Foreword by Dr. Peter Körte, Chief Technology Officer & Chief Strategy Officer at Siemens AG

Our energy system is undergoing an epoch-making transformation. This decade's major trends—digitalization, decentralization, and sustainability—are instrumental in the energy sector. Forward-looking technologies, such as artificial intelligence (AI), digital twins, and the Internet of Things (IoT), have already been partially implemented and will have a decisive influence on tomorrow's energy systems. Challenges such as decarbonizing energy systems, maintaining cybersecurity and continuing to drive the energy transition will further increase the demands being placed on all players within the energy economy. After all, establishing global connectivity for information and systems will significantly alter or even completely reshape our energy supply within just a few years. Pilot projects, such as those underway in the German towns of Wunsiedel and Wildpoldsried—projects that are presented in this handbook and in other publications—are already showing some of the impact these trends will have.

A Historic Transformation is Underway

If we want to meet the major challenges of the future, we must fundamentally change the way we produce, distribute, and use electricity: We need to tread new and, above all, climate-friendly paths.

In connection with digitalization, innovations have long been extending beyond the area of machines and individual systems. One representative example of this development is the supply of power for "the Big Island," which is the largest island in the state of Hawaii. In principle, the island has enough wind and sunlight to meet its demand for electricity, entirely from production plants that generate power from renewable sources. Until now, however, the existing power grid's restrictions meant that it was not possible to integrate high percentages of renewable energy into the grid. Like the grids used nearly everywhere in the world, the Big Island's distribution grid dates to a time when power plants that were fired exclusively by fossil fuels covered most of the electricity load. Of course, feeding in electricity from fossil energy sources differs inherently from feeding in electricity from renewable sources. The dynamics and stability of grids change fundamentally when the share of fluctuating electricity supplied

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from renewables exceeds a critical level and conventional powerplants are shut down. The challenge, therefore, is to use renewable sources to the greatest possible extent to cover the demand for power, while always ensuring grid stability. In an innovative research project, the power company Hawaiian Electric, the research institute Pacific Northwest National Laboratory, the real-time simulation specialist OPAL-RT Technologies, and Siemens AG are laying the foundations for stable operation. Initially, not a single plant or line needs to be changed as part of this project. Using what is known as a digital twin makes this approach possible.

With the aid of such a digital representation of a real transportation network or distribution grid, a decentralized energy system or a specific powerplant, we can now develop and optimize all kinds of energy infrastructures in an extraordinarily resource-efficient, fast, flexible, and cost-effective manner. But digital twins can do much more. They can accompany any energy system, and even entire infrastructures, through all stages of their lifecycles—from design to manufacturing and operation and all the way to maintenance and even disposal.

Digital twins made it possible to take a first step toward successfully integrating renewable energy into the Big Island's existing distribution grid. Hundreds of solar- and wind-power plants were integrated into a previously created digital twin of the entire Hawaiian power grid. Subsequently, this extensive simulation made it possible to model Hawaii's real load behavior. Within this virtual demonstrator, it was possible to operate and optimize the Hawaiian grid in such a way that the share of renewable energy at peak times was increased to 100 %. All in all, this was a great outcome for both Hawaii in particular and the global climate in general. And since this digital technology scales easily, it represents a suitable solution for a wide range of environmental conditions and application areas.

A Bird's-Eye View

The practical example of using a digital twin in Hawaii illustrates a key point: We can find the best answers when we successfully employ innovative, digital solutions, and the ability to transform in order to reconcile social goals, sustainability requirements, and other framework conditions with one another. As a result, the quality of the solutions we develop depends particularly heavily on ensuring a fruitful exchange between disciplines, though these disciplines can sometimes differ greatly. If we continue this line of thinking, we see that the idea of dialogue as pursued in this book also means that, within our ecosystems, we must be prepared to engage in this dialogue on a much broader basis than would be the case, for example, if the focus were purely on technology. We will only be able to create "technology with purpose" if we successfully turn such an interdisciplinary dialogue into true partnership-based collaboration in which suppliers work together side-by-side with customers and stakeholders. In an increasingly complex world, the success of innovation hinges not least on considering numerous factors that all go far beyond purely technical issues. None of the challenges we face these days is merely an isolated technical issue. On the contrary, these challenges are all part of a comprehensive legacy ecosystem. Optimizing this existing ecosystem must be part of the solution.

