
CONTENT EDITORS:
Chloe Thomas, Director, Education, Solar Energy Trade Shows
Danielle Danko, Sr. Director, Marketing, Solar Energy Trade Shows
Tabitha Kasik, Manager, Education Design, Solar Energy Trade Shows

DESIGN AND LAYOUT:
Devin Overbey, Sr. Graphic Designer, Solar Energy Trade Shows

Solar Energy Trade Shows, 225 Reinekers Ln, Suite 680, Alexandria, VA 22314, USA

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Solar Energy Trade Shows
customerservice@sets.solar, +1-703-738-9460


LIST OF REVIEWERS:
Michele Boyd
Evelyn Butler
Troy Chatwin
Ben Hertz-Shargel
Qilin Li
Andrea Alberto Mammoli
James Mater
Ingrid Repins
Larry Sherwood
Meng Tao
Ajith Weerasinghe
Tim Zgonena
THE TECHNICAL SYMPOSIUM at Solar Power International (SPI) and Energy Storage International (ESI) offers professional from the academic, R&D, technical, and scientific disciplines in photovoltaics, energy storage, and “smart” energy the opportunity to submit abstracts for peer review, presentation and discussion, and publication at the largest gathering of the solar community in North America. As solar, storage, and smart energy continue to mature, it is important to continue to bring together the knowledge, experience, and expertise of the best and brightest minds advancing the industry.

ABOUT SOLAR POWER INTERNATIONAL

Solar Power International (SPI) generates success for energy professionals and the global solar industry. SPI sets the standard for solar events as the fastest growing and largest solar in North America as recognized by Trade Show Executive and Trade Show News Network. SPI has also been among the Gold 100 for eight years running and named this year’s “Best Use of Technology” and the 2016 “Stickiest Show Floor” by Trade Show Executive for the innovative ways in which attendees stay engaged.

ENERGY STORAGE INTERNATIONAL

Energy Storage International (ESI), co-located with Solar Power International, paves the way for greater integration between energy storage and solar markets. As the largest energy storage event in North America, ESI features over 250 exhibitors and 12,000 attendees interested in energy storage technology, and three full days of education investigating policy advances, market forecasts, new technology, and applications, as well as additional relevant, timely industry-developed content designed to grow the storage market.
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COMMITTEE MEMBERS:

MICHELE BOYD,
Technology Manager & Policy Analyst,
US Department of Energy

EVELYN BUTLER,
Senior Director, Codes and Standards,
Solar Energy Industries Association (SEIA)

TROY CHATWIN,
Emerging Technologies Leader,
GE Transportation

VASILIS FTHENAKIS,
Senior Research Scientist and Adjunct Professor,
Columbia University

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Solar/Fuel Cells,
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Energy Hub

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Professor & Co-Director, NEWT Center,
Rice University

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Professor,
University of New Mexico

JAMES MATER,
General Manager, Smart Grid Business,
QualityLogic

INGRID REPINS,
Principal Scientist,
US Department of Energy

LARRY SHERWOOD,
Technology Manager & Policy Analyst,
National Renewable Energy Laboratories

AARON SMALLWOOD,
Vice President, Technical Services
Smart Electric Power Alliance (SEPA)

MENG TAO,
Professor,
Arizona State University

JIANHUI WANG,
Editor-in-Chief,
IEEE Transactions, Smart Grid

AJITH WEERASINGHE,
Assistant Professor,
California State University, Fresno

TIM ZGONENA,
Principal Engineer,
UL LLC
**ES1/ST1: TECHNICAL SYMPOSIUM**
**KEYNOTE: OVER THE HORIZON: SOLAR TECHNOLOGIES AND USES TO COME**

**Presenter:** Garrett Nilsen, Manufacturing Competitiveness Program Manager, US Department of Energy

Solar technologies are evolving quickly, from cells and modules to system-level innovations and storage. In the next decade, the U.S. Department of Energy Solar Energy Technologies Office expects to see this rapid technology development continued, reaching the energy market and beyond (such as solar desalination). The office funds early-stage technology research with an eye towards what technologies will help to keep the U.S. solar industry on the leading edge. Join us to learn more.

**ES2: SOLUTION-PROCESSED COMPOSITE TRANSPARENT METAL NETWORK CONDUCTORS FOR NEXT GENERATION SCALABLE PV**

**Presenter:** John MacKenzie, Professor and Technical Director, University of Washington

Transparent conductors (TCs) are essential components of thin film PV cells. Inherently, ITO and other related TC oxides, have fundamental trade-offs that balance conductivity versus optical transmission losses from metallic absorption and reflectivity. Furthermore, the ITO sputtering, materials and patterning costs represent one of the highest cost elements in the thin film cell process. As we consider emerging technologies such as roll to roll processing on lower temperature substrates, the problem is compounded by high ITO processing temperatures. Low temperature alternatives do exist, however, they cannot reach the metrics for high efficiency PV on their own. Numerical modeling has shown that combining high transparency, modestly conducting films with printed conductive grids can provide a TC with a 30% reduction in power loss relative to ITO. During this talk, current work on nanowire and printed TC films will be presented and the scale-up pathways for these technologies will be discussed.

**ES3: EFFECTIVE INVESTMENT RISK MITIGATION AND YIELD OPTIMIZATION – TWO SIDES OF THE SAME COIN?**

**Presenter:** Thomas Sauer, President & Chief Executive Officer, EXXERGY Inc.

**OBJECTIVE:**
Discuss effective risk mitigation measures to improve long term financial yields for PV power plants. The train of thought is as follows: The number of photovoltaic installations worldwide has increased exponentially over the last 20 years evolving from one of small scale applications to a mainstream electricity source with a trend towards increasingly utility-scale PV systems that may involve hundreds of millions of USD investments. At the same time, an increasing number of PV power plants underperform as a result of various factors. To enable the push the energy transition to the next level, joint efforts need to enable the entire PV sector to push the electricity share generated by PV power plants towards 20% and beyond. At least evenly important, it is of the essence to enhance the profitability for all stakeholders in the PV sector.

**METHODS:**
The methods applied consist of field data analysis from PV power plants, results from reviewing and assessing the root cause of more than 3,600 insurance claim cases, and an analysis where the observed deficiencies might stem from. Furthermore, the resulting recommendations to enable a quantitative approach to rate PV power plants related to their to be expected performance will be discussed.

**RESULTS:**
Results from actual PV-park performance: The result from the findings is alarming as approx. 30% of all selected PV power plants (representing approx. 10% of all power plants inspected by the alliance partners) show severe defects requiring immediate corrective action. From this analysis, more than 40% of failures are originated by modules. The cause for module related defects range from PID – the #1 performance killer – to delamination, cell breakage, snail trails, non-complying components etc. The alarming deterioration of module performance suggests taking a closer look at module production and further upstream into cell manufacturing. At the same time, other defect sources have as well been identified. Similar findings from PV power plant safety compliance and performance assessments have been reported by other stakeholders over the last years. Current status in risk mitigation: To mitigate risks, as part of an overall project due diligence, the financial sector currently reviews technical assessment reports. However, depending on the assessor, these technical assessment reports vary significantly in terms of thoroughness, accurateness, completeness, reliability, validity, transparency etc. so that the actual investment decision turns out to contain a large number of imponderabilities.
CONCLUSION:
To counter the resulting inefficiencies, internationally accepted standards are essential to drive the further deployment of PV forward. The IECRE global certification system will be discussed in more detail. To complement the certification system allowing a more differentiated view on to be expected PV power plant performance, the status of the IECRE rating system approach will be discussed.

ES4: IMPACTS OF LOWER O&M COSTS ON SYSTEM PERFORMANCE AND LONGEVITY

Presenter: John Doty, Senior Solar Engineer, UL - Renewables

As the installed costs for large scale PV systems have dropped below US$1/watt, O&M costs are becoming a significant portion of the LCOE for a PV plant. The cost of preventative maintenance services for PV plants, on a kw/year basis, has dropped due to increased competition between service providers, improved use of system performance metrics and a desire to lower LCOE for the PV system. UL has compiled performance data on over 1000 PV systems ranging in size from 10 kWAC to over 250 MWAC including individual systems, systems in large portfolios and various distressed assets. With the data collected, UL is evaluating how lower CAPEX and OPEX spending impacts system reliability and performance for systems ranging in age from less than one year to well over 10 years. The lower contracted PM costs can result in an increase in deferred maintenance, longer response times and systems that are under performing relative to initial energy estimates. To make up for the lower PM costs, the maintenance costs are shifted to different categories in the financial models and appear as higher corrective maintenance budgets and higher costs for incidentals such as balance of plant repairs and inverter reserves. UL will present data on system performance metrics compared to initial energy production estimates (back casts) and will highlight areas where improved monitoring, maintenance or design practices can increase energy production. In the coming years, UL expects that more and more projects will start to use data analytics and just in-time preventative maintenance to reduce O&M costs. In addition, system designers will deploy bifacial PV modules, smart inverters and module level power electronics to both enhance system energy production and to provide additional reductions in O&M costs. UL will outline how these new technologies will impact the O&M landscape and provide recommendations on how to make best use of the data that these and other new technologies to streamline the O&M process. UL will present key findings from the analysis, including the impacts of obsolete equipment, ground faults, broken modules, soiling and vegetation management on system availability and provide recommended best practices to minimize the impacts of these and other issues on system performance. UL will also provide recommendations on necessary CAPEX and OPEX to return the system through repowering, alternate sourcing of spare parts and/or inverter upgrades.

