Photovoltaic (PV) and concentrated solar power (CSP) systems for the conversion of solar energy into electricity are technologically robust, scalable, and geographically dispersed, and they possess enormous potential as sustainable energy sources. Systematic planning and design considering various factors and constraints are necessary for the successful deployment of PV and CSP systems. This book on solar power system planning and design includes 14 publications from esteemed research groups worldwide. The research and review papers in this Special Issue fall within the following broad categories: resource assessments, site evaluations, system design, performance assessments, and feasibility studies.

Modern power systems are affected by many sources of uncertainty, driven by the spread of renewable generation, by the development of liberalized energy market systems and by the intrinsic random behavior of the final energy customers. Forecasting is, therefore, a crucial task in planning and managing modern power systems at any level: from transmission to distribution networks, and in also the new context of smart grids. Recent trends suggest the suitability of ensemble approaches in order to increase the versatility and robustness of forecasting systems. Stacking, boosting, and bagging techniques have recently started to attract the interest of power system practitioners. This book addresses the development of new, advanced, ensemble forecasting methods applied to power systems, collecting recent contributions to the development of accurate forecasts of energy-related variables by some of the most qualified experts in energy forecasting. Typical areas of research (renewable energy forecasting, load forecasting, energy price forecasting) are investigated, with relevant applications to the use of forecasts in energy management systems.

It is the purpose of this book to provide the meteorological knowledge and tools to improve the risk management of energy industry decisions, ranging from the long term finance and engineering planning assessments to the short term operational measures for scheduling and maintenance. Most of the chapters in this book are based on presentations given at the inaugural International Conference Energy & Meteorology (ICEM), held in the Gold Coast, Australia, 8-11 November 2011. The main aim of the conference was to strengthen the link between Energy and Meteorology, so as to make meteorological information more relevant to the planning and operations of the energy sector. The ultimate goal would be to make the best use of weather and climate data in order to achieve a more efficient use of energy sources. This book seeks to realise the same objective.

Integration of Distributed Energy Resources in Power Systems: Implementation, Operation and Control covers the operation of power transmission and distribution systems and their growing difficulty as the share of renewable energy sources in the world’s energy mix grows and the proliferation trend of small scale power generation becomes a reality. The book gives students at the graduate level, as well as researchers and power engineering professionals, an understanding of the key issues necessary for the development of such strategies. It explores the most relevant topics, with a special focus on transmission and distribution areas. Subjects such as voltage control, AC and DC microgrids, and power electronics are explored in detail for all sources, while not
neglecting the specific challenges posed by the most used variable renewable energy sources. Presents the most relevant aspects of the integration of distributed energy into power systems, with special focus on the challenges for transmission and distribution. Explores the state-of-the-art in applications of the most current technology, giving readers a clear roadmap. Deals with the technical and economic features of distributed energy resources and discusses their business models.

This book constitutes revised selected papers from the 4th ECML PKDD Workshop on Data Analytics for Renewable Energy Integration, DARE 2016, held in Riva del Garda, Italy, in September 2016. The 11 papers presented in this volume were carefully reviewed and selected for inclusion in this book and handle topics such as time series forecasting, the detection of faults, cyber security, smart grid and smart cities, technology integration, demand response and many others.

Solar Energy Forecasting and Resource Assessment

This presentation provides a high-level overview of a fast radiative transfer model for solar resource assessment and forecasting. Increase in electricity demand and environmental issues resulted in fast development of energy production from renewable resources. In the long term, application of RES can guarantee the ecologically sustainable energy supply. This book indicates recent trends and developments of renewable energy resources that organized in 11 chapters. It can be a source of information and basis for discussion for readers with different backgrounds.

