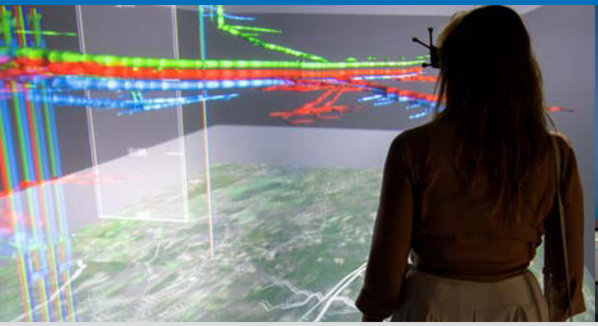
NATIONAL RENEWABLE ENERGY LABORATORY



Grid Integration Science

NREL Power Systems Engineering Center

2017 Publications Summary

NREL's Power System Engineering Center published 62 journal and magazine articles in the past year highlighting recent research in integrating renewable energy into power systems. For information about these or any other NREL articles or reports please contact the author(s) or myself. NREL would like to acknowledge the U.S. Department of Energy for the funding support that made this research possible.

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Unlocking Flexibility: Energy Systems Integration, *IEEE Power and Energy Magazine*

This article reviews energy systems integration (ESI). ESI is the process of coordinating the operation and planning of energy systems across multiple pathways and/or geographical scales to deliver reliable, cost-effective energy services with minimal impact on the environment. Integrating energy domains adds flexibility to the electric power system. ESI includes interactions among energy vectors and with other large-scale infrastructures that are enabling technologies for ESI, including water, transport, and data and communications networks.

Achieving a 100% Renewable Grid: Operating Electric Power Systems with Extremely High Levels of Variable Renewable Energy, *IEEE Power and Energy Magazine*

This paper examines what it means and what is required to achieve a 100% renewable grid. Variable renewable generation such as wind and solar photovoltaic systems will be a major contributor, and with the reduction in costs for these technologies during the last five years, large-scale deployments of variable renewable generation are happening around the world.

Terawatt-Scale Photovoltaics: Trajectories and Challenges, *Science*

The annual potential of solar energy far exceeds the world's total energy consumption; however, the vision of photovoltaics (PV) providing a substantial fraction of global electricity generation and total energy demand is far from being realized. This paper explores the technical, infrastructure, economic, and policy barriers that need to be overcome for PV to grow to the multiple-terawatt scale. It assesses realistic future scenarios and makes suggestions for a global agenda to move toward PV at this level.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Integrating High Levels of Variable Renewable Energy into Electric Power Systems, *Journal of Modern Power Systems and Clean Energy*

As increasing amounts of variable renewable energy (VRE) such as wind and solar are integrated into electric power systems, technical challenges arise from the need to maintain the balance between load and generation at all timescales. This paper examines the challenges of integrating ultrahigh levels of VRE into electric power systems, reviews a range of solutions to these challenges, and describes several examples of ultrahigh VRE systems that are in operation today.

Integrated Devices and Systems

Rapid Active Power Control of Photovoltaic Systems for Grid Frequency Support, *IEEE Journal of Emerging and Selected Topics in Power Electronics*

This paper proposes a predictive photovoltaic (PV) inverter control method for very fast and accurate control of active power. This rapid active power control method will increase the effectiveness of various higher level controls designed to mitigate grid frequency contingency events, including fast power-frequency droop, inertia emulation, and fast frequency response, without the need for energy storage.

Change in Brooklyn and Queens: How New York's Reforming the Energy Vision Program and Con Edison Are Reshaping Electric Distribution Planning, *IEEE Power and Energy Magazine*

This paper reviews the renewal of New York City's electricity system to meet the needs of a growing population. The New York State Public Service Commission and Con Edison are considering and adopting strategies that include renewable generation, demand response, battery energy storage systems, fuel-cell distributed generation, combined heat and power, volt-volt ampere reactive optimization, and a host of other innovative solutions that would both reduce electricity demand and transform how and when Con Edison's consumers use electricity.