ES5: TURNKEY ELECTRICAL SYSTEMS FOR UTILITY SCALE SOLAR POWER PLANTS

Presenter: Andrea Jones, Founder, Sol Source

With the explosive growth of the solar industry and the lack of skilled laborers it is becoming imperative to implement simplified and efficient construction methods. This research focuses specifically on streamlining the design, procurement and installation of electrical systems for utility scale solar power plants. It has been observed that there is currently no standardization of electrical equipment and it is becoming increasingly difficult for electrical engineers to keep up with code changes and new product offerings. Electrical contractors are often required to “figure out” what materials they need from electrical drawings and loosely defined scopes which leads to missed material and project delays. There are often no procedures for managing the material onsite of which some can be over 500 acres. The answer to these issues is as simple as to look over to the other trade onsite – mechanical. When developers or EPCs receive a proposal on a mechanical system they get just that – a system. They aren’t given mechanical drawings and have the responsibility of figuring out where to buy the posts, motors, actuators, etc and their mechanical contractors aren’t responsible for providing the nuts and bolts. The mechanical scope often includes engineering, procurement of components, scheduling and receiving shipments, onsite training and commissioning. Providing a turnkey electrical system that mirrors the scope of the mechanical system would greatly improve efficiency on construction of solar power plants. There would be better accountability and coordination – one point of contact for all electrical material. Engineers would specify material that is readily available and consolidate as much as possible to reduce waste on site. No longer would electrical contractors have to interpret what is needed to build the system – all components needed would be provided by the electrical system provider along with simplified instruction manuals to alleviate the need for highly skilled electricians onsite. This methodology should become the standard for the utility scale solar industry.
ENERGY STORAGE: ORAL PRESENTATIONS

ES6: FUTURE DESIGNS IN HIGH EFFICIENCY PHOTOVOLATICS: PATHWAYS AND MARKETS

Presenter: Kelsey Horowitz, Techno-Economic Analyst, National Renewable Energy Laboratory

OBJECTIVE:
While the world’s most efficiency photovoltaic (PV) cells, which utilize III-V materials, have achieved efficiencies above 30% and even 40% at concentration, these cells have been used primarily in space applications due to their expense. Prior attempts to move III-V solar into terrestrial markets have largely involved the use of concentrator PV (CPV) technology, which requires the use of external trackers, is only able to collect direct irradiance, and has not taken off in the marketplace. Additionally, traditional CPV cannot be installed on rooftops where the potential for efficiency to drive system savings is the greatest. However, there are several emerging fixed-tilt CPV concepts which can absorb some diffuse light, addressing these prior challenges and providing a potential pathway for rooftop modules with 25-40% efficiency. By examining four different fixed-tilt CPV designs, we explore the potential for these modules to drive reductions in installed system cost and influence the size of the residential PV market in the United States. While this analysis focuses on CPV, our analysis of the balance-of-system cost and the markets for high-efficiency rooftop PV is be broadly applicable to a suite of high-efficiency PV technologies.

METHODS:
We evaluate the value proposition of these high-efficiency, fixed-tilt CPV modules in residential rooftop applications by modeling: 1) the potential for increased efficiency to drive balance-of-system cost savings, 2) energy production and the levelized cost of energy, and 3) the influence of module efficiency and system size on adoption in residential rooftop markets across the United States. In particular, we explore how the market for high efficiency PV modules could evolve in highly electrified futures where increased electric loads could result in a large number of area-constrained rooftops. PV adoption modeling will be achieved by utilizing the National Renewable Energy Laboratory (NREL) Distributed Generation Market Demand (dGen) model. Balance-of-system cost reductions are estimated using a detailed bottom-up PV system cost model created using data collected from installers and developers.

RESULTS:
This analysis indicates that several important factors could drive customer demand for higher-efficiency solar modules in residential markets. First, high-efficiency modules drive installed cost savings, particularly in residential markets. Second, in the future, increased electrification of building and transportation loads will result in a greater number of homes with insufficient roof area to host a standard efficiency PV system large enough to offset 100% of their consumption.

CONCLUSION:
We find that fixed-tilt CPV modules could drive reduced system costs and increased residential PV adoption in certain cases, with the market size dependent on how residential electric rate structures and solar policies evolve, the ability of the modules to achieve high energy yield in the field, and the cost of manufacturing modules at scale.

ES7: QUALITY ASSURANCE FOR PV BATTERY STORAGE PROJECTS

Presenter: Matthias Vetter, Head, Department Electrical Energy Storage, Fraunhofer Institute for Solar Energy Systems ISE

Energy storage is a key enabler for high shares of renewables in power supply systems – for mini-grids as well as for interconnected grids. Especially advanced battery storage technologies play a major role in this context allowing new business models for various stakeholders of behind-the-meter and before-the-meter applications on a distribution and transmission grid level. In the first part of this presentation an overview of these various opportunities will be described and selected international examples will be highlighted. Corresponding challenges will be addressed, especially these issues which come along with innovative technologies and new systems concepts. The second part of this presentation deals with risk mitigation as long-term experiences especially with advanced battery technologies are missing, which leads to a lack of confidence for the investment and insurance sector. Therefore quality assurance measures are key. Amongst others the single steps of quality assurance include proper analyses of load profiles, simulation based system design, component selection according to the specific requirements of the single project, characterization of the components, yield prediction in case of a combination with a PV generator, system testing including commissioning tests as well as quality monitoring to identify at an early stage technical problems on the component and/or system level as well as their optimization.
potential. This presentation will describe the developed concept for quality assurance and will show results of residential PV battery systems, field examples of mini-grid implementations as well as commercial PV battery applications highlighting lessons-learnt from various projects.

**ES8: TMEIC’S LOW-VOLTAGE AC COUPLED STORAGE**

**Presenter:** Andrew Zorn, Sales Application Engineer, TMEIC

**OBJECTIVE:**
Co-locate PV and energy storage inverters on a single platform through low voltage AC coupling to provide optimized capital cost while maintaining the benefits of traditional DC and AC coupled solutions.

**METHODS:**
Multiple PV and storage inverters will be installed on the same platform. By electrically connecting multiple inverters to the same low voltage winding of the MV transformer, the benefits of DC and AC coupled storage are realized. Like DC to DC conversion, this solution allows charging from the array. It also allows for charging from the grid like a traditionally AC coupled system. Skid-level management of these storage options can provide even more flexibility.

**RESULTS:**
Preliminary efficiency estimates confirm this method will allow for the features of DC and AC coupled storage systems. Furthermore, the ability to co-locate storage and PV inverters means more options for installation.

**CONCLUSION:**
The new low voltage AC coupled storage system will provide users a cost-effective and flexible system, without sacrificing efficiency.

**ES9: ADVANCED PERSPECTIVES ON TECHNICAL DILIGENCE OF SOLAR + STORAGE PROJECTS 2019**

**Presenter:** Fleming Ray, Senior Project Manager, DNV GL Energy

2018 saw continued build-out of hybrid solar + storage projects at all size scales (residential, C&I, utility), and 2019 is expected to see additional growth with the filing of FERC 841 compliance plans and continued storage density improvements and cost declines. SEIA cites NREL analysis which notes the increasing Benefit/Cost ratio for solar + storage deployments as the generation of solar electricity on the grid grows from 15% - 24% in 2020. NREL’s work notes the sensitivity of the Benefit/Cost ratio to the system architecture, with DC-DC coupling representing the highest Benefit/Cost ratio at high (24%) solar penetration rates. While FERC 841 is seen as a watershed development for the storage industry, the Energy Storage Association (ESA) has noted barriers to scale-up exist in some of the ISO and RTO filings. DNV GL’s perspective includes insight into the influence of state of charge (SOC), SOC swing, C-rate, and temperature on battery performance across different materials platforms. In a supply-constrained environment for common chemistries, such as NMC, matching equipment selection to use case (for example, TOU markets, demand charge management, frequency regulation) is critical for optimizing financial return. DNV GL will provide leading edge technical due diligence observations for hybrid solar + storage projects, focusing on key items pertinent for revenue forecasting and O&M cost modeling and management. Case examples will be drawn from DNV GL’s project diligence experience. Insights will be provided from solar + storage energy modeling as well as battery replacement modeling which incorporates highly accelerated life cycle testing results. Major design strategies regarding BESS sizing and control system considerations for utility-scale projects and distributed portfolios will be highlighted. Cost management strategies enabled by energy storage system monitoring will also be discussed.