In the past decade, there has been a substantial increase of grid-feeding photovoltaic applications, thus raising the importance of solar electricity in the energy mix. This trend is expected to continue and may even increase. Apart from the high initial investment cost, the fluctuating nature of the solar resource raises particular insertion problems in electrical networks. Proper grid managing demands short- and long-time forecasting of solar power plant output. Weather modeling and forecasting of PV systems operation is focused on this issue. Models for predicting the state of the sky, nowcasting solar irradiance and forecasting solar irradiation are studied and exemplified. Statistical as well as artificial intelligence methods are described. The efficiency of photovoltaic converters is assessed for any weather conditions. Weather modeling and forecasting of PV systems operation is written for researchers, engineers, physicists and students interested in PV systems design and utilization. “p>

Predictive Modeling for Energy Management and Power Systems Engineering introduces readers to the cutting-edge use of big data and large computational infrastructures in energy demand estimation and power management systems. The book supports engineers and scientists who seek to become familiar with advanced optimization techniques for power systems designs, optimization techniques and algorithms for consumer power management, and potential applications of machine learning and artificial intelligence in this field. The book provides modeling theory in an easy-to-read format, verified with on-site models and case studies for specific geographic regions and complex consumer markets. Presents advanced optimization techniques to improve existing energy demand system Provides data-analytic models and their practical relevance in proven case studies Explores novel developments in machine-learning and artificial intelligence applied in energy management Provides modeling theory in an easy-to-read format
Solar Resources takes stock of the resource - sunlight - on which any plan for solar heat conversion technologies must be based. It describes the evolution of theoretical models, algorithms, and equipment for measuring, analyzing, and predicting the quantity and composition of solar radiation, and it reviews and directs readers to insolation databases and other references that have been compiled since 1975. Following an overview of solar energy research by the editor, Raymond J. Bahm presents a comprehensive guide to available insolation databases and other information resources in the United States. Charles M. Randall and Richard Bird discuss the theoretical models and algorithms used to characterize the transference of solar radiation through the earth's atmosphere. Their chapter also addresses the important question of the accuracy of the data sets produced by the various modeling methods and algorithms. The National Weather Service (NWS) monitoring network and other major monitoring networks in the United States are discussed by Kirby Hanson and Thomas Stoffel. And Eugene Zerlaut covers the instrumentation used to measure total solar irradiance and spectral solar irradiance; he describes types of equipment, their manufacturers, procedures for calibration, and the accuracy of the data produced. Richard Bird and Carol Riordan explain the nature of spectral solar irradiance at the earth's surface, and John Jensenius describes the NWS Operational Solar Insolation Forecast System, which predicts the daily total global-horizontal insolation for two days. In the concluding chapter, Claude Robbins summarizes daylighting models and resources, and details methods for converting insolation date to illuminance data. Solar Resources is volume 2 in the series Solar Heat Technologies: Fundamentals and Applications, edited by Charles A. Bankston

The present book focuses on recent advances methods and applications in photovoltaic (PV) systems. The book is divided into two parts: the first part deals with some theoretical, simulation and experiments on solar cells, including efficiency improvement, new materials and behavior performances. While the second part of the book devoted mainly on the application of advanced methods in PV systems, including advanced control, FPGA implementation, output power forecasting based artificial intelligence technique (AI), high PV penetration, reconfigurable PV architectures and fault detection and diagnosis based AI. The authors of the book trying to show to readers more details about some theoretical methods and applications in solar cells and PV systems (eg. advanced algorithms for control, optimization, power forecasting, monitoring and fault diagnosis methods). The applications are mainly carried out in different laboratories and location around the world as projects (Algeria, KSA, Turkey, Morocco, Italy and France). The book will be addressed to scientists, academics, researchers and PhD students working in this topic. The book will help readers to understand some applications including control, forecasting, monitoring, fault diagnosis of photovoltaic plants, as well as in solar cells such as behavior performances and efficiency improvement. It could be also be used as a reference and help industry sectors interested by prototype development.

