From economical point of view, most renewable energy sources currently show competitive economical properties in comparison with conventional sources, especially if their true lifecycle costs are taken into consideration. This multidisciplinary book focuses on the evaluation of the techno-economic performances of photovoltaic and wind energy systems. Various modes of operation are considered. These modes include grid-connected and off-grid applications. In addition, various types of loads are considered, including non-deferrable and deferrable loads. Viable techno-economic performance and optimization of Renewable Energy Systems (RESs) for economic performance maximization is among the main objectives of this reference. The book is written for students, researchers, and relevant specialists. Nineteen authors contributed to this book. They are from seven countries; Egypt, Turkey, Croatia, Mexico, Germany, Algeria, and Norway. The authors are: M. EL-Shimy (ed.), H. Balcioglu, K. Soyer, M. A. Abdelraheem, M. Said, M. Noor, T. Abdo, B. Đurin, J.G. Vargas-Hernández, A.C. Rangel, L. Nađ, K. Pallagst, P. Hammer, N. Bailek, K. Bouchouicha, A. Slimani, N. Aoun, A. Razagui, and N. Veggeland.

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Economics of Variable Renewable Sources for Electric Power Production

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May, 2017

To my wife Hala, and my children (Sara, Malak, Omar, and Aly)

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PREFACE

Renewable energy sources (RESs) are essential for the future energy security. These energy sources provide a viable alternative energy, and cost effective sources in various types of electric energy grids such as utility grids, smart grids, and microgrids. In addition, RESs are currently considered as a feasible techno-economic alternative for supplying remotely located off-grid electric and non-electric energy loads.

RESs are freely abundant and accessible, and environmentally friendly; however, the widespread use and large-scale integration of renewable energy systems to electric power systems face three critical challenges. These categories cover the main operational, dynamical, and economical prospective.

From electricity grid operation point of view, the popular renewable sources have high and risky levels of variability, intermittency, resource predictability, interface controllability, and economic generation dispatchability. These inherent problems are mainly attributed to the stochastic and varying nature of renewable energy sources as well as the inherent uncontrollability of the input natural resources (such as wind speed or solar radiation) and the impossibility of storing them in their natural form. Many approaches are proposed for reducing these operational problems. These approaches include geographical diversity, interconnections between systems, energy storage, distributed renewable sources, and smart grids. More details about the operational characteristics of variable RESs are presented in Chapter 3. In addition, the chapter includes suggestions for 100% renewable energy sources based on the power-to-gas-to-power conversions. These energy conversions minimize the inherent operational characteristics of variable energy sources.

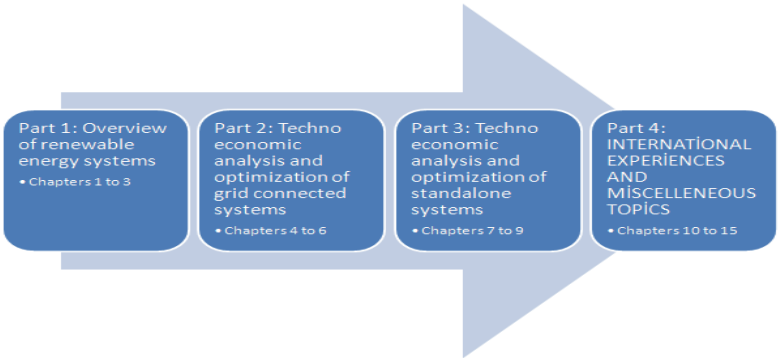
From dynamical point of view, the behaviors of the host power grid are significantly modified by the dynamic characteristics, control settings, and switching of converters utilized in the grid interface of the generators, the active elements in the power networks, and the dynamic loads as well as their interactions. In comparison with conventional synchronous generators,

renewable energy includes a massive number of technologies, each of which has different technological structural, control capabilities, and dynamical properties. Therefore, the dynamic behavior of renewable energy sources as well as their interaction with power systems is highly different in comparison with conventional synchronous generators. This situation requires continuous updating of the models to cope with these technologies and assessment of their impacts on power systems for various themes of power system studies. The dynamical issues of RESs and their impacts on power grids are out of the scope of this textbook; however, numerous previous publications effectively handle these issues. The readers may refer to the following textbooks for recent details about the dynamical behavior of electric power systems and RESs.

1. M. EL-Shimy. Dynamic Security of Interconnected Electric Power Systems - Volume 1. Lap Lambert Academic Publishing / Omniscriptum Gmbh & Company Kg; Germany; ISBN: 978-3-659-71372-9; May, 2015.
2. M. EL-Shimy. Dynamic Security of Interconnected Electric Power Systems - Volume 2: Dynamics and stability of conventional and renewable energy systems. Lap Lambert Academic Publishing / Omniscriptum Gmbh & Company Kg; Germany; ISBN: 978-3-659-80714-5; Nov. 2015.

From economical point of view, most renewable energy sources currently show competitive economical properties in comparison with conventional sources, especially if their true lifecycle costs are taken into consideration. This book focuses on the evaluation of the techno-economic performances of solar-PV and wind energy systems. Various modes of operation are considered. These modes include grid-connected and off-grid applications. In addition, various types of loads are considered, including non-deferrable and deferrable loads. Viable techno-economic performance and optimization of Renewable Energy Systems (RESs) for economic performance

maximization is among the main objectives of this textbook. This book consists of four parts as illustrated in the following figure.



For the convenience of the readers, each part is constructed as self contained structure with minor dependence on the surrounding parts. We hope that this multi-disciplinary book will provide a significant support to students and researchers as well as various related specialists. We welcome any supporting feedback from the readership.

M. EL-Shimy

May, 2017