Trans-Oceanic Remote Power Hardware-in-the-Loop: Multi-Site Hardware, Integrated Controller, and Electric Network Co-Simulation, *IET Generation, Transmission and Distribution*

This study describes a novel platform that combines three emerging research areas: power systems cosimulation, power hardware-in-the-loop simulation, and lab-to-lab links. The platform is distributed, real-time capable; allows for easy Internet-based connection from geographically dispersed participants; and is software platform agnostic. This capability enables smart grid researchers throughout the world to leverage their unique simulation capabilities for multisite collaborations that can effectively simulate and validate emerging smart grid technology solutions.

Evaluation of Different Inertial Control Methods for Variable-Speed Wind Turbines Simulated by Fatigue, Aerodynamic, Structures, and Turbulence (FAST), *IET Renewable Power Generation*

To mitigate the degraded power system inertia and undesirable primary frequency response caused by large-scale wind power integration, this work studies the frequency support capabilities of variable-speed wind turbines. The authors calculate the short-term dynamic equivalent loads and discuss the turbine structural loadings related to the inertial response.

Real-Time Co-Simulation of Adjustable-Speed Pumped Storage Hydro for Transient Stability Analysis, *Electric Power Systems Research*

Pumped storage hydropower (PSH) generation of electricity is a proven grid-level storage technique. This paper discusses and models a new configuration, called adjustable-speed PSH (AS-PSH). The work performs a real-time cosimulation at the subsecond regime of AS-PSH connected to the IEEE 14-bus test system using a digital real-time simulator and discusses the results.

Power-Smoothing Scheme of a DFIG Using the Adaptive Gain Depending on the Rotor Speed and Frequency Deviation, *Energies*

This paper proposes a power-smoothing scheme of a doubly-fed induction generator that significantly mitigates the system frequency fluctuation of wind power plants while preventing overdeceleration of the rotor speed. The proposed scheme employs an additional control loop relying on the system frequency deviation that operates in combination with the maximum power point tracking control loop.

Flexible IQ-V Scheme of a DFIG for Rapid Voltage Regulation of a Wind Power Plant, *IEEE Transactions on Industrial Electronics*

This paper proposes a flexible reactive current-to-voltage (IQ – V) scheme of a doubly-fed induction generator (DFIG) for the rapid voltage regulation of a wind power plant (WPP). In the proposed scheme, the WPP controller dispatches different voltage set points to the DFIGs depending on their rotor voltage margins. The performance of the proposed flexible scheme was verified under scenarios with various disturbances. The proposed scheme can help increase wind power penetration without jeopardizing voltage stability.

Guest Editorial: Modeling and Advanced Control of Wind Turbines/Wind Farms, *IEEE Transactions on Energy Conversion*

The papers in this special section focus on recent advancements and breakthroughs in modeling and enhanced active/reactive power control of wind power conversion systems, ranging from components of wind turbines to wind power plants.

Impedance-Based Stability Analysis in Grid Interconnection Impact Study Owing to the Increased Adoption of Converter-Interfaced Generators, *Energies*

This study investigates the emerging harmonic stability concerns to be addressed by grid planners in generation interconnection studies owing to the increased adoption of renewable energy resources connected to the grid via power electronic converters. By complementing conventional electromagnetic transient simulation studies, the proposed analytical approach enables grid planners to identify critical design parameters to seamlessly integrate new converter-interfaced generators and ensure the reliability of the grid.

Adaptive Gain-Based Stable Power Smoothing of a DFIG, *Journal of Electrical Engineering and Technology*

In a power system that has a high penetration level of wind generation, the output power fluctuation of a large-scale wind turbine generator caused by varying wind speeds increases the maximum frequency deviation, an important metric to assess the quality of electricity, because of the reduced system inertia. This paper proposes a stable power-smoothing scheme of a doubly-fed induction generator that can suppress the maximum frequency deviation, particularly for a power system with a high penetration level of wind generation.