Optimization in Renewable Energy Systems: Recent Perspectives covers all major areas where optimization techniques have been applied to reduce uncertainty or improve results in renewable energy systems (RES). Production of power with RES is highly variable and unpredictable, leading to the need for optimization-based planning and operation in order to maximize economies while sustaining performance. This self-contained book begins with an introduction to optimization, then covers a wide range of
applications in both large and small scale operations, including optimum operation of electric power systems with large penetration of RES, power forecasting, transmission system planning, and DG sizing and siting for distribution and end-user premises. This book is an excellent choice for energy engineers, researchers, system operators, system regulators, and graduate students. Provides chapters written by experts in the field Goes beyond forecasting to apply optimization techniques to a wide variety of renewable energy system issues, from large scale to relatively small scale systems Provides accompanying computer code for related chapters

This book is a printed edition of the Special Issue "Offshore Renewable Energy: Ocean Waves, Tides and Offshore Wind" that was published in Energies

Concerns about energy resources and the environmental impact of energy use will continue to be important globally. World Scientific's unique series of books on Current Energy Issues is intended, in part, as an expansion and update of the material contained in the World Scientific Handbook of Energy. Each volume will focus on related energy resources or issues and will contain a broader range of topics with more explanatory text. This Solar Energy volume covers a variety of approaches to the use of solar energy. These include large scale photovoltaic production of electricity as well as more local applications in the home and businesses. Similarly, there is an extensive discussion of large scale solar thermal electricity production and smaller scale uses such as solar water heating, home heating and cooling plus crop drying. There is also discussion of more forward-looking technologies including the production of fuels using artificial photosynthesis and the production of biomass. Contents:

- Introduction to Solar Energy (R Corkish, W Lipiński and Robert Patterson)
- Fundamentals of Photovoltaic Cells and Systems (Ignacio Rey-Stolle)
- Large-Scale Solar Thermal Plants (CSP) (Manfred Becker, Robert Pitz-Paal and Wes Stein)
- Large Scale Photovoltaic Power Plants (G Almonacid Puche, P G Vidal and E Muñoz-Cerón)
- Biomass (Anthony Turhollow)
- Artificial Photosynthesis (Nathan Skillen and Peter K J Robertson)
- Small Scale PV Applications in Home and Business (Estefanía Caamaño-Martín, Miguel Ángel Egido and Jorge Solórzano)
- Low Temperature Solar Thermal Applications (Brian Norton, Hans Martin Henning and Daniel Mugnier)
- Solar Thermochemical Processes (Roman Bader and Wojciech Lipiński)

Readership: Researchers, academics, professionals and graduate students in energy studies/research and environmental/energy economics.

Solar Energy Forecasting and Resource Assessment is a vital text for solar energy professionals, addressing a critical gap in the core literature of the field. As major barriers to solar energy implementation, such as materials cost and low conversion efficiency, continue to fall, issues of intermittency and reliability have come to the fore. Scrutiny from solar project developers and their financiers on the accuracy of long-term resource projections and grid operators’ concerns about variable short-term power generation have made the field of solar forecasting and resource assessment pivotally important. This volume provides an authoritative voice on the topic, incorporating contributions from an internationally recognized group of top authors from both industry and academia, focused on providing information from underlying scientific fundamentals to practical applications and emphasizing the latest technological developments driving this discipline forward. The only reference dedicated to forecasting and
assessing solar resources enables a complete understanding of the state of the art from the world’s most renowned experts. Demonstrates how to derive reliable data on solar resource availability and variability at specific locations to support accurate prediction of solar plant performance and attendant financial analysis. Provides cutting-edge information on recent advances in solar forecasting through monitoring, satellite and ground remote sensing, and numerical weather prediction.

This book covers major technological advancements in, and evolving applications of, thermal and photovoltaic solar energy systems. Advances in technologies for harnessing solar energy are extensively discussed, with topics including the fabrication, compaction and optimization of energy grids, solar cells and panels. Leading international experts discuss the applications, challenges and future prospects of research in this increasingly vital field, providing a valuable resource for all researchers working in this field.

