Preface

This book is motivated by the rapidly growing challenges and opportunities on the road to the sustainable energy services. Present efforts toward integrating clean and efficient resources are often not aligned with the objectives of the end users nor with the business strategies needed to make these technologies affordable. The role of "smart grids" as enablers of such integration remains fuzzy. The main premise in this book is that the information technology (IT) in its broadest sense of the word could play a major role in overcoming these problems and in integrating these new resources according to the consumers' specifications. The design of IT architectures to support the functionality of given electric grids for aligning the characteristics of the existing and new resources with the demand needs is the key challenge. The trade-off between the IT complexity and the cost relative to the potential benefits is a major underlying question. To the best of our knowledge this is the first comprehensive model-based treatment demonstrating through systematic simulations that the existing and new resources could be integrated for meeting users' needs according to their preferences and within the prespecified cost ranges for electricity service. As such, the book represents first-of-its-kind proof-of-concept that it is, indeed, possible to utilize very diverse resources in alignment with customers' preferences while meeting prespecified societal goals. The mathematical treatment for the proposed concepts is not extensive. Mathematical problem formulations are used only to the extent needed to pose the new approach and to contrast it with the currently used approaches. The objective is, instead, to briefly summarize the concepts and then illustrate the potential game-changing outcomes using as realistic data gathered for the electric energy systems in the Azores Islands of Portugal.

The vision put forward is a result of the efforts by the team of over dozen researchers who, at one point of time or the other, have worked closely with the coeditors of this book. The three coeditors themselves have collaborated for nearly one decade. They hope to convince the reader that green future electric energy systems cannot be determined by looking solely at the coarse capacity estimates and the characteristics of individual technologies. Instead, a systems approach to enhancing today's planning and operating practices is required to begin to utilize the hidden potential of many distributed clean resources. If done right, this would lead to achieving much higher system-level efficiency than it is currently achieved even in systems with conventional and fully controllable technologies.

The new technologies considered are small hydro-, geothermal-, wind-power plants, photovoltaics (PVs), electric vehicles (EVs), and fast controllable storage, like flywheels and stationary batteries. When equipped with the embedded model-based sensing, communications, and decision-making algorithms, these new resources can be coordinated with the adaptive load management (ALM) automation on the customers' side to provide just-in-time (JIT) and just-in-place (JIP) value directly contributing to flexible and efficient asset utilization. One good measure of system-level efficiency is the system load factor which is defined as the ratio of average energy consumed and the peak demand. It is demonstrated in this book that the achievable system load factor by means of IT-enabled flexible asset utilization is significantly higher than today's system load factor. To the contrary, if new technologies are deployed as mandated by the regulators without enhancing today's operating and planning industry practices it will be very difficult to manage the new resources efficiently and reliably.

This book reports on our work in progress toward IT-enabled electricity services. The concepts are demonstrated by simulating electric power systems in two Azores Islands, Flores and Sao Miguel. We are truly encouraged by the results obtained as they demonstrate that it is possible to manage uncertainties created by the intermittent resources, such as wind power and PVs, without relying on excessively large amounts of expensive storage and on expensive and polluting diesel fuels currently used on these islands. Perhaps the most important message in this book is that it is not effective to pre-commit to the deployment of certain fixed capacity of renewables without understanding the characteristics of the existing resources and the demand characteristics and customers' preferences. Targets like deployment of prespecified capacity of renewable resources could become difficult to justify without designing new methods for their integration. As with everything else, it is necessary to assess long-term potential costs and benefits which may be brought about by the new resources. Unique to the electric energy systems, the cost/benefit analysis is critically dependent on the operating methods for utilizing these resources. In this book we present a possible framework for assessing possible technologies, for designing IT to enable their effective utilization and, notably, for utilizing efficiency brought about by the interdependence of various technologies. The emphasis is on potential savings from deploying predictive look-ahead decision methods under uncertainties and on the multi-temporal risk management.

The most effective solutions are nonunique. Possible trade-offs between complex software methods (predictions and look-ahead decision making for managing future uncertainties dynamically), on the one side, and the novel adaptive hardware technologies for managing imbalances created by the intermittent resources, on the other side, are truly striking. The need for expensive fast-responding storage can be greatly offset by predicting wind fluctuations and scheduling slower, less expensive resources. The complexity of JIT and JIP system operations and planning by the single utility is likely to become overwhelming. Instead, it is envisioned in this book that an interactive IT-enabled framework could facilitate flexible system management; much distributed intelligence is embedded into system users and minimal coordination is required by the utility system operators. This change of operating paradigm requires fast automation to prevent extremely fast instabilities following forced equipment outages, as well as to make the dynamic system response robust with respect to various uncertainties. In order to achieve this, it becomes critical to establish new mathematical models, analysis, and control design. Qualitatively different methods for managing fast small wind power fluctuations are needed than when managing fast large wind power surges or large prolonged wind power deviations from the predicted levels. While relatively small flywheels or batteries can be used to reduce wear and tear of the slow mechanically controlled generators, it becomes necessary to rely on power-electronically controlled equipment for managing large wind surges of short duration; finally, to compensate imbalances created by the prolonged wind power deviations it becomes necessary to use larger flywheels and storage. Moreover, the control capacity required to manage these imbalances during the time window needed for the more conventional slower resources to respond greatly depends on the sensing, communications, and control logic used for automatic control.

We close by pointing out that we are at the very cusp of what promises to be a major era of IT innovations for future electric energy systems. As one of our industry friends pointed out, we are in the midst of once-in-fifty-years opportunity to make major innovations in today's electric energy industry. This must be done with clear sense of how systems work today and with a real appreciation of the fact that the most effective solutions are likely to be the result of many diverse technologies, software and hardware, complementing each other for meeting complex customers' preferences. These are no longer just needs for uniform uninterrupted electricity service. Customers differ in so many ways with respect to both their needs and preferences, as well as with respect to their ability to respond to the technical and economic signals. We have had fun testing otherwise highly theoretical concepts using realistic data from the Azores Islands. We are grateful for the opportunity given to us by having this information to illustrate recent concepts from our research on how much cleaner Azores Islands could become without increasing the actual cost and with full awareness of customers' characteristics.

On behalf of all authors Marija Ilić wishes to thank Professors Jose' M.F. Moura and Ernest J. Moniz for suggesting to study Azores islands. She also thanks her colleagues Joao A.P. Lopes, Stephen Connors and Dan Spang for sharing early on what they knew about various data sources. This book would have not happened without the help by Filipe R.G. Mendonça and António J. L. A. Furtado from Electricite de Azores (EDA). May the tale of the beautiful Azores Islands always warm all of our hearts.

Pittsburgh, PA, USA Marija Ilić
College Station, TX, USA Le Xie
Pittsburgh, PA, USA Qixing Liu

http://www.springer.com/978-0-387-09735-0

Engineering IT-Enabled Sustainable Electricity Services
The Tale of Two Low-Cost Green Azores Islands
Ilic, M.; Xie, L.; Liu, Q. (Eds.)
2013, XV, 562 p. 363 illus., 275 illus. in color.,
Hardcover
ISBN: 978-0-387-09735-0