**ES10: BESS: SELECTING THE RIGHT SIZE AND TYPE OF ENERGY STORAGE TO SUPPORT YOUR PV SYSTEM**

**Presenter:** Scott Barrington, Business Development Manager, Trimark Associates

When integrating a battery energy storage system (BESS) with distributed PV generation, it’s essential to compare the characteristics of various battery types, as well as size options. This presentation will address the shortcomings of the commercially available battery sizing tools. It will also outline the methodology behind a cost analysis that incorporates investment costs, maintenance costs, and the benefits of installing a BESS. In addition, it will cover energy storage applications, technologies, and requirements, such as peak shaving, ramp rate limiting, and grid reliability. The goal is for the BESS to fulfill the anticipated needs at the lowest cost, while maximizing the lifetime of the battery.
ES11: IMPROVED ESS SAFETY THROUGH EARLY DETECTION OF THERMAL RUNAWAY

Presenter: Steve Cummings, Director, Sensors Business Unity, Li-ion Tamer

Projections for new installations of energy storage systems continue to grow. This growth can be seen in energy storage targets established by an increasing number of states. However, concerns over the safety of these systems are evidenced by ongoing work on NFPA 855, the release of the UL9540A test method, and number of battery fires in South Korea and the US. Monitoring and controls play a vital role in the safety of these systems. During this presentation, Li-ion Tamer will report on gas analyses conducting during recent large-scale fire testing using methods specified in UL9540A. New gas monitoring capabilities are being developed to improve detection of faults in the ESS. These methods have also been demonstrated to improve operational safety by preventing fires when the signal is used to electrically isolate the battery prior to thermal runaway. Li-ion Tamer has developed a monitoring system that provides advanced diagnostics to enhance situational awareness of the state of lithium ion battery systems. The off-gas monitor detects electrolyte vented from battery cells with sufficient early warning to stop thermal runaway. Machine learning algorithms have been incorporated in the controls to distinguish environmental anomalies from potential catastrophic events. Early warning provided by the off-gas monitoring system has been demonstrated to detect faults prior to smoke detectors and flammable gas detectors that are commonly used in lithium ion battery installations. Further, third party testing has confirmed the off-gas monitor signal tracks with FTIR gas measurements. Gas analysis is required for propagation testing during certification of many of today’s large-scale lithium ion battery systems such as those required by UL 9540A. While FTIR measurements are not required during field operation of a battery system, installing a network of off-gas monitors into a battery system enables advanced diagnostics to detect off-gas from a single cell within the system. This provides the earliest possible warning of battery failure when compared to other detection systems currently used. Fault detection information supplied by a battery management system can be used in combination with gas detection to diagnose battery health issues prior to an event. Multiple mitigating actions including system shut-down, fire suppression and alarms are possible. Because the gas detection system does not require physical integration with the cells, it offers the potential for redundant safety monitoring, even during transport or storage conditions. Nexceris has monitored the off-gassing characteristics to a range of operational and abuse conditions, including over-temperature, over-charging, and slow leak/pinhole tests in pouch, prismatic, and cylindrical cells. This presentation will provide an overview of the enhanced safety that is enabled through off-gas detection in lithium ion battery systems and how it can add additional layers of safety to protect systems from thermal runaway.
ENERGY STORAGE: POSTER PRESENTATIONS

POSTER PRESENTATIONS:

T1: AN EVALUATION OF VARIOUS PHOTOVOLTAIC BACKSHEETS USING SEQUENTIAL EXPOSURE TESTING ON COUPONS AND MODULES

Presenter: Christopher Thellen, Product Development Engineer, Tomark-Worthen

As the PV industry moves forward with novel and innovative technologies designed to increase the performance and efficiency of photovoltaic (PV) modules, so does the need to evaluate these technologies in a reasonable time frame. Sequential testing of PV systems and components has been identified as a method in which it is possible to subject materials to multiple stresses which have been shown to cause degradation similar to what has been observed in the field. One component of the PV module that can be highly affected by these stresses is the backsheet, which is typically a multilayer polymeric sheet used as both insulation to the module and protection against environmental exposures such as ultraviolet (UV) light and moisture. The method for the sequential test carried out in this work followed DuPont’s Module Accelerated Sequential Test (MAST 1) which is fit for both coupon and mini-module type samples. This test combines damp heat exposure with several UV exposure steps followed by thermal cycling in order to subject the samples to the stresses that these types of exposures apply to real modules in the field. Properties that were measured during this test includes yellowing, backsheet mechanical strength, backsheet/encapsulant adhesion and power generation of mini-modules subjected to these exposures. Backsheet types that were examined in this test include thermoplastics co-extruded backsheets, TPE, FPE and PPE as well as clear backsheet for bi-facial modules.

T2: DON’T FORGET TO PLAN FOR LANDSCAPING AND VISUALIZATION ANALYSIS NEEDS WITH YOUR SOLAR PROJECT!

Presenter: Michael Ross, Landscape Architect Environmental and Renewable Energy, TRC Companies, Inc.

This informative and relevant nature of this abstract is to expose re-occurring issues often encountered during the design and permitting phase and present measured steps in project approach by incorporating landscape architectural services early on to prevent these issues from occurring in the first place. This abstract will provide clear and immediate application to the learner’s work as well as an understanding approach or praxis will provide confidence in having up front honest conversation with clients about scope and pricing costs. The attendess that will benefit most from this information are fellow engineering and landscape architecture design professionals, project managers, and clients.

T3: EMBEDDED SYSTEM DESIGN WITH IMPLEMENTATION OF A CRYPTOGRAPHIC ALGORITHM FOR PAY AS YOU GO

Presenter: Audrey Jean-Martial Kakpohoue, Technical Manager, Nadji.Bi Senegal

According to the International Energy Agency, about 30% of african population have access to electricity in 2014. Without electricity, people use solutions like kerosene and candles which are risky and costly. Solar kit is secure, environmentally friendly and the best solution for off-grid population. However, the kits cost is a barrier to the population because of their low income. It is therefore necessary, to set up the payment mechanism Pay As You Go (PAYGO), which takes into account the financial resources of the population in order to facilitate the kits acquisition. PAYGO allows the customer to repay progressively and remotely, the total kit price through a series of payments (weekly or monthly) according to his resources. A PAYGO platform uses an electronic system to guarantee the payments. This system locks the kit when the payment is not made and unlocks it when the payment is done by the customer. In our work, we designed this embedded system that will compel the customer to the payments in order to repay the kit cost. The system contains a software part where the operation has been programmed and a hardware part where the components we have chosen react to perform the functions. To ensure the secure transmission of information from the producer to the kit through the customer, we used cryptography and we implemented a symmetric algorithm in the embedded system. We have designed a solution very cheap which performs very well the assigned functions.

T4: INCORPORATING LARGE CUSTOMER RENEWABLE ENERGY DEMAND INTO INTEGRATED RESOURCE PLANNING (IRP)

Presenter: Lori Bird, Director, US Energy Program and Polsky Chair for Renewable Energy, World Resources Institute

Utilities and customers can both benefit from collaboration and joint planning to meet clean energy goals. As renewable energy and carbon goals proliferate at the state, utility, corporate and city level,
partiers are increasingly interested in how to align these efforts to ensure clean energy development is efficient and impactful. To achieve their clean energy goals, many large customers have begun to more actively engage in utility planning processes. This poster explores case studies of customer engagement in IRP processes, approaches to increased collaboration, and potential areas of alignment in customer and utility planning.

**T5: MORE THAN A TICKETING SYSTEM: O&M DATABASES AS AN ANALYTICAL TOOL**

**Presenter:** Thushara Gunda, Senior Member, Technical Staff, Sandia National Laboratories

There has been tremendous growth in solar installations over the last couple of decades. In addition to capacity, we are also seeing an increase in age of our systems over time, which has generated new and unknown set of challenges regarding how we maintain productivity and performance in aging photovoltaic (PV) systems. PV plants, in effect, are complex systems due to interactions between physical and social components; there are many parts and interconnections in PV plants whose performance is influenced by climate conditions as well as corrective and preventative maintenance practices. With numerous non-linear pathways affecting the dynamics of the system state at any given time, understanding the issues and possible solutions required to optimize PV plant operations becomes a significant challenge. Fortunately, most PV plants have ongoing data collection pipelines that can help inform current practices. This talk will focus specifically on the O&M ticketing systems and how they are a wealth of information for not only informing which system issues to repair but also understand systemic issues facing the industry. Specifically, a topology for O&M ticketing systems will be presented that will highlight the different types of analyses that can be conducted based on what is captured in the O&M ticketing systems (e.g., developing distributions for time-to-failure and time-to-repair statistics for different components). All information presented in the talk will be informed by data and insights gained from industry partners that have partnered with Sandia National Laboratories on this effort. Feedback from diverse aspects of the industry (including power plant owners, O&M service providers, and data scientists) is welcome to help ground-truth the findings presented and help steer research directions as well as dissemination strategies of future efforts.