In addition to describing core concepts and principles, this book reveals professional methodologies and tools used by national agencies and private corporations to predict sites’ potential for wind and solar power generation. Each chapter focuses on a different issue, showing readers the corresponding methodology, as well as examples of how to apply the techniques described. These techniques are explained with step-by-step guides that demonstrate how environmental variables in complex terrains can be characterized and forecasted. The authors present an adaptive finite element mass-consistent model, which computes a diagnostic wind field in the three-dimensional area of interest using observed wind data from measurement stations – data which is then interpolated using a physical model of the wind field in the boundary layer. An ensemble method is presented based on the perturbation of the numerical weather prediction models’ results. The book goes on to explain solar radiation characterization and forecasting. Solar radiation and electrical power generation temporal and spatial variability are discussed and modelled. Different statistical methods are presented in order to improve solar radiation forecasting using ground measurement, numerical weather predictions (NWPs) and satellite-derived data. This book is focused on both probabilistic and point forecast explaining different models and methodologies to improve the forecasting. The results obtained from various simulations around the world are presented in tables. Finally, the book explains a possible methodology to develop a Solar Map taking into account solar radiation, terrain surface conditions and cast shadows. As such, the book provides an overview of the concepts, principles and practices involved in the treatment of environmental variables related to solar radiation or wind fields, especially when complex terrains are involved, offering useful resources for students and researchers alike. It also equips professionals with the methodologies and tools needed to construct environmental variable maps and conduct forecasting for solar radiation and wind fields.

This report summarizes the technical presentations, outlines the core research recommendations, and augments the
information of the Solar Resources and Forecasting Workshop held June 20-22, 2011, in Golden, Colorado. The workshop brought together notable specialists in atmospheric science, solar resource assessment, solar energy conversion, and various stakeholders from industry and academia to review recent developments and provide input for planning future research in solar resource characterization, including measurement, modeling, and forecasting. Renewable energy generation has been constantly increasing during recent years. Wind and solar have had the most significant growths among all renewable resources. Wind and solar resources are highly intermittent and dependent on meteorological parameters and climatic conditions. The power output of wind turbines is subject to various meteorological parameters, such as wind speed, wind direction, air temperature, relative humidity, etc., among which the wind speed is the most direct and influential factor in wind power generation. Solar photovoltaic (PV) power is a function of solar radiation. Wind speed and solar radiation time series data exhibit unique features which complicate their prediction. This makes wind and solar power forecasting challenging. Accurate wind and solar forecasting enhances the value of renewable energy by improving the reliability and economic feasibility of these resources. It also supports integrating solar and wind power into electric grids by reducing the integration and operation costs associated with these intermittent generation sources. This chapter provides an overview of the time series methods that can be used for more accurate wind and solar forecasting.

The aim of this book is to provide a comprehensive overview of the fundamentals and engineering of high concentrator photovoltaic (HCPV) technology and to elucidate how this complex and emerging technology is applied in power plants. It is the first of its kind to focus exclusively on HCPV technology and offers a valuable reference volume to readers. This book is the result of an international collaboration among experts and each chapter is written by a specialist in the field. The conversion of solar energy to electricity plays an important role in power generation and HCPV is signalled by many researchers and professionals as one of the most promising sources of solar power. Therefore this book provides an important resource for companies, research institutes and universities to assist with the understanding of fundamentals, different applications and potential of such technology.

In recent years, several projects and studies have been launched towards the development and use of new methodologies, in order to assess, monitor, and support clean forms of energy. Accurate estimation of the available energy potential is of primary importance, but is not always easy to achieve. The present Special Issue on ‘Renewable Energy Resource Assessment and Forecasting’ aims to provide a holistic approach to the above issues, by presenting multidisciplinary methodologies and tools that are able to support research projects and meet today’s technical, socio-economic, and decision-making needs. In particular, research papers, reviews, and case studies on the following
subjects are presented: wind, wave and solar energy; biofuels; resource assessment of combined renewable energy forms; numerical models for renewable energy forecasting; integrated forecasted systems; energy for buildings; sustainable development; resource analysis tools and statistical models; extreme value analysis and forecasting for renewable energy resources.

The rise in population and the concurrently growing consumption rate necessitates the evolution of agriculture to adopt current computational technologies to increase production at a faster and smoother scale. While existing technologies may help in crop processing, there is a need for studies that seek to understand how modern approaches like artificial intelligence, fuzzy logic, and hybrid algorithms can aid the agricultural process while utilizing energy sources efficiently.

