time and effort in coordination and integration. Incorporating the simulator as an integral part of the control system, itself, as shown in Figure 5 below, simplifies and accelerates the process.

As shown in the figure above, Siemens Energy's Omnivise T3000 Simulator can be configured to mirror the set-up of the real production platform in every detail. The simulator will normally use a different Application Host configured exactly as the real controls, but with **virtual controllers to run the control program.** This means the simulator uses the exact same software backup as the real control solution, because the simulation is embedded in the same software platform as the real production system. The only requirements are the necessary licenses and libraries to activate the simulator.

Staying secure

One of the greatest advantages of the Omnivise T3000 Simulator is that it is identical in look, feel and user experience to the real production system. This can lead to a certain concern that operators and trainees might accidentally make changes to the production system while still believing they are working on the simulator. By using separate Run Time Containers for production system and simulator, we ensure there is a complete air gap between the two, which avoids the risk of overlap.

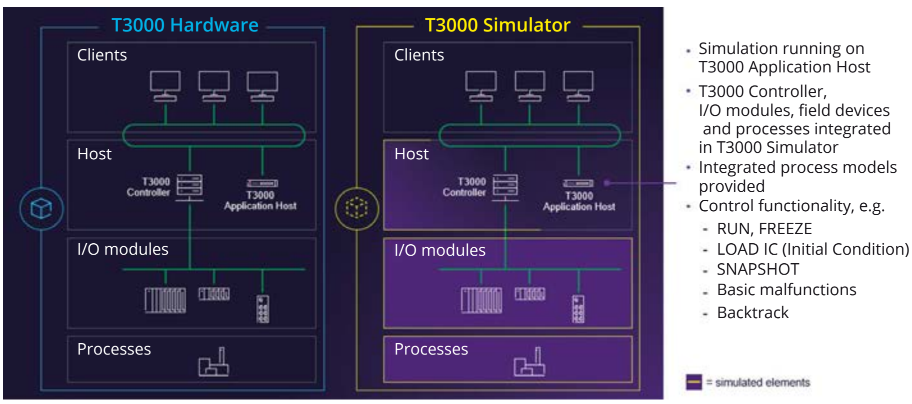

Fig. 5. Software architecture of the Omnivise T3000 Simulator.

This effectively turns the simulator into a process and automation Digital Twin that accurately represents the plant, its assets, and its processes. This adds further value to the operator by enabling them to unlock the full value to their design and development activities that Digital Twin can offer.

Conclusions

Changes caused by emerging technologies, environmentally driven policy and the need for entirely new skills mean that the energy production industry is not just being disrupted but transformed. Businesses and human operators are now managing a landscape of extreme complexity, where continuous change is a normal way of life, and where the skills, capabilities and training of the past are no longer relevant. Digitalization is the key to enabling this transformation, and simulation plays a vital part in facing the challenges.

Integrated design approach

Use of simulators has become an essential tool for enabling rapid evolution of energy management. The Siemens Energy Omnivise T3000 Simulator, which is technically integral to the control solution, itself, offers a software-based approach that replicates the full detail of a plant's configuration through a model library that combines the chemical and physical elements of energy production, with varying fidelity levels. This innovative solution captures the fundamental chemical and physical behaviors of real process units and equipment, designed to meet the individual needs of each customer. As, the simulator uses the same software platform as the real plant, implementation is not only fast and straightforward but also reduces engineering requirements and ensures a user-friendly experience.

Pragmatic solutions to key requirements

The Omnivise T3000 Simulator enables operators to resolve three urgent requirements at speed and with exceptional efficiency:

– Training operators to develop a rich and complex range of skills faster than would otherwise be possible, without the risk of real-world errors.
– Diagnosing control logic issues prior to plant commissioning, leading to smoother go-live, better testing of new technologies and fewer issues at start-up.
– Accelerating and simplifying changes, optimization and introduction of new components. This reduces risk, cuts maintenance costs and enhances operational efficiency: all vital considerations in a capital-intensive industry.

Simulators can be used to establish a knowledge platform that preserves corporate know-how and expertise, addresses workforce shortages, develops sophisticated digital twins for plant optimization, streamlines maintenance schedules and empowers autonomous operations. Simulators play a central role in the future of energy generation by enabling faster, earlier testing of different scenarios and operating conditions before implementing them in the real world. Simulators decode and and optimize complex systems – a decisive advantage in a rapidly changing energy landscape.

Abstract/Kurzfassung

Wie Simulatoren dabei helfen, eine komplexe Energieerzeugungsumgebung zu verwalten

Die europäischen Energieerzeugungsunternehmen stehen vor Veränderungen, die in Umfang und Reichweite beispiellos sind. Das Bestreben, bis 2050 Netto-Null zu erreichen, führt zu einem raschen Anstieg der Nutzung erneuerbarer Energiequellen, die naturgemäß intermittierend sind. Gleichzeitig wächst die Netzkapazität stetig, da die Nationen versuchen, fossile Brennstoffe für Heizung und Transport auslaufen zu lassen.

Energieerzeuger stehen vor der Herausforderung, den höheren Energiebedarf zu decken, während die Produktion fossiler Brennstoffe aus politischen Gründen reduziert wird. Dies soll durch einen Ausgleich der Produktion aus physisch verteilten und weitgehend intermittierenden Quellen erreicht werden. Gleichzeitig beginnt es an qualifizierten Arbeitskräften zu mangeln, nicht nur weil eine Generation erfahrener Ingenieure in den Ruhestand geht, sondern auch weil dringend neue Kompetenzen entwickelt werden müssen, um die wachsende Komplexität der Energieerzeugungslandschaft zu bewältigen.

Viel hängt vom richtigen Managementansatz ab. Wie die jüngsten Ereignisse gezeigt haben, ist jede Unterbrechung der Versorgung wirtschaftlich schädlich und kann das Vertrauen in die Politik untergraben. Wir müssen sicherstellen, dass zuverlässige, bewährte Lösungen vorhanden sind und weiterentwickelt werden können, um zukünftige Herausforderungen ohne Beeinträchtigungen für die Nutzer zu bewältigen.

Wie können Betreiber diese Herausforderung erfolgreich bewältigen?

Diese strategischen Veränderungen haben zu einer zunehmenden Fokussierung auf die Digitalisierung und vor allem auf die Rolle von Steuerungen geführt, um den Energiefluss aus verschiedenen Quellen von Moment zu Moment zu steuern und eine konstante, vorhersehbare Leistung zu liefern. Dies unterstreicht auch die Bedeutung der Simulation: Sie hilft dabei, eine Vielzahl von Szenarien zu testen, neue Mitarbeiter schneller einzuarbeiten und die Widerstandsfähigkeit und Bereitschaft für unvorhersehbare Entwicklungen in der Energieerzeugung zu stärken.

In diesem Artikel untersuchen wir, wie Simulatoren zu einem wesentlichen Bestandteil von Lösungen für die Energieerzeugung geworden sind, und zeigen, wie die Steuerungslösung Omnivise T3000 von Siemens Energy mit integrierter Simulationsfunktion die wichtigsten Prioritäten von heute, von der Schulung bis zum Betrieb, erfüllen kann. Die Herausforderungen für Energieerzeuger entwickeln sich rasant: Sie benötigen Managementsysteme mit der Flexibilität und dem Entwicklungspotenzial, die erforderlich sind, um alle zukünftigen Anforderungen zu bewältigen.