**T6: DISTRIBUTED GENERATION AND ENERGY STORAGE FOR RESILIENCY**

**Presenter:** Roberto Baldizon, Founder & Chief Executive Officer, Luszol

The energy industry is known as one where widespread technological adoption moves rather slowly due to the high capital costs of switching current equipment, behavior, and culture. Nevertheless, forecasts for distributed generation plus storage solution remain bullish as these are already providing users with energy resiliency, independence, reliability, and security, all of which are becoming continuously more valuable as the effects of climate change aggravate. Distributed generation from renewable energy sources, such as solar plus storage is proving to be a viable solution for areas of the world prone to natural disasters, where the local electrical grid infrastructure lacks the sturdiness and adaptability to withstand such events.
ES1/ST1: TECHNICAL SYMPOSIUM KEYNOTE: OVER THE HORIZON: SOLAR TECHNOLOGIES AND USES TO COME

Presenter: Garrett Nilsen, Manufacturing Competitiveness Program Manager, US Department of Energy

Solar technologies are evolving quickly, from cells and modules to system-level innovations and storage. In the next decade, the U.S. Department of Energy Solar Energy Technologies Office expects to see this rapid technology development continue, reaching the energy market and beyond (such as solar desalination). The office funds early-stage technology research with an eye towards what technologies will help to keep the U.S. solar industry on the leading edge. Join us to learn more.

ST2: UTILITY-SCALE SOLAR – EMPIRICAL ANALYSES OF PROJECT COST, PERFORMANCE, AND PRICING TRENDS IN THE U.S.

Presenter: Joachim Seel, Senior Scientific Engineering Associate, Lawrence Berkeley National Laboratory

The objective of our annual investigation of industry developments in the utility-scale solar sector is to provide consistent high-quality data and analysis to keep the audience abreast of market trends at times of enormous industry growth. Our research complements other projects well, such as SEPA’s and SEIA’s annual Solar Market Snapshot and is widely recognized in the industry. We do original primary data collection from the Energy Information Administration, the Federal Energy Regulatory Commission, incentive programs and regulatory proceedings on the state and federal level, interviews with developers, EPCs, and project owners, ISO electricity market data and 35 interconnection queues around the county. As a result, we have the most comprehensive database on utility-scale solar projects larger than 5MWac in the United States with 711 projects (26.3GWac) that achieved a commercial operations date at the end of 2018, including technical design specifications, capital costs, O&M costs, project performance, and PPAs. The size of the database allows for a representative sample, robust summary statistics and ensures confidentiality of individual project data to the extent that it is non-public. By the time of the presentation we will have updated our analysis with new 2018 and 2019 insights. Tracking c-Si installations have extended their lead in 2017 annual installations as most ubiquitous technology choice and about 80% of all new installations now feature single-axis tracking capabilities. The median utilized solar resource has continued to fall to 4.65 kWh/m²/day, following the market expansion to and increasing solar economic viability in less sunny regions - tracking installations continue to be built primarily in higher-insolation regions, with fixed-tilt installations retracting increasingly to regions with less than 4.5kWh/m²/day. Capital costs have declined to $1.6/Wdc or 2.0/Wac for the median 2017 projects, and for the first time the median tracking project did not command a premium over the median fixed-tilt project. Overall O&M costs decreased slightly in 2017 to $16/kW-yr or 8$/MWh. Average Net-Capacity Factors (AC) for new installations were about 26%. Recently negotiated PPA data include several projects below $40/MWh, with some PV+S PPAs going as low as $20/MWh, although growing solar penetrations continue to erode the value proposition in some markets such as CAISO (realized wholesale market energy revenue for solar declined to just 175$/MWh in H1 2018). Many announcements describe a variety of PV plus storage pairings leveraging different business model, with some projects already operating.

ST3: ORANGE BUTTON DATA EXCHANGE STANDARD: IMPLICATIONS ON SOLAR SOFT COST REDUCTIONS

Presenter: Tom Tansy, Chairman, SunSpec Alliance

OBJECTIVE:
The Orange Button data exchange standard, developed and maintained by the SunSpec Alliance, is designed to reduce solar soft costs associated with finance, system design, and operational set up. Orange Button enables the smooth flow of information between project developers, contractors, vendors, financiers and other stakeholders. It facilitates the interchange of datasets created throughout the project lifecycle and speeds data transfer by eliminating redundant data entry and the errors that accompany the process. Orange Button is available royalty free and includes a data taxonomy, information models, Application Program Interfaces (API’s), a compliance test suite and reference software. It leverages the fact that enterprises that guard information zealously are willing to share to achieve efficiency and financial gain.

METHODS:
SunSpec convened working groups with participation from 330+ companies to validate the Orange Button functional requirements and define use cases to focus on reducing solar finance soft costs. Approximately 4,000 industry-expert hours were invested
to dissect 25 priority use cases and develop 4,500 Orange Button taxonomy entries. The taxonomy is implemented using XBRL, an extensible platform that standardizes and automates sharing business-related data. Since release of Orange Button v1.0 in April 2018, development efforts have focused building open-source software to facilitate use of the taxonomy and extending the taxonomy to operations and maintenance use cases.

RESULTS:
This project produced a number of significant accomplishments:
1. Produced the Orange Button taxonomy consisting of 4,500 solar terms, 15,000 financial terms, APIs, and open source test tools, and accompanying APIs.
2. Established and Orange Button developer community that is actively producing open source code and improving the taxonomy.
3. Secured many early adopters including: Aurora Solar, BayWa r.e., Clean Power Research, DNV-GL, LG, Mercatus, Oracle, Salesforce, sPower, SunPower, Wells Fargo, and many others.

CONCLUSION:
1. Reduced cost of capital: By increasing efficiency and data portability through the solar project lifecycle, potential finance savings are $0.10 to $0.15 per watt.
2. Lowered installation and commissioning costs: A standard interface reduces install time by three- to six hours saving up to $0.03 to $0.06 per watt.
3. Reduced maintenance costs: For fleet operators with 1,000 or more systems, savings from monitoring standardization equates to $0.02 per watt.
4. Reduced development and integration costs: Uniform standards for test and validation improves product development economics and reduces customization.

ST4: BIG DATA PROVES THE CASE FOR SOLAR + STORAGE OVER SUBSTATION INVESTMENT

Presenter: Cassandra Quaintance, Head, Operations, Kevala, Inc.

OBJECTIVE:
Solar + storage is a viable alternative for consideration in a regulatory non-wires alternative (NWA) analysis to replace traditional utility investment. This is accomplished using an integrated data platform that aggregates load, generation, and infrastructure data alongside solar + storage analytics to produce avoided load shapes and a determination if the distributed energy resource (DER) behavior adequately serves the distribution need.

METHODS:
The following methods will be discussed as part of this analysis:
1) ingestion of time-series datasets on load and distributed generation;
2) probable solar + storage adoption based on customer bill reduction;
3) a comparison of the modified net load to determine whether the non-wired alternative is feasible.

RESULTS:
The results show a rank order of parcels likely to benefit from adding storage to their existing solar systems, the estimated hourly MW reduction achievable per feeder, and analysis of whether solar + storage projects will sufficiently meet system needs to fully defer the wires upgrade. This analysis is beneficial to both regulators and utilities in determining whether DERs can replace some types of traditional wires infrastructure. Our study indicates that solar + storage certainly can for some proposed wires projects, where the identified need is for additional distribution capacity to meet projected load growth.

CONCLUSION:
While residential solar + storage adoption continues to grow at a rapid rate, utility load growth forecasts and distribution planning efforts have not kept pace, so that DER solutions are often not appropriately valued to replace traditional wires upgrades. The analysis shows one way to evaluate how storage can potentially mitigate local demand on specific utility infrastructure, and whether the identified distribution capacity need is reduced sufficiently so that the proposed substation upgrade is no longer necessary. This analysis can provide a pathway for utilities or regulators to determine how to target procurement for NWA resources, based on their location. This analysis also provides a potential means for 3rd party providers to apply for aggregated DER programs and target specific customers to meet that MW reduction required.

ST5: FINANCIAL ANALYSIS OF A UTILITY-OWNED ROOFTOP SOLAR PROGRAM

Presenter: Galen Barbose, Research Scientist, Lawrence Berkeley National Laboratory

OBJECTIVE:
Utilities in different regions of the country have launched pilot programs involving utility ownership of rooftop solar PV. By rate-basing these assets, utilities are hoping to find new profit opportunities, while also providing value to all customers. But what potential does this model hold for broader and full-scale adoption? To answer that question requires a more-complete understanding...
of the impacts on utility shareholders and ratepayers, and the drivers thereof. This presentation seeks to explore those dynamics through a financial analysis of a hypothetical utility-owned rooftop solar program.