The Handbook of Research on Smart Computing for Renewable Energy and Agro-Engineering is an essential publication that examines the benefits and barriers of implementing computational models to agricultural production and energy sources as well as how these models can produce more cost-effective and sustainable solutions. Featuring coverage on a wide range of topics such as bacterial foraging, swarm intelligence, and combinatorial optimization, this book is ideally designed for agricultural engineers, farmers, municipal union leaders, computer scientists, information technologists, sustainable developers, managers, environmentalists, industry professionals, academicians, researchers, and students.

"A significant barrier to the widespread adoption of many forms of renewable energy, including wind, solar, and marine and hydrokinetic power, is that these sources are intermittent. Electric grid managers address this intermittency by adjusting the delivery of other sources of power based on expected changes in renewable power output. These expected changes are called power production forecasts. Such forecasts must take into account changing weather conditions in conjunction with the land's topography near a renewable energy device, along with the device's expected technical performance ... Several recent reports have determined that improving the accuracy and frequency of these forecasts can have a major impact on the economic viability of renewable energy resources" ... This hearing provides "testimony on the roles that various Federal agencies as well as the private sector play in providing forecasting data and services relevant to expanding the availability of reliable, renewable power, and the extent to which these efforts are coordinated. The hearing will also explore any research, development, demonstration, and monitoring needs that are not currently being adequately addressed."--P. 3-4.

After decades of research and development, concentrating solar thermal (CST) power plants (also known as concentrating solar power (CSP) and as Solar Thermal Electricity or STE systems) are now starting to be widely commercialized. Indeed, the IEA predicts that by 2050, with sufficient support over ten percent of global electricity could be produced by concentrating solar thermal power plants. However, CSP plants are just but one of the many possible
applications of CST systems. Advances in Concentrating Solar Thermal Research and Technology provides detailed information on the latest advances in CST systems research and technology. It promotes a deep understanding of the challenges the different CST technologies are confronted with, of the research that is taking place worldwide to address those challenges, and of the impact that the innovation that this research is fostering could have on the emergence of new CST components and concepts. It is anticipated that these developments will substantially increase the cost-competitiveness of commercial CST solutions and reshape the technological landscape of both CST technologies and the CST industry. After an introductory chapter, the next three parts of the book focus on key CST plant components, from mirrors and receivers to thermal storage. The final two parts of the book address operation and control and innovative CST system concepts. Contains authoritative reviews of CST research taking place around the world Discusses the impact this research is fostering on the emergence of new CST components and concepts that will substantially increase the cost-competitiveness of CST power Covers both major CST plant components and system-wide issues

This two-volume set constitutes the refereed post-conference proceedings of the 8th International Conference on Advancement of Science and Technology, ICAST 2020, which took place in Bahir Dar, Ethiopia, in October 2020. The 74 revised full papers were carefully reviewed and selected from more than 200 submissions of which 157 were sent out for peer review. The papers present economic and technologic developments in modern societies in 6 tracks: Chemical, food and bio-process engineering; Electrical and computer engineering; IT, computer science and software engineering; Civil, water resources, and environmental engineering; Mechanical and industrial engineering; Material science and engineering.

This leading-edge volume on advances in photovoltaic technology features diverse contributions from experts in every major geographic PV market. It examines emerging applications such as electricity grid load-balancing and demand-response, PV storage systems, photovoltaic/thermal solar collectors and carbon-offset in buildings. Engineers, researchers, developers and students alike will find new avenues for exploration and fresh insights into this continually evolving field. Highlights the most recent advances in Photovoltaics, from Next-Gen Storage Systems to Bifacial PV/T Solar Collectors; Provides expert insights on the recent evolution and near future of PV markets around the globe; Covers applications from grid-tied storage and power generation to green buildings.