Short-Term Frequency Response of a DFIG-Based Wind Turbine Generator for Rapid Frequency Stabilization, *Energies*

This paper proposes a short-term frequency-response scheme of a doubly-fed induction generator wind turbine generator for improving rotor speed recovery and frequency nadir. The simulation results demonstrate that the proposed scheme successfully achieves rapid frequency stabilization with the improved frequency nadir under various wind conditions based on the IEEE 14-bus system.

Coordinated Control Strategy of a Battery Energy Storage System to Support a Wind Power Plant Providing Multi-Timescale Frequency Ancillary Services, *IEEE Transactions on Sustainable Energy*

With increasing penetrations of wind generation on electric grids, wind power plants (WPPs) are encouraged to provide frequency ancillary services (FAS); however, it is a challenge to ensure that variable wind generation can reliably provide these services. This paper proposes using a battery energy storage system (BESS) to ensure the WPPs' commitment to FAS. This method also focuses on reducing the BESS's size and extending its lifetime. In this paper, a state-machine-based coordinated control strategy is developed to use a BESS to support the obliged FAS of a WPP (including both primary and secondary frequency control).

Grid-Level Application of Electrical Energy Storage: Example Use Cases in the United States and China, *IEEE Power and Energy Magazine*

Electrical energy storage (EES) systems are expected to play an increasing role in helping the United States and China meet the challenges of integrating increasing amounts of variable renewable resources and enhancing the reliability of power systems by improving the operating capabilities of the electric grid. EES systems are becoming integral components of a resilient and efficient grid through a diverse set of applications that include energy management, load shifting, frequency regulation, grid stabilization, and voltage support.

Sensing and Predictive Analytics

Reducing Broadband Shortwave Radiometer Calibration-Bias Caused by Longwave Irradiance in the Reference Direct Beam, *Atmospheric and Climate Sciences*

This article describes a method to reduce calibration bias for shortwave radiometers. Shortwave radiometers are calibrated to absolute cavity radiometers (ACRs), which measure the broadband spectrum of terrestrial solar beam irradiance. Shortwave radiometers, however, cover a reduced range of the spectrum, leading to a calibration bias that can exceed 1%. This paper proposes an alternative calibration method that uses an ACR with Schott glass window to measure the reference broadband shortwave irradiance.

Pioneer Design of Non-Contact Synchronized Measurement Devices Using Electric and Magnetic Field Sensors, *IEEE Transactions on Smart Grid*

This paper presents two innovative designs for noncontact synchronized measurement devices (NCSMD), including an electric field sensor-based NCSMD (E-NCSMD) and a magnetic field sensor-based NCSMD (M-NCSMD). Compared with conventional synchrophasors, E-NCSMD and M-NCSMD are much more flexible to be deployed and have much lower costs, making them highly accessible and useful for a wide array of phasor measurement applications.

Developing a Spectroradiometer Data Uncertainty Methodology, *Solar Energy*

In this paper, the uncertainties associated with the responsivity of a spectroradiometer are examined using the Guide to the Expression of Uncertainty in Measurement protocols. This is first done for a generic spectroradiometer, then, to illustrate the methodology, the calibration of a LI-COR 1800 spectroradiometer is performed.

Building the Sun4Cast System: Improvements in Solar Power Forecasting, *Bulletin of the American Meteorological Society*

As the integration of solar power into the national electric grid rapidly increases, it becomes imperative to improve the forecasting of this highly variable renewable resource. Thus, a team of researchers from the public, private, and academic sectors partnered to develop and assess a new solar power forecasting system, Sun4Cast. The partnership focused on improving decision-making for utilities and independent system operators, ultimately resulting in improved grid stability and cost savings for consumers. This paper analyzes the collaborative design process, discusses the project results, and provides recommendations for best practices for solar forecasting.

Big Data-Based Approach to Detect, Locate, and Enhance the Stability of an Unplanned Microgrid Islanding, *Journal of Energy Engineering*

This paper proposes a big data-based approach for the security improvement of an unplanned microgrid islanding (UMI). The proposed approach contains two major steps: the first step is big data analysis of wide-area monitoring to detect and locate a UMI; the second step is particle swarm optimization-based stability enhancement for the UMI.