METHODS:
This analysis relies on a pro-forma utility financial model to estimate changes in two key metrics—shareholder earnings and non-participant bills—resulting from the implementation of a utility-owned rooftop solar program. The model accounts for the effects of rooftop solar on utility revenue requirements, including deferred capital expenditures, and simulates general rate cases that occur periodically over the analysis timeframe. We measure the effects of a utility-owned rooftop solar program relative to two different baselines: one with no residential solar and one in which residential solar is instead owned by the site-host or a third-party financier. We also explore these effects under a wide range of assumptions in order to test the sensitivity of the results to varying regulatory and market conditions and variations in program design.

RESULTS:
Under our base assumptions—in which residential solar penetration ramps up to 8% of total residential electricity demand—the utility-owned rooftop solar program increases shareholder earnings by roughly 2% relative to no-PV (on a 20-year net-present-value basis); this compares to a 4% drop in earnings from host-owned or third-party owned (TPO) solar. Non-participant bills are roughly 2% higher under both PV scenarios, compared to no-PV. These results, however, are highly sensitive to a number of parameters, including the installed cost of rooftop solar, underlying retail rate design, and whether solar is installed on a stand-alone basis or in conjunction with customer-sited battery storage. Of particular note is that shareholder earnings fall, relative to no-PV, when battery storage is paired with the rooftop solar, as a result of the much greater deferral of traditional utility capital investments.

CONCLUSION:
Whether shareholders and ratepayers are better off with utility-owned rooftop PV, and by how much, depends in part on whether it is additional to or substitutes for host-owned/TPO PV. In general, it is almost always a “win” for shareholders in terms of increased earnings. Utility-owned rooftop solar tends to increase non-participant bills relative to no PV, but is something of a “wash” compared to host-owned/TPO PV, at least under our core case. That said, the analysis does reveal some limited potential for utility-owned PV to mitigate the ratepayer impacts of rooftop solar, under specific conditions.

ST6: DATA-DRIVEN APPROACH TO DYNAMIC-VAR COMPENSATOR PLACEMENT FOR VOLTAGE STABILIZATION ON FEEDERS WITH HIGH PV PENETRATION

Presenter: Nader Samaan, Senior Power Systems Research Engineer, Pacific Northwest National Laboratory

OBJECTIVE:
Distribution feeders with a high penetration of distributed PV systems can experience voltage variability caused by the changing load flow injections corresponding to the availability of the solar resource. The rapid, uncontrolled voltage fluctuations can affect the system. Tap-changing voltage regulators, switched capacitors, and smart inverter functions have been used to stabilize voltage. However, in some cases, when these options are insufficient or unavailable, dedicated reactive power control devices such as Dynamic Var Compensators (DVCs) can be used for local voltage stabilization. This presentation introduces a statistical framework to characterize voltage variability and stabilization, proposes a data-driven approach to DVC placement, and presents the results of a planning study on a real feeder using real data.

METHODS:
We define voltage stabilization as a reduction in voltage variability: both dynamic range and fluctuations are considered. To quantify variability and stabilization, the voltage variability index (VVI) is developed based on the variability index for irradiance and PV output variability. We introduced an approach to determine how DVCs can contribute to voltage stabilization by addressing both factors of variability. To fully leverage the capability of a DVC or multiple DVCs, location planning should include consideration of the full range of locations and operating conditions using Quasi-Static Time-Series (QSTS) simulations. The following procedural algorithm is proposed: 1) Collect feeder data 2) Simulate to determine present variability 3) Rank variability at possible DVC locations 4) Simulate DVC(s) to determine stabilization affect 5) Monitor the location(s) and calibrate the DVC(s).

RESULTS:
We present case-studies in which three feeders on a Duke Energy Carolinas substation, that has 10 MW of distributed PV installed, are considered for DVC deployment. For each feeder, a QSTS simulation was performed and the VVI was computed at the downstream terminal of each three-phase line in the feeder. Results show that a Voltage Change Reduction (VCR) of 18% to 28% can be achieved. We will also show actual field
validation results and quantify the overall improvements due to the installation of 180 KVar and 120 KVar DVCs at two different locations on feeders connected to the same Substation.

CONCLUSION:
Simulations using historical load and PV data can be used to determine the location with maximum uncontrolled voltage variability. This location is sensitive to fluctuations in load and PV generation and is therefore likely to be biased towards the locations of large PV systems, large loads, and remote locations. Simulation tools today do not include models of feedback-controlled DVCs. A droop-controlled reactive power device was used as an alternative. Simulation results show that DVCs can reduce variability and improve grid voltage stabilization. Statistical analyses were required to evaluate voltage improvements. Tuning and coordination will be important for effective DVC performance in the field.

ST7: SIMPLIFYING COMMERCIAL & INDUSTRIAL MICROGRID DESIGN WITH A CONTROLS-ENABLED SWITCHGEAR

Presenter: Tony Sovorns, Chief Technical Officer, Go Electric

Most microgrids deployed today are entirely custom designed, requiring contractors to start from square one for each system component. This degree of customization drives up the cost and time required for design and installation and represents a prohibitive obstacle for greater adoption by commercial and industrial customers looking for resilient, reliable microgrid solutions. Soft costs associated with engineering, construction and commissioning of microgrid systems make up as much as 43 percent of the total cost per megawatt for commercial and industrial customers, according to an October 2018 report by the National Renewable Energy Lab and Navigant Research. In February 2019, leading microgrid innovator Go Electric unveiled a controls-enabled switchgear, developed in response to the commercial and industrial sector’s need for greater adoption by commercial and industrial customers and offer opportunities for greater microgrid adoption in these sectors.

ST8: INCREASING ISLAND MICROGRID RESILIENCE AND RENEWABLE INTEGRATION WITH ENERGY STORAGE SOFTWARE SYSTEMS

Presenter: Chris Kuhl, Director, Sales Midwest, Greensmith Energy, a Wartsila company

Islands have become ground zero for maximizing renewable energy resources, as they are increasingly establishing 100% renewable energy goals and provide a great case study for doing so. Powering these communities with carbon-free energy helps to address unique island challenges, but incorporating renewables also comes with its own hurdles. Islands have weak, radial microgrids and experience high power costs because they have to import all traditional fuel sources used by their system. Many islands are located in regions that favor wind and solar, and now many of them are working to harness these resources to reduce costs and improve reliability. Though these renewable energy sources are abundant, they are also intermittent and which makes the process of harnessing them as complex. It requires a sophisticated energy management system, because solar-storage and wind infrastructure alone are not enough. Greensmith Energy’s GEMS is being deployed to help islands at the forefront of this shift, continually increase their renewable energy capacity factor while mitigating grid impacts and resolving instability. GEMS uses data from weather, load and market forecasts to manage and deploy multiple generation assets in fractions of a second, creating an optimized and flexible system that ensures grid reliability. The GEMS technology neutral-approach, machine-learning and AI capabilities have been proven in real-world applications to maximize island microgrid performance and flexibility. Join Andy Tang of Wärtsilä as he examines the role of advanced energy storage technologies and the importance of software for renewables integration. Greensmith
ST10: ENABLING DISPATCHABLE RENEWABLE PV+S PLANTS USING MESA-ESS

Presenter: Gautham Ramesh, Energy Storage Software Engineer, 8minute Solar Energy

OBJECTIVE:
Integration of intermittent renewable resources have presented challenges for grid stability especially as the penetration of solar and wind generation increases with falling costs and government mandates for zero carbon energy. Existing simple charge/discharge controls do not deliver maximum value to utilities building solar integrated with energy storage (PV+S) nor the deterministic output needed to reliably serve load. However, advanced controls built around common standards can enable intermittent PV+S to be dispatched much like a gas turbine/engine, but faster. This presentation will summarize two years of research and testing in creating a “dispatchable” PV+S plant using the MESA-ESS control mode specification. Specifically, we will discuss: 1. How MESA-ESS (Modular Energy Storage Association – Energy Storage System) controls (“control modes”) allow dispatchable and flexible operation of PV+S plants, 2. How a utility may achieve “value stacking” by performing multiple grid services and energy dispatch objectives simultaneously, and 3. How leveraging an accurate PV energy production forecast allows the utility to perform optimize battery utilization.