Forecasting is one of the enabling technologies for the integration of weather-dependent renewable resources (e.g., solar and wind) into the electric grid. Accurate forecasts can reduce operational costs associated with intra-day variability, reduce imbalance charges incurred by plant operators due to inaccurate energy bids, decrease utility costs associated with day-ahead scheduling (thereby reducing overall O&M costs), as well as assist grid operators with balancing energy
demand schedules. As the market penetration of solar-based power generation continues to grow, accurate and reliable forecasting techniques become increasingly more important. In this work, two key areas of solar forecasting are advanced. First, we develop intra-day (>1-hour) and day-ahead (>24-hour) forecasting methods to directly predict the generation of operational solar power plants, without the need for intermediate solar irradiance forecasts and resource-to-power modeling. Here we take a data-driven approach, leveraging Machine Learning (ML) techniques and publicly available, spatially resolved meteorological and remote sensing datasets. The proposed methods are analyzed and validated using two grid-connected 1 MW photovoltaic (PV) power plants in California. Second, we develop a method to directly and efficiently estimate cloud optical properties from longwave remote sensing data. The output of solar-based power generation systems is strongly dependent on cloud cover and optical depth, but in most solar forecasting methodologies cloud optical properties are over-simplified due to a lack of real-time, accurate estimates. The proposed estimation method builds upon a two-stream, spectrally resolved infrared radiation model coupled with high-resolution (5-minute, 2 km) spectral satellite imagery. We show that the proposed method can provide real-time, accurate estimates of cloud optical depth (COD) and cloud top height for all-sky (clear or cloudy) conditions during both daytime and nighttime.

Gathering selected, revised and extended contributions from the conference ‘Forecasting and Risk Management for Renewable Energy FOREWER’, which took place in Paris in June 2017, this book focuses on the applications of statistics to the risk management and forecasting problems arising in the renewable energy industry. The different contributions explore all aspects of the energy production chain: forecasting and probabilistic modelling of renewable resources, including probabilistic forecasting approaches; modelling and forecasting of wind and solar power production; prediction of electricity demand; optimal operation of microgrids involving renewable production; and finally the effect of renewable production on electricity market prices. Written by experts in statistics, probability, risk management, economics and electrical engineering, this multidisciplinary volume will serve as a reference on renewable energy risk management and at the same time as a source of inspiration for statisticians and probabilists aiming to work on energy-related problems.

PRINCIPLES OF SUSTAINABLE ENERGY SYSTEMS, Third Edition, surveys the range of sustainable energy sources and the tools that engineers, scientists, managers, and policy makers use to analyze energy generation, usage, and future trends. The text provides complete and up-to-date coverage of all renewable technologies, including solar and wind power, biofuels, hydroelectric, nuclear, ocean power, and geothermal energy. The economics of energy are introduced, with the SAM software package integrated so students can explore the dynamics of energy usage and
prediction. Climate and environmental factors in energy use are integrated to give a complete picture of sustainable energy analysis and planning.

This book presents methods for optimising the spatial and network configuration of solar radiation measuring stations. Various physical and mathematical models are demonstrated, which together with high quality measurements, provide the essential tools to generate and validate solar resource estimates to improve the mapping of solar resources. Each chapter deals with a specific topic, showing its methodology, and providing examples of how to apply these techniques with reference to current projects around the world. These topics include:

- Radiometric measurement campaigns;
- Equipment calibration, installation, operation, and maintenance;
- Data quality assurance and assessment;
- Solar radiation modelling from satellite images and numerical models;
- Downscaling and kriging interpolation of solar radiation;
- Simulation of electric solar power plant generation;
- Solar radiation forecasting;
- Applications of solar energy;
- Socio-economic benefits of solar energy.

The contributors present the statistical and physical models needed to derive solar radiation from satellite images and numerical models, emphasising the importance of measuring solar radiation accurately. They also show the classical models used to generate synthetic data, clear sky models and ancillary air quality and meteorological data from different input sources. Solar Resources Mapping provides industry professionals with methodologies and tools to build solar irradiance maps for different applications. The book will also benefit students and researchers as it serves as a main technical reference, presenting the basic terminology and fundamentals for solar resource mapping that include methods for assessing measurement uncertainty.