In addition to the requirements mentioned above, other factors are increasing the complexity of supplying electrical energy. Among other things, the need to transition to electromobility and to meet the changing demands within the grid landscape are important here. The same applies, of course, to other large energy consumers that will be used in the future. Heat pumps, for instance, are just one example of such consumers that we need to consider in this connection. Another factor exacerbating the situation is "blindness" at the distribution-grid level. The resulting lack of visibility means that grid operators generally have very little specific consumption data available, especially at the end-user level. The same applies to advanced bidirectional plants operated by energy prosumers and to the data on the power that their systems generate.

But how can we maintain an overview when faced with these numerous factors of both a technical and non-technical nature? The best way to see all, or at least most, sides of a task, and therefore draw the best conclusions, is to examine the situation from a bird's eye view. Digital technologies offer new possibilities, and we're only just beginning to tap their potential. Considering as many perspectives as possible—and doing so with what we could call a "high-level view"—is the basic notion behind this book.

It is Time for Interdisciplinary Dialogue

The energy world is more complex and exciting than ever before. On the one hand, new and sometimes disruptive technologies are making broad inroads into the energy world. On the other hand, grid infrastructure can remain in place for decades. The old and the new coexist and are developing together at a rapid pace.

The fundamental challenges facing the energy sector these days include the need to successfully implement novel technologies and methods, provide energy in a sustainable and safe manner, and always keep customer needs in mind. Consequently, activities in the energy sector are—now more than ever—characterized by growing complexity and, in particular, by the interplay of different disciplines, such as natural science, economics, and management. Technology and the humanities, the energy economy and politics, operations and management are not always in harmony—quite the contrary to the current trend, given humanity's sustainable energy needs. Being largely restricted to one's own area of expertise makes it difficult to foster a collective understanding and assess the relevant issues in a way that the various stakeholders can agree on. At the same time, the rising complexity of supplying electrical power makes it more difficult for specialists to understand the overall system. For a long time now, engineers and technicians have not only been exchanging ideas with physicists and mathematicians, but also with economists, climate researchers, data scientists, information security experts, energy prosumers, and citizens. The new energy world is interdisciplinary and collaborative.

Against this backdrop, it is time for the engineering and business communities to engage in a new dialogue that takes place on an equal footing. With the title of their book “Handbook of Electrical Power Systems: Energy Technology and Management in Dialogue,” Oliver D. Doleski and Monika Freunek place the idea of dialogue at the very center of their publication. By closing this gap, the editors, together with selected authors, are forging a new path in the trade literature on energy supply.

As a first for a handbook on the supply of electrical power, this book deliberately addresses specialists from all disciplines. It focuses on communicating the content across professional and national boundaries without losing any of the necessary depth. These days, designers, contributors, decision-makers, and observers of the present energy-supply system require levels of expertise and understanding that extend far beyond those reached in their original training.

The book clearly shows that, when it comes to supplying electrical power in today’s world, focusing primarily on technical topics is not nearly enough. There is much more to be considered. Therefore, in addition to foundational knowledge of the technology, readers will gain a comprehensive, interdisciplinary insight into aspects of today’s energy systems, such as AI, IoT, information security, regulation, and market incentives. And this insight is presented in a “bilingual” manner, so to speak—one that brings the fields of engineering and economics together in a dialogue.

Transforming the world of energy is one of the most challenging yet exciting tasks of our time. It requires excellent innovation capabilities and in-depth knowledge as well as an entrepreneurial spirit, but it also requires communication skills, collaboration in ecosystems, and an understanding that transcends the boundaries of specialized disciplines and of organizations. This book makes an important contribution toward achieving this transformation.

Munich, June 2024 Dr. Peter Körte