METHODS:
Our team has completed a three-step process for the last two years and we will be starting a two-year extended field trial starting in October of 2019. First, was to build a simulation environment that supports the MESA-ESS control modes as defined in DNP3 Application Note. Secondly, the controls simulation was transitioned to a time-accurate emulator, using 1-minute resolution solar production data test the controls in a more realistic environment. Thirdly, we have tested these controls in our own testbed in Sacramento, CA using a 30kW PV and 30kW/68kWh Li-Ion BESS. The extended field trial will utilize a 3MW solar inverter with a DC-coupled 1.5MW/1-hour BESS to implement the controls in a real power plant. Our presentation will focus on all of these steps and will clearly guide our audience through the MESA controls and our implementation methodology.
RESULTS:
Metrics for validating the performance of various control modes have been developed to evaluate the accuracy/performance of MESA-ESS control modes. The validation metric for most control modes is “Accuracy” which is calculated by dividing the number of seconds a control mode objective is not violated over the total number of seconds the control mode is enforced. Some control modes like the “Co-ordinated Charge-Discharge ” have specific metrics like “SOC miss ” which is the difference between target SOC and SOC achieved at the target time. When control modes and their objectives are stacked on top of each other in order of priority, these metrics can be used to evaluate the effectiveness of the individual control modes. For example, SOC management using Co-ordinated Charge-Discharge and Ramp-Rate control stacked with Active Power Smoothing + Frequency-Watt mode yields a 0.5 SOC miss %, 100% Ramp-rate control accuracy and 98% Frequency response accuracy.

ST11: SOLAR ENERGY MICROGRIDS FOR MILITARY INSTALLATIONS

Presenter: Cory McNamara, Lead Engineer, Hannah Solar Government Services

Hannah Solar Government Services was contracted to build a solar energy microgrid system on Wake Island which is a possession of the United States located about 2300 miles west of Hawaii in the Pacific Ocean. Wake Island is a 2.7 square mile island which is a military base and is home to the largest airfield in the Pacific islands. Wake also hosts missile launching and tracking facilities of the United States Missile Defense Agency. The solar energy microgrid system installed included a 740 kW solar array, a 571 kWh battery system and a microgrid controller system that manages the new solar array, the new battery system and existing diesel generators. This project was extremely cost effective for the US Government as diesel fuel to run the power generation on the island must be shipped from Hawaii to Wake twice a year over a distance of 2300 miles by ocean-going barge. Additionally, a return barge had to be scheduled after construction was complete to remove the shipping containers with all equipment, excess materials and trash from Wake Island. This presentation will provide an overview of the various types of microgrid systems relevant to the US military, why they are beneficial and discuss the complex logistics of implementing the Wake Island microgrid system.
POSTER PRESENTATIONS:

T7: FIGHT CLIMATE CHANGE AND DECLINE OF ROOFTOP SOLAR-PV IN HAWAII WITH ISLAND NANO-GRID AND ZGB-EQUIVALENCE

Presenter: John Borland, President, J.O.B. Technologies

Problem Statement: 1) The US at #2 has increased carbon emissions by +2.5% to 5.4B tons in 2018 and globally +2.9% to 37.1B tons. May 11, 2019 CO2 level reached an all-time high of 415.26ppm so we must all do our part to fight Climate Change (Global Warming) today by reducing carbon footprint one home/building at a time by switching to 100% Renewable Clean Energy (Solar Energy + Multi-Storage) in our Day-to-Day life! 2) The 1st Solar Wave in Hawaii driven by the Net Energy Metering (NEM) program was not sustainable, residential rooftop solar-PV market has declined by ~84% from 16,700 permits in 2013 to <2,900 permits in 2018. 3) Lessons learned from; 1) Puerto Rico hurricane Maria, 2) California blackouts, wildfires and mudslides and 3) Hawaii volcano lava flow disaster show utilities with centralized grid, especially with above ground distribution power lines are not resilient to natural disasters that can cut-off power, locally isolating homes and communities for weeks and months costing 2,975 lives as in the case for Puerto Rico. During the 2018 California wildfire, many people described not being able to see at night to escape their homes after losing power highlighting safety issues and importance of resilience with 85 lives lost while in Hawaii homes that were not engulfed by the lava flow still lost power due to power lines destroyed by lava, were looted so security issues and again the importance of resilience 24/7.

Solution: 2nd Solar Wave sustainability requires more customer education and interaction to control Home/Building energy ecosystem to achieve Island Nano-Grid and Zero Grid-Buy Equivalence for resilience, safety, security, savings and save lives. Many homeowners achieved Zero-NEM (actually negative NEM) thanks to their oversized rooftop solar-PV systems excess daytime solar-PV generation exported back to the grid at full retail rate (~30¢/kWh) resulting in the minimum monthly Hawaiian Electric (HECO) bill of $25/month requiring no interaction between homeowner and their PV generation system. With the NEM program, the grid acts as an infinite storage battery for each solar-PV customer but this was not sustainable causing utility grid instability due to large amount of excess daytime PV generation exporting back to the grid and Duck Curve problem. NEM program ended in 2016. To achieve the same cost savings as Zero-NEM with the minimal monthly HECO bill of $25/month requires Zero Grid-Buy (ZGB) or Equivalence. The key to achieving ZGB-Equivalence is having the right data analytics for daily energy usage monitoring and by being renewable energy conservation minded with interactive assets that can be controlled to make the necessary lifestyle behavioral changes. We integrated the use of IoT home automation devices and Smart (Home/Building) Energy Management System to maximize solar PV & thermal generation, optimize electrical battery charge/discharge and hot/cold thermal storage. Using future weather forecasting smart devices, for all of 2018 we achieved Island Nano-Grid and 100% Renewable Clean energy for 336 days or 92% of the time requiring Grid-Buy for 8% or the 29 rainy/cloudy days.

T8: TODAY’S CONNECTIVITY: USING DATA TO ANTICIPATE RISK

Presenter: Jessica Turner, Client Development, Terracon

What lies beneath the surface of any given solar array? Risk. Specifically, the risk associated with unknown subsurface conditions during project conception and initial design. Unanticipated subsurface conditions have the potential to cause delays and cost overruns on even the best-managed and well-executed projects. As geotechnical engineers, it is our job to explore and characterize the subsurface soil conditions at a potential solar development site. Thorough delineation takes tremendous effort, time and expense that may not be practical at the conceptual stage of development. Yet, solar developers must make “Go, No-Go” decisions based on an extremely limited understanding of the conditions that will likely have the largest impact on project success. In this digital era, mitigating risk associated with subsurface exploration and unanticipated subsurface conditions during construction is a top priority. Utilizing processes for compiling and managing data, and GIS methods to analyze and present site data along with historical subsurface information, we can ultimately lower risk for the entire project team. Consider for more than a century, geotechnical professionals have meticulously documented the location and conditions encountered in hundreds of thousands of subsurface borings. We are utilizing the power of GIS-processing in conjunction with this library of historical subsurface information to more efficiently set through exploration scope development, project feasibility studies, site selection, and preliminary budgeting.

Digitizing the historical subsurface information creates a catalyst for an interactive, web-based platform that combines the publicly...
available information and collected data, and culminates with the invaluable opinion of a local, experienced geotechnical engineer. This connectivity aids in the reduction of risks associated with unknown conditions on prospective project sites, and for our valuable team members. By using past information to better understand the present, there is a way to develop smarter work scopes and able to more efficiently anticipate subsurface conditions.
**SE1: TECHNICAL SYMPOSIUM KEYNOTE: DEGRADATION, SOILING LOSS AND TOXICITY OF SOLAR PV MODULES**

**Presenter:** Dr. Mani GovindaSamy TamizhMani – Founder and Director, Photovoltaic Reliability Laboratory at Arizona State University

This presentation will focus on three key operations, maintenance and recycling areas of PV modules: i) determination of median degradation rate of PV modules and strings in large plants using statistical approaches; ii) climate-specific soiling loss and anti-soiling coating effectiveness determination; and iii) toxicity determination according to EPA requirements for landfill disposal.

**SE2: SOLAR PV PERFORMANCE MODELING IN NORTHERN LATITUDES**

**Presenter:** Christopher Pike, Research Engineer, University of Alaska Fairbanks

**OBJECTIVE:**
Solar photovoltaic (PV) power is becoming a viable investment in Alaska and other northern latitudes due to decreasing costs, low maintenance needs, and unique performance characteristics. This project analyzes the accuracy of solar PV production modeling performed with Typical Meteorological Year (TMY) solar irradiance data in Alaska. Due to Alaska’s northern latitudes, most satellite-based irradiance data sets that are available to the rest of the continental United States cannot be reliably used to predict solar PV system outputs. Installers and developers continue to use TMY data to estimate system outputs for planning and decision making. This project systematically quantifies how well outputs are modeled relative to measured values for 25 solar PV installations across Alaska using PVWatts with input TMY irradiance data.

**METHODS:**
Measured solar PV system production for 25 solar PV systems was compared on a monthly basis to modeled production using PVWatts. Production was measured using reported energy production from system inverters. Modeled outputs from PVWatts were generated using both TMY2 and TMY3 irradiance data sets. Installations ranged in size from 2.6 kW – 18.0 kW. While these systems are small for the rest of the United States, systems larger than 100 kW were only installed for the first time in Alaska in 2018 and were not included in this study.

**RESULTS:**
PVWatts outputs sourced from TMY3 irradiance data corresponded most closely to measured energy outputs for the selected solar PV installations. Further comparisons indicated PVWatts outputs had significant monthly variations in model accuracy. Modeled outputs for the months of November through February were over 100% greater than measured outputs. Modeled outputs for the months of April through September were within 10% of measured values excluding the August TMY3 modeled output (13%).