Machine Learning and Data Science in the Power Generation Industry explores current best practices and quantifies the value-add in developing data-oriented computational programs in the power industry, with a particular focus on thoughtfully chosen real-world case studies. It provides a set of realistic pathways for organizations seeking to develop machine learning methods, with a discussion on data selection and curation as well as organizational implementation in terms of staffing and continuing operationalization. It articulates a body of case study–driven best practices, including renewable energy sources, the smart grid, and the finances around spot markets, and forecasting. Provides best practices on how to design and set up ML projects in power systems, including all nontechnological aspects necessary to be successful. Explores implementation pathways, explaining key ML algorithms and approaches as well as the choices that must be made, how to make them, what outcomes may be expected, and how the data must be prepared for them. Determines the specific data needs for the collection, processing, and operationalization of data within machine learning algorithms for power systems. Accompanied by numerous supporting real-world case studies, providing practical evidence of both best practices and potential pitfalls.
Renewable Energy Forecasting: From Models to Applications provides an overview of the state-of-the-art of renewable energy forecasting technology and its applications. After an introduction to the principles of meteorology and renewable energy generation, groups of chapters address forecasting models, very short-term forecasting, forecasting of extremes, and longer term forecasting. The final part of the book focuses on important applications of forecasting for power system management and in energy markets. Due to shrinking fossil fuel reserves and concerns about climate change, renewable energy holds an increasing share of the energy mix. Solar, wind, wave, and hydro energy are dependent on highly variable weather conditions, so their increased penetration will lead to strong fluctuations in the power injected into the electricity grid, which needs to be managed. Reliable, high quality forecasts of renewable power generation are therefore essential for the smooth integration of large amounts of solar, wind, wave, and hydropower into the grid as well as for the profitability and effectiveness of such renewable energy projects. Offers comprehensive coverage of wind, solar, wave, and hydropower forecasting in one convenient volume Addresses a topic that is growing in importance, given the increasing penetration of renewable energy in many countries Reviews state-of-the-science techniques for renewable energy forecasting Contains chapters on operational applications

In recent years, ground-based sky imagers have emerged as a promising tool for forecasting solar energy on short time scales (0 to 30 minutes ahead). Following the development of sky imager hardware and algorithms at UC San Diego, we present three new or improved algorithms for sky imager forecasting and forecast evaluation. First, we present an algorithm for measuring irradiance with a sky imager. Sky imager forecasts are often used in conjunction with other instruments for measuring irradiance, so this has the potential to decrease instrumentation costs and logistical complexity. In particular, the forecast algorithm itself often relies on knowledge of the current irradiance which can now be provided directly from the sky images. Irradiance measurements are accurate to within about 10%. Second, we demonstrate a virtual sky imager testbed that can be used for validating and enhancing the forecast algorithm. The testbed uses high-quality (but slow) simulations to produce virtual clouds and sky images. Because virtual cloud locations are known, much more advanced validation procedures are possible with the virtual testbed than with measured data. In this way, we are able to determine that camera geometry and non-uniform evolution of the cloud field are the two largest sources of forecast error. Finally, with the assistance of the virtual sky imager testbed, we develop improvements to the cloud advection model used for forecasting. The new advection schemes are 10-20% better at short time horizons. The rather specialized field of solar and infrared radiation measurements has become increasingly important due to the increased demands by the renewable energy and climate change research communities for data with higher accuracy and increased temporal and spatial resolutions. Recent advances in radiometry, measurement systems, and information
dissemination also have increased the need for refreshing the literature available for this topic. This book provides the reader with an up-to-date review of the important aspects of solar and infrared radiation measurements: radiometer design; equipment installation, operation, maintenance, and calibration; data quality assessment parameters; and the knowledge necessary to properly interpret and apply the measured data to a variety of topics. Each of the authors has more than 40 years of experience with this subject, primarily as the result of developing and operating multiple measurement stations, working with the industry to improve radiometry, and conducting various research projects. The book’s scope and subject matter have been designed to help a wide audience gain a general understanding of this subject and to serve as a technical reference. A student new to the field will benefit from the review of terminology and the historical perspective for radiometry before addressing more detailed topics in radiometry that we hope will be of interest to the more experienced reader. It describes the strengths and weaknesses of irradiance instruments. Provides detailed information on how to assess uncertainty in measurements. Offers comprehensive background information needed to understand the use of solar instrumentation. Discusses design concepts for shadowband radiometers, sky imagers, and satellite-based estimates of solar irradiance at the Earth’s surface. Includes chapter-end questions, references, and useful links

The book “Assessment of Renewable Energy Resources with Remote Sensing” focuses on disseminating scientific knowledge and technological developments for the assessment and forecasting of renewable energy resources using remote sensing techniques. The eleven papers inside the book provide an overview of remote sensing applications on hydro, solar, wind and geothermal energy resources and their major goal is to provide state of art knowledge to contribute with the renewable energy resource deployment, especially in regions where energy demand is rapidly expanding. Renewable energy resources have an intrinsic relationship with local environmental features and the regional climate. Even small and fast environment and/or climate changes can cause significant variability in power generation at different time and space scales. Methodologies based on remote sensing are the primary source of information for the development of numerical models that aim to support the planning and operation of an electric system with a substantial contribution of intermittent energy sources. In addition, reliable data and knowledge on renewable energy resource assessment are fundamental to ensure sustainable expansion considering environmental, financial and energetic security.

demonstrated best practices developed by operators around the world. The book's focus on practical implementation of strategies provides real-world context for the theoretical underpinnings and the development of supporting policy frameworks. The second edition considers myriad integration issues, thus ensuring that grid operators with low or high penetration of renewable generation can leverage the best practices achieved by their peers. It includes revised chapters from the first edition as well as new chapters. Lays out the key issues around the integration of renewables into power grids and markets, from the intricacies of operational and planning considerations to supporting regulatory and policy frameworks. Provides updated global case studies that highlight the challenges of renewables integration and present field-tested solutions and new Forewords from Europe, United Arab Emirates, and United States. Illustrates technologies to support the management of variability, uncertainty, and flexibility in power grids.

The Performance of Concentrated Solar Power (CSP) Systems: Analysis, Measurement, and Assessment offers a unique overview of the information on the state-of-the-art of analysis, measurement, and assessment of the performance of concentrated solar power (CSP) components and systems in a comprehensive, compact, and complete manner. Following an introductory chapter to CSP systems and the fundamental principles of performance assessment, individual chapters explore the component performance of mirrors and receivers. Further expert-written chapters look at system performance assessment, durability testing, and solar resource forecasting for CSP systems. A final chapter gives an outlook on the actual methods and instruments for performance and durability assessment that are under development.

The Performance of Concentrated Solar Power (CSP) Systems: Analysis, Measurement, and Assessment is an essential reference text for research and development professionals and engineers working on concentrated solar power systems, as well as for postgraduate students studying CSP. Presents a unique, single literature source for a complete overview of the performance assessment tools and methods currently used for concentrated solar power (CSP) technology. Written by a team of experts in the field of CSP. Provides information on the state-of-the-art of modeling, measurement, and assessment of the performance of CSP components and systems in a comprehensive, compact, and complete manner.

Solar and wind energy have the potential to power the world's energy needs. However, the variable and uncertain power generation from these sources are posing a major challenge for the reliable and economic integration in the existing electric power system. For solar energy, the problem consists of two related parts, (1) variability in the resource (determined by the location of a solar plant) and (2) uncertainty in power output, (determined by the local meteorological conditions). First, this work presents a verification of the accuracy of satellite image based irradiance models, used to globally assess the solar resource. The focus is placed on the direct normal irradiance (DNI) component of solar radiation and its variability. Second, we develop two solar forecasting methods, necessary for grid integration and market
participation of solar energy generators. For intra-day forecasting, a satellite imagery based global horizontal irradiance (GHI) forecast methodology is proposed. For day-ahead forecasting, we present a numerical weather prediction (NWP) based model to predict hourly values of DNI, necessary for power output scheduling of concentrated solar power (CSP) plants. The proposed day-ahead forecast is extensively validated for regions in North America with high and medium potential for the deployment of CSP. The benefits of this forecast for large scale grid integration of CSP plants, combined with optimized siting to reduce variability and uncertainty, are shown. Results include the quantification of errors in satellite based DNI assessment, the successful application of cloud tracking in satellite images for forecasts up to 3h ahead and the significant reduction of power output uncertainty for day-ahead market participation of CSP plants.

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