Social Energy: Mining Energy from the Society, *IEEE/CAA Journal of Automatica Sinica*

The inherent nature of energy—physicality, sociality, and informatization—implies the inevitable and intensive interaction between energy systems and social systems. From this perspective, the authors of this paper define "social energy" as a complex socio-technical system of energy systems, social systems, and the derived artificial virtual systems that characterize the intense intersystem and intra-system interactions. Recent advancements in intelligent technology, massive high-performance computing, and extreme-scale data analytics technologies enable the possibility of substantial advancements in socio-technical system optimization, scheduling, control, and management. This paper provides a discussion on the nature of energy and proposes the concept and intention of social energy systems for electric power.

Consumption Behavior Analytics-Aided Energy Forecasting and Dispatch, *IEEE Intelligent Systems*

This article investigates data analytics and forecasting methods to identify correlations between electricity consumption behavior and distributed photovoltaic output. The forecasting results feed into a predictive energy management system that optimizes energy consumption in the near future to balance customer demand and power system needs.

Distributed Electrical Energy Systems: Needs, Concepts, Approaches, and Vision, *Acta Automatica Sinica*

Intelligent distributed electrical energy systems (IDEES) have vast system components, diversified component types, and difficulties in operation and management, such that the traditional centralized power system management approach no longer fits the operation. Thus, it is believed that blockchain technology is an important feasible technical path for building future large-scale distributed electrical energy systems. This paper reviews the needs and approaches for developing blockchain-based IDEES.

Spectral Binning for Energy Production Calculations and Multijunction Solar Cell Design, *Progress in Photovoltaics: Research and Applications*

Currently, most solar cells are designed for and evaluated under standard spectra intended to represent typical spectral conditions; however, no single spectrum can capture the spectral variability needed for annual energy production (AEP) calculations, and this shortcoming becomes more significant for series-connected multijunction cells as the number of junctions increases. This paper shows how a large spectral set can be reduced to a few "proxy" spectra that still retain the spectral variability information needed for AEP design and evaluation.

Short-Term Solar Irradiance Forecasting via Satellite/Model Coupling, *Solar Energy*

This paper describes how geostationary satellite observations are used with operational cloud masking and retrieval algorithms, wind field data from Numerical Weather Prediction (NWP), and radiative transfer calculations to produce short-term forecasts of solar insolation for applications in solar power generation. Typical errors range from 8.5% to 17.2%, depending on the complexity of cloud regimes, and an operational demonstration outperformed persistence-based forecasting of global horizontal irradiance under all conditions by approximately 10 W/m^2.

Wind and Solar Resource Data Sets, *Wiley Interdisciplinary Reviews: Energy and Environment*

The range of resource data sets spans from static cartography showing the mean annual wind speed or solar irradiance across a region to high temporal and high spatial resolution products that provide detailed information at a potential wind or solar energy facility. These data sets are used to support continental-scale, national, or regional renewable energy development; facilitate prospecting by developers; and enable grid integration studies. This review introduces the wind and solar resource data sets and provides an overview of the common methods used for their creation and validation.

Image Phase Shift Invariance-Based Cloud Motion Displacement Vector Calculation Method for Ultra-Short-Term Solar PV Power Forecasting, *Energy Conversion and Management*

This paper proposes an image-phase-shift-invariance (IPSI) cloud motion displacement vector calculation (CMDV) method using Fourier phase correlation theory (FPCT) for minute-timescale solar power forecasting. Simulations under various scenarios including both thick and thin cloud conditions indicated that the proposed IPSI-based CMDV calculation method using FPCT is more accurate and reliable than the original FPCT method, optimal flow method, and particle image velocimetry method.

Energy Systems Optimization and Control

In Microgrid Controllers: Expanding Their Role and Evaluating Their Performance, *IEEE Power and Energy Magazine*

Microgrids have long been deployed to provide power to customers in remote areas as well as critical industrial and military loads. Today, they are also being proposed as grid-interactive solutions for energy-resilient communities. Properly designed and grid-integrated microgrids can provide the flexibility, reliability, and resiliency needs of both the future grid and critical customers. These systems can be an integral part of future power system designs that optimize investments to achieve operational goals, improved reliability, and diversification of energy sources.

Chance-Constrained AC Optimal Power Flow for Distribution Systems with Renewables, *IEEE Transactions on Power Systems*

This paper focuses on distribution systems featuring renewable energy sources (RES) and energy storage systems, and it presents an AC optimal power flow (OPF) approach to optimize system-level performance objectives while coping with uncertainty in RES generation and loads. The proposed method hinges on a chance-constrained AC OPF formulation, where probabilistic constraints are used to enforce voltage regulation with prescribed probability. A computationally more affordable convex reformulation is developed by resorting to suitable linear approximations of the AC power flow equations as well as convex approximations of the chance constraints.

Unlocking Flexibility: Integrated Optimization and Control of Multienergy Systems, *IEEE Power and Energy Magazine*

Electricity, natural gas, water, and district heating/cooling systems are predominantly planned and operated independently; however, it is increasingly recognized that integrated optimization and control of such systems at multiple spatiotemporal scales can bring significant socioeconomic, operational efficiency, and environmental benefits. This paper reviews the objectives of these multienergy systems.

Coordinated Control Method of Voltage and Reactive Power for Active Distribution Networks Based on Soft Open Point, *IEEE Transactions on Sustainable Energy*

The increasing penetration of distributed generators exacerbates the risk of voltage violations in active distribution networks (ADNs). The conventional voltage regulation devices limited by the physical constraints are difficult to meet the requirement of real-time voltage/volt-ampere reactive control (VVC) with high precision when distributed generators fluctuate frequently; however, soft open point (SOP), a flexible power electronic device, can be used as the continuous reactive power source to realize fast voltage regulation. This paper proposes a coordinated VVC method based on SOP for ADNs.

Efficient Relaxations for Joint Chance-Constrained AC Optimal Power Flow, *Electric Power Systems Research*

In this paper, joint chance constraints are used to solve an AC optimal power flow problem that maintains desired levels of voltage magnitude in distribution grids under high penetrations of photovoltaic systems. A tighter version of Boole's inequality is derived and used to provide a new upper bound on the joint chance constraint, and simulation results are shown demonstrating the benefit of the proposed upper bound.

Beyond Relaxation and Newton-Raphson: Solving AC OPF for Multi-Phase Systems with Renewables, *IEEE Transactions on Smart Grid*

This paper focuses on the AC optimal power flow (OPF) problem for multiphase systems. Particular emphasis is given to systems with high integration levels of renewable generation, where adjustments of the real and reactive output power from renewable sources of energy are necessary to maintain voltage regulation. To identify feasible and optimal AC OPF solutions in challenging scenarios where existing methods might fail, this paper leverages the feasible point pursuit successive convex approximation algorithm, a powerful approach for general nonconvex quadratically constrained quadratic programs.

Optimal Load-Side Control for Frequency Regulation in Smart Grids, *IEEE Transactions on Automatic Control*

This paper presents a comprehensive load-side frequency control mechanism that can maintain the grid within operational constraints. In particular, controllers are presented that can rebalance supply and demand after disturbances, restore the frequency to its nominal value, and preserve interarea power flows. The controllers are distributed (unlike the currently implemented frequency control), can allocate load updates optimally, and can maintain line flows within thermal limits.

Analysis of Operating Reserve Demand Curves in Power System Operations in the Presence of Variable Generation, *IET Renewable Power Generation*

The presence of wind and solar generation (commonly referred to as variable generation) can increase variability and uncertainty in the net load profile. One mechanism to mitigate this issue is to schedule and dispatch additional operating reserve. A new operating reserve strategy, flexibility reserve, has been introduced in some regions. This study explores a similar implementation and analyzes its implications on power system operations.

Review of Reactive Power Dispatch Strategies for Loss Minimization in a DFIG-based Wind Farm, *Energies*

This paper reviews and compares the performance of reactive power dispatch strategies for the loss minimization of doubly-fed induction generator wind power plants (WPPs). The paper investigates twelve possible combinations of three reactive power dispatch strategies at the level of the plants and four reactive power control strategies at the level of the turbines. The effectiveness of these strategies is evaluated by simulations on a carefully designed WPP under a series of cases with different wind speeds and reactive power requirements of the plant.

Prediction-Correction Algorithms for Time-Varying Constrained Optimization, *IEEE Transactions on Signal Processing*

This paper develops online algorithms to track solutions of time-varying constrained optimization problems. Particularly for those resembling workhorse Kalman filtering-based approaches for dynamic systems, the proposed methods involve prediction-correction steps to provably track the trajectory of the optimal solutions of time-varying convex problems. Numerical simulations corroborate the analytical results and showcase the performance and benefits of the proposed algorithms. The paper presents a realistic application of the proposed method to real-time control of energy resources.

Network-Cognizant Voltage Droop Control for Distribution Grids, *IEEE Transactions on Power Systems*

This paper examines distribution systems that have a high integration level of distributed energy resources (DERs) and addresses the design of local control methods for real-time voltage regulation. Particularly, the paper focuses on proportional control strategies wherein the active and reactive power output of DERs are adjusted in response to (and proportionally to) local changes in voltage levels.

Optimal Operation of Soft Open Points in Active Distribution Networks Under Three-Phase Unbalanced Conditions, *IEEE Transactions on Smart Grid*

The asymmetric integration of distributed generators exacerbates the three-phase unbalanced condition in distribution systems. Soft open point (SOP) is a flexible power electronic device that can achieve accurate active and reactive power flow control to balance power flow among phases. This paper proposes an SOP-based operation strategy for unbalanced active distribution networks. By regulating the operation of SOPs, the strategy can reduce power losses and simultaneously mitigate the three-phase unbalance of the upper-level grid.

Optimal Regulation of Virtual Power Plants, *IEEE Transactions on Power Systems*

This paper develops a real-time algorithmic framework for aggregations of distributed energy resources in distribution networks to provide regulation services in response to transmission-level requests. Leveraging online primal-dual-type methods for time-varying optimization problems and suitable linearizations of the nonlinear AC power flow equations, this work establishes a system-theoretic foundation to realize the vision of distribution-level virtual power plants.

Foresee: A User-Centric Home Energy Management System for Energy Efficiency and Demand Response, *Applied Energy*

This paper presents foresee™, a user-centric home energy management system that can help optimize how a home operates to concurrently meet users' needs, achieve energy efficiency and commensurate utility cost savings, and reliably deliver grid services based on utility signals. foresee is built on a multiobjective model predictive control framework wherein the objectives consist of energy cost, thermal comfort, user convenience, and carbon emission. Results indicate that foresee generated up to 7.6% whole-home energy savings without requiring substantial behavioral changes.

Optimizing Power-Frequency Droop Characteristics of Distributed Energy Resources, *IEEE Journal of Power Sources*

This paper outlines a procedure to design power– frequency droop slopes for distributed energy resources installed in distribution networks to optimally participate in primary frequency response. In particular, the droop slopes are engineered such that DERs respond in proportion to their power ratings and they are not unfairly penalized in power provisioning based on their location in the distribution network.

An Enhanced SOCP-Based Method for Feeder Load Balancing Using the Multi-Terminal Soft Open Point in Active Distribution Networks, *Applied Energy*

This paper proposes an enhanced second-order cone programming-based method for feeder load balancing using the multiterminal soft open point. By regulating the operation of the multiterminal soft open point, the proposed method can mitigate the unbalanced condition of feeder load and simultaneously reduce the power losses of advanced distribution networks.

An Incentive-Based Online Optimization Framework for Distribution Grids, *IEEE Transactions on Automatic Control*

This paper formulates a time-varying social-welfare maximization problem for distribution grids with distributed energy resources (DERs) and develops online distributed algorithms to identify (and track) its solutions. In the considered setting, the network operator and DER owners pursue given operational and economic objectives while ensuring that voltages stay within prescribed limits. The proposed algorithm affords an online implementation to enable tracking the solutions in the presence of time-varying operational conditions and changing optimization objectives.

Parallel Dispatch: A New Paradigm of Electrical Power System Dispatch, *IEEE/CAA Journal of Automatica Sinica*

Modern power systems are evolving into socio-technical systems with massive complexity, whose real-time operation and dispatch go beyond human capability. This paper introduces the overall business model of power system dispatch, the top-level design approach of an intelligent dispatch system, and the parallel intelligent technology with its dispatch applications.

Power Systems Design and Studies

Wind-Friendly Flexible Ramping Product Design in Multi-Timescale Power System Operations, *IEEE Transactions on Sustainable Energy*

Wind is typically thought of as causing the need for ramping services in the electric grid; however, wind system operators are implementing new ramping products as a type of ancillary service. In this paper, a multi-timescale unit commitment and economic dispatch model is developed to study the wind power ramping product. An optimized swinging door algorithm with dynamic programming is applied to identify and forecast wind power ramps. Results show that that the product reduces production costs and possibly enhances the reliability of power system operations.

Ramp Forecasting Performance from Improved Short-Term Wind Power Forecasting over Multiple Spatial and Temporal Scales, *Energy*

The large variability and uncertainty in wind power generation present a concern to power system operators, especially given the increasing amounts of wind power being integrated into the electric power system. Large ramps, one of the biggest concerns, can significantly influence system economics and reliability. The Wind Forecast Improvement Project aimed to improve the accuracy of forecasts and to evaluate the economic benefits of these improvements to grid operators. This paper evaluates the ramp forecasting accuracy gained by improving the performance of short-term wind power forecasting.

Characterizing and Analyzing Ramping Events in Wind Power, Solar Power, Load, and Net Load, *Renewable Energy*

This paper adopts and extends an optimized swinging door algorithm (OpSDA) to accurately and efficiently detect ramping events. To detect wind power ramps, a process of merging "bumps" (that have a different changing direction) into adjacent ramping segments is integrated to improve the performance of the OpSDA method.

Dynamic Price Vector Formation Model-Based Automatic Demand Response Strategy for PV-Assisted EV Charging Stations, *IEEE Transactions on Smart Grid*

This paper proposes a real-time price-based automatic demand response strategy for photovoltaic-assisted electric vehicle charging stations without vehicle to grid. The charging process is modeled as a dynamic linear program instead of the normal day-ahead and real-time regulation strategy to capture the advantages of both global and real-time optimization.

An Extended IEEE 118-Bus Test System with High Renewable Penetration, *IEEE Transactions on Power Systems*

This article describes a new publicly available version of the IEEE 118-bus test system, NREL-118. The database is based on the transmission representation (buses and lines) of the IEEE 118-bus test system, with a reconfigured generation representation using three regions of the U.S. Western Interconnection from the latest Western Electricity Coordinating Council 2024 Common Case (Transmission Expansion Planning home and GridView database). Time-synchronous hourly load, wind, and solar time series are provided for one year.

A Methodology for Quantifying Reliability Benefits from Improved Solar Power Forecasting in Multi-Timescale Power System Operations, *IEEE Transactions on Smart Grid*

This paper aims to quantify reliability benefits from solar power forecasting improvements. To systematically analyze the relationship between solar power forecasting improvements and reliability performance in power system operations, an expected synthetic reliability metric is proposed to integrate state-of-the-art independent reliability metrics. Numerical simulations show that the reliability benefits of multi-timescale power system operations are significantly increased because of the improved solar power forecasts.

Towards Improved Understanding of the Applicability of Uncertainty Forecasts in the Electric Power Industry, *Energies*

Deterministic forecasts are still predominant in utility practice although truly optimal decisions and risk hedging are only possible with the adoption of uncertainty forecasts. One of the main barriers to the industrial adoption of uncertainty forecasts is the lack of understanding of its information content (e.g., its physical and statistical modeling) and standardization of uncertainty forecast products. This paper aims to improve this understanding by establishing a common terminology and reviewing the methods to determine, estimate, and communicate the uncertainty in weather and wind power forecasts.

Approach to Fitting Parameters and Clustering for Characterizing Measured Voltage Dips Based on Two-Dimensional Polarization Ellipses, *IET Renewable Power Generation*

This study proposes and evaluates an alternative approach to characterize real voltage dips. The proposed methodology is based on voltage-space vector solutions, identifying parameters for ellipses trajectories by using the least-squares algorithm applied on a sliding window along the disturbance. The most likely patterns are then estimated through a clustering process based on the k-means algorithm. The objective is to offer an efficient and easily implemented alternative to characterize faults and visualize the most likely instantaneous phase-voltage evolution during events through their corresponding voltage-space vector trajectories.

Voltage Regulation with Rooftop Solar PV in Hawai'i—What are the Impacts to the Utility and PV Customers? *IEEE Smart Grid Newsletter*

The combination of renewable portfolio standards, which require utilities to generate a specified amount of electricity from renewable sources; falling costs of renewable generation; and the financial incentives for residential distributed generation have dramatically increased the penetration of distributed electricity generation in the residential sector across the United States. This paper describes an example of utilities seeking to proactively plan for distributed energy resource integration.

Bilevel Arbitrage Potential Evaluation for Grid-Scale Energy Storage Considering Wind Power and LMP Smoothing Effect, *IEEE Transactions on Sustainable Energy*

This paper deals with extended-term energy storage arbitrage problems to maximize the annual revenue in deregulated power systems with high penetrations of wind power. This paper proposes a bilevel energy storage arbitrage model where the upper level maximizes the energy storage arbitrage revenue and the lower level simulates the market-clearing process considering wind power and energy storage. The results from the conventional model and the bilevel model are compared under different energy storage power and energy ratings as well as various load and wind penetration levels.

Assessing the Costs and Benefits of U.S. Renewable Portfolio Standards, *Environmental Research Letters*

Renewable portfolio standards (RPS) exist in 29 U.S. states and the District of Columbia. This article summarizes the first national-level, integrated assessment of the future costs and benefits of existing RPS policies, and the same metrics are evaluated under a second scenario in which widespread expansion of these policies is assumed to occur. The findings suggest that U.S. RPS programs are not likely to represent the most cost-effective path toward achieving air quality and climate benefits but that the programs are, on a national basis, cost-effective when considering externalities.

A Review of Power Distribution Test Feeders in the United States and the Need for Synthetic Representative Networks, *Energies*

This paper presents a first-of-a-kind structured literature review of published distribution test networks with a special emphasis on classifying their main characteristics and identifying the types of studies for which they have been used. This both aids researchers in choosing suitable test networks for their needs and highlights the opportunities and directions for further test system development. In particular, this paper highlights the need for building large-scale synthetic networks to overcome the identified drawbacks of current distribution test feeders.

Load Modeling: A Review, *IEEE Transactions on Smart Grid*

This paper presents a review on load modeling and identification techniques. Load modeling has received more attention in recent years because of renewable integration, demand-side management, and smart metering devices. There is a need to systematically review existing load modeling techniques and suggest future research directions to meet the increasing interests from industry and academia.

Analytic Considerations and Design Basis for the IEEE Distribution Test Feeders, *IEEE Transactions on Power Systems*

For nearly 20 years, the Test Feeder Working Group of the Distribution System Analysis Subcommittee has been developing openly available distribution test feeders for use by researchers. This paper provides an overview of the existing distribution feeder models and clarifies the specific analytic challenges that they were originally designed to examine.

Multiobjective Model of Time-of-Use and Stepwise Power Tariff for Residential Consumers in Regulated Power Markets, *IEEE Systems Journal*

Time-of-use (TOU) rates and stepwise power tariffs (SPTs) are important economic levers to motivate residents to shift their electricity usage in response to electricity price. This paper proposes a new multiobjective optimal tariff-making model of TOU and SPT (TOUSPT) that combines the complementary characteristics of two power tariffs for residential energy conservation and peak load shaving. Results from case studies demonstrate that TOUSPT can achieve efficient end-use energy savings and shift load from peak to off-peak periods.

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