**CONCLUSION:**
The effort to improve performance modeling for Alaska solar PV systems continues, and these results have been further validated by new larger installations that have been installed in 2018. Further analysis to compare NASA POWER satellite solar irradiance data to measured solar irradiance data and solar PV system production is ongoing. This effort will eventually lead to an improved solar irradiance data set that will reduce system production uncertainty with respect to solar PV system modeling and design.

**SE3: INCREASED PERFORMANCE OF PHOTOVOLATIC SYSTEMS INSTALLED AT NORTHERN LATITUDES**

**Presenter:** Laurie Burnham, Principal Member of the Technical Staff, Sandia National Laboratories

**OBJECTIVE:**
This 3-year project aims to increase the performance and resilience of PV systems deployed in regions of the US that regularly experience below-freezing precipitation in order to increase the efficiency of performance and thus expand solar capacity in those areas. Specifically, we aim to: 1. Quantify snow losses across multiple sites and technologies, 2. Identify snow- and ice-provoked reliability issues, 3. Identify topological and component features that enhance or inhibit snow shedding, and 4. Develop advanced snow-loss models.

**METHODS:**
Our multi-institutional team has begun to identify and quantify the multiple factors that contribute to improved system performance at northern latitudes, where snow accumulation on the ground and on solar panels can be significant. Our methods include: 1. Camera imaging of installed systems (also synched with power, irradiance and meteorological data) to measure snow-shedding rates under different variables (framed vs frameless; coated and uncoated glass and frames; orientation and tilt angle) and quantify associated energy yields, 2. Performance analysis of bifacial
modules at different tilt angles and on a dual-axis tracker based on high-resolution DC voltage and current measurements; also tracker-error monitors. 3. EL-imaging of multiple modules types to identify patterns of damage likely attributable to ice buildup, snow loading, tracker stress under extreme cold conditions and shunt formation induced by partial shading (monolithic CIGS modules), and 4. Laboratory characterization in a temperature-controlled room of module glass and coatings for their ice-phobic properties.

RESULTS:
Our results to-date show: 1. Certain module architectures significantly outperform others, most notably frameless modules, suggesting the frame is a significant impediment to snow shedding and therefore needs to be redesigned, 2. Bifacial modules, especially those mounted on a dual-axis tracker, deliver significantly more DC energy than adjacent mono-facial modules, with bifacial gain during the winter months as high as 91 percent and as high as 13 percent in non-snowy months. Our data also suggests that vertically mounted bifacial modules may provide a performance advantage over latitude-tilt modules, and 3. Characterization of coatings for icephobicity and optical transmissivity are helping define an optimal set of properties for ice-phobic PV coatings, with expectation that field validation next winter will show a significant reduction in snow losses for the top-performing coatings, which in turn will create new market opportunities for anti-ice PV coatings.

CONCLUSION:
Our pioneering multi-faceted investigation into system performance in wintry climates is generating data that will inform new system designs, lowering LCOE, increasing resource availability in the aftermath of extreme weather events, and resulting in greater system efficiency.

SE4: DURAMAT: DURABLE MATERIALS RESEARCH TO IMPROVE MODULE RELIABILITY

Presenter: Teresa Barnes, Manager, PV Reliability and System Performance, National Renewable Energy Laboratory

The Durable Module Materials (DuraMAT) Consortium brings together the national lab and university research infrastructure with the photovoltaic (PV) and supply-chain industries. Our goal is to discover, develop, and de-risk new materials, designs, and accelerated tests for PV modules. DuraMAT is working to establish a central data resource for PV system performance and materials data, a generalized multi-scale and multi-physics/stress model for modules, disruptive accelerated testing protocols, and materials forensics to understand degradation modes in fielded modules. We will provide an overview of the DuraMAT DataHUB, including information on the PV Fleets time series data hub. The DataHUB enables us to access different types of data on PV modules, materials, accelerated testing, and system performance in a single location, along with data analytics tools. The DuraMAT multi-physics model has the ability to model detailed physics, environmental stresses, and material property changes on full-scale modules. Our accelerated testing work focuses on combined accelerated stress testing (C-AST). C-AST enables accelerated testing at the extremes of natural climatic conditions to accelerate field failure modes. We have demonstrated the C-AST approach on mini-modules with different backsheets and will present results on two field relevant failures at the conference. C-AST is able to mimic failure modes seen in the field that are not detected in traditional accelerated testing protocols. Finally, the DuraMAT materials forensics effort is our application of traditional national laboratory characterization tools applied to PV modules. These have identified causes for delamination, backsheet degradation, anti-soiling coating functionality and other materials challenges. This kind of foundational knowledge provides guidance for improved module materials.

SE5: LAKE EFFECT: WHAT IS THE EVIDENCE

Presenter: Wallace Erickson, Statistician, West Inc.

Given the rapid expansion of PV solar energy development and its predicted continued expansion, it is important to summarize the impacts to birds so that the potential impacts of future development can be evaluated [5,8]. Given the sparse data in the peer-reviewed literature, generalizations of direct impacts of PV solar to birds are limited. However, one unexpected pattern has emerged at PV solar facilities in the southwestern U.S. where water-dependent birds such as loons, grebes, and diving ducks have been detected as injuries or fatalities. As these species are depend on water for landing and take-off and are non-ambulatory, the presence of these species at PV solar facilities has led to the development of the lake effect hypothesis, which posits that water-dependent birds misinterpret the PV panels as water. Given the sparse data, it is unknown if the pattern of water-dependent species at PV solar facilities is localized or widespread. A potential source of information to enhance the understanding of bird fatality patterns at PV solar facilities is the gray literature. Numerous fatality monitoring reports have been prepared as a result of permit conditions or voluntarily, and these reports contain important
information that should be synthesized. Based on the limited information on direct impacts to birds from PV solar facilities, our objective involved searching the gray literature to identify fatality studies that could be synthesized to provide inference into broad scale patterns. Specifically, we were interested in species composition and fatality estimate and how patterns varied spatially and temporally within and among facilities. Further, we compared the range of fatality estimates to those calculated by Walston and others and determine if the estimates generated by Walston and others for multiple technology fall within the range we determined or PV solar. The data to date suggests some bird carcasses at solar projects, and some water-dependent birds in a few cases, but in general the rates do not appear high.

**SE6: INVERTER FAULT & FAILURE ANALYSIS**

**Presenter:** Sean Hackett, Engineer/Scientist III, Electric Power Research Institute

In a Photovoltaic (PV) generation plant, the central inverters are a critical component affecting system performance. If a central inverter fails or stops operating, there will be a large, negative impact to the plant capacity and energy production.

Given the critical nature of the inverter in a PV plant, monitoring and maintenance efforts are focused on keeping inverters operating and limiting downtime of inverters. Understanding the most common fault and failure modes of inverters will help develop standards around preventative maintenance and condition based maintenance practices, especially focussed on inverter post warranty expiration maintenance tasks. Through inverter expert elicitation and data analysis if maintenance logs (currently 50+ sites in database), we will analyze fault and failure trends, discuss best practices for inverter maintenance and investigate standardization of fault and failure codes to improve plant performance baselines.

**SE7: CAPACITY PLANNING FOR RENEWABLE PROJECTS: ADDRESSING CAL. RULE 21 AND SIMILAR REGULATIONS**

**Presenter:** Daniel Desrosiers, General Manager, Eaton Corporation

The integration of renewable energy resources into the electric grid is one of the most significant challenges facing both solar project developers and utilities. With increasing solar projects, there are more interconnection requests and impact to the electric grid. This presentation will discuss a successful and efficient approach to meeting Cal. Rule 21 and other regulations in the works that require utilities to publicly share capacity for renewables. Through capacity analysis modeling, both utilities and renewable project developers are able to quickly and intuitively access critical data that facilitates solar project development. Attendees will learn how to rapidly identify the parameters critical in the design of specific installations or complete networks through network modeling, initial network performance diagnostics and a wide range of power engineering studies, ranging from transient phenomenon to strategic investment plans. Attendees will see a live capacity circuit map that provides guidance on suitable locations for distributed energy resource interconnection projects. The presentation will illustrate the importance of running capacity analysis simulations in order to reduce labor and human error, prior to budgeting and engaging in new projects – leaving attendees with the knowledge and resources required to simplify the integration of solar projects, capacity analysis and growth planning.

**SE8: IMPROVING RELIABILITY OF UTILITY-SCALE PV PLANTS – THE NERC INVERTER-BASED RESOURCE PERFORMANCE TASK FORCE**

**Presenter:** Kevin Collins, Senior Technologist/PV Systems Development, First Solar

The North American Bulk Power System (BPS) and electric transmission grids around the world are undergoing rapid changes in generation resource mix with increasing amounts of renewable generation such as wind and solar photovoltaic (PV) power plants. These resources are asynchronously connected to the grid and are either completely or partially interfaced with the BPS through power electronics, hence referred to as inverter-based resources. The power electronics aspects of these generating resources present new opportunities in terms of grid control and response to abnormal grid conditions. Regardless of the type of resource, it is paramount that all BPS-connected resources are capable of providing essential reliability services (ERSs) and operate in a manner that supports BPS reliability. Recently, the North American Electric Reliability Corporation (NERC) has been conducting analyses of BPS-connected solar PV generating plants and their response to transmission disturbances. To support these analyses, NERC formed the Inverter-Based Performance Task Force (IRPTF) in 2017, consisting of experts from multiple sectors of the electric industry. Among the first cases analyzed were the 2016 Blue Cut Fire and 2017 Canyon 2 Fire events in the Southern California. These transmission fault events caused...
the unintended tripping of significant amounts of solar photovoltaic (PV) generation capacity. The IRPTF analyses and subsequent reports on these events identified several causes and corrective measures which have been communicated to generators owners/ operators. NERC issued industry advisories in an effort to inform registered entities of the potential risk of tripping as well as recommend mitigating actions. Recognizing the need for additional industry guidance, the IRPTF drafted a Reliability Guideline for Inverter-Based Resource Performance in 2018, published by NERC, which provides comprehensive technical guidance for the recommended behavior of inverter-based resources connected to the BPS. The material presented throughout the guideline is based on extensive research, system modeling, and discussions with industry experts and members of the IRPTF. This guideline is now forming the basis of proposed revisions to NERC standards as well as the new IEEE Standard P2800, Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems. The IRPTF also plans to issue a NERC Reliability Guideline for Improvements to Interconnection Requirements for Inverter-Based Resources, that is intended to provide specific technical recommendations for interconnection requirements (grid codes, interconnection agreements, etc.) between the owners of inverter-based resources and transmission operators. This will cover a wide range of related aspects from dynamic performance, protective functions, to plant monitoring capability. The presentation proposed for the Technical Symposium will cover the multiple aspects of inverter-based resource performance recommended by the NERC IRPTF.

**SE9: EMERGING DISTRIBUTED ENERGY RESOURCE (DER) COMMUNICATION PROTOCOLS AND THEIR IMPACT ON GRID INTERCONNECTION AND SECURITY**

**Presenter:** Tom Tansy, Chairman, SunSpec Alliance

The introduction of data communications represents a sea change for the Distributed Energy Resource (DER) industry. New communication requirements in the IEEE 1547-2018 standard for DER, and the introduction of the IEEE 2030.5 and IEEE 1815 communication protocols that the IEEE 1547 standard references, will affect every part of system operation—including finance, permitting, interconnection, operations and maintenance. These protocols, inherent in smart inverters, gateways or other communication devices, also introduce a new responsibility for DER systems to support cybersecurity. Aim/Objective: This session will review applicable standards—what they are, what they do, and early lessons learned through a recently-completed California Rule 21 test and field trial project—to assist attendees in being prepared for the IEEE 1547-2018 rollout across the U.S. starting in 2020. Every major DER market in the U.S. (approximately half the states) will be affected. Methods: The session will update participants on the IEEE 1547-2018 national rollout, including the current status of CA Rule 21 and its implementation of the IEEE 2030.5 standard. It will explore the relationship between IEEE 1547-2018 and IEEE 1547.1, describe changes to the 2018 revision of the IEEE 2030.5 standard, and illustrate how this standard is implemented according to the SunSpec Common Smart inverter profile (CSIP). Results from the SunSpec project titled “Interoperability Standards and Open Testing Framework to Support High-Penetration Distributed Photovoltaics and Storage” will be used to illustrate key impacts of the IEEE 1547 and IEEE 2030.5 standards. Dr. Robby Simpson, System Architect at GE Grid Solutions, and Tom Tansy, Chairman of the SunSpec Alliance, will co-present in order to provide a high-quality experience for participants. Conclusion: Attendees will gain an understanding of how data communications are impacting DER equipment and interconnection requirements, the rollout of these protocols by state, utility and aggregator communication structures emerging in the market, and responsibilities and implications for cybersecurity and the emerging DER digital security landscape.

**SE10: VIBRATION-INDUCED BOLT SELF-LOOSENING PHENOMENON IN SOLAR APPLICATIONS**

**Presenter:** Hidenori Araki, Business Development Manager, Nord-Lock Group

It is vital that bolted joints holding sub-assemblies together remain secure. Fasteners used to secure bolted joints should resist the loosening caused by vibrations and dynamic loads, while keeping the ease of removal during maintenance. However, when a threaded fastener is subjected to vibration, the rapid transverse movement causes a lowering of friction against the contact planes and unintentional bolt self-loosening occurs. The self-loosening phenomenon causes the fasteners to vibrate loose and could lead to unwanted consequences for critical solar applications. To mitigate the problem of unintentional bolt self-loosening, one must understand what parameters are critical in the bolted joint that influences this. The critical displacement threshold and the Junker vibration principle will be discussed to understand the bolt self-loosening phenomenon and preventative measures. There are many locking methods out on the market today and the Junker Vibration Test (DIN 65151) will analyze these locking
systems to compare among them how effective they are under extreme transverse loading conditions where bolt self-loosening is most susceptible. Several locking methods will be compared under this test procedure and analyzed.

SE11: CLAMP LOAD LOSS IN PV RACKING SYSTEM BOLTED JOINTS AND SOLUTIONS FROM OTHER INDUSTRIES

Presenter: Jon Ness, Principal Engineer, Matrix Engineering Consultants

It is widely accepted that the reliable aluminum PV racking system bolted joint must have a clamp load which is high enough to prevent the joint from either opening or slipping under the dynamic loading which results from wind loading. This joint clamp load is generally created through the torque tightening of a bolt and nut. Unfortunately, much of the initial clamp load developed in PV racking system bolted joint is often lost due to non-rotational and rotational loosening of the bolt and nut after tightening. This presentation will briefly present each of these loosening mechanisms and describe general methods in use in the automotive and off-highway industries to address these problems. Non-rotational loosening of the bolt and nut occurs when no relative movement occurs between the internal and external threads but a loss of joint clamp load still occurs. In general, non-rotational loosening or joint relaxation in bolted joints is caused by localized plastic collapse which occurs at each contacting interface within the joint. In aluminium PV racking systems, another source of plastic strain in the joint is electrical bonding devices or serrated surfaces which purposely pierce the non-conductive anodized aluminium outer surface to improve the electrical bond. As a result, a significant portion the clamp load developed through tightening can be lost after the fastened and bonded joint is placed in service, especially with very short grip lengths and if the bolts or nuts are not retightened. Rotational loosening of the bolt and nut, more commonly referred to as self-loosening, occurs when the nut rotates under the action of external loading. Gerhard Junker is credited with explaining why and how rotational loosening (self-loosening) occurs. He showed that bolts and nut will self-loosen when relative movement occurs between the mating threads and the fastener bearing surface. Such relative movement will occur when the transverse force acting on the joint is larger than the frictional resisting force generated by the joint clamp load and the joint slips. PV racking bolted joints are prone to self-loosening because of the dynamic loading of the joints due to very high wind loads. Automotive and off-highway equipment manufacturers have long recognized these joint loosening mechanisms of dynamically loaded joint and as result, have developed standards and methods to either reduce the clamp losses or prevent the loosening altogether. It is believe that the application of these standards and methods to PV racking system bolted joint could improve the reliability of PV racking system bolted joints substantially.

SE12: BENEFITS OF DRONE BASED IR INSEPECTIONS OF RESIDENTIAL PV SYSTEMS

Presenter: Gordon Dowrey, Director, Operations and Service Delivery, Suntuity Airworks

Inspection of Solar Photovoltaic systems with drone-based visible and infrared (IR) sensors can identify defects that contribute to underperforming and non-performing elements of a solar panel array. With large commercial and utility size systems with a high concentration of PV panels in one location, the benefits of this type of inspection is readily apparent. It is with small residential systems that the cost benefit analysis of this type of inspection is less clear. The performance loss at the site level may not warrant immediate troubleshooting or repair. However, when defects and their associated performance degradation are aggregated at the PPA/Lease portfolio level the financial impacts become significant over the life of the portfolio. The defects that these inspections can find range from cell, to panel, to string level issues. Another loss that can be found is by generating a drone-based shading report for a snapshot of current shading that can be compared to the original shading values from the installation. A cell level issue may only incur a low wattage loss that would not justify repair or replacement of the panel. When the defects are causing losses at the panel and string level of the system they can significantly impact the annual kWh performance of the system. When the dollar value of the kWh loss and SREC loss is taken into consideration over a 15 - 20 life cycle of the system the financial impact can surprisingly large. The aggregated losses over a whole portfolio of systems can then be significant over the performance period of the portfolio. The Pareto principle tells us that 80% of the losses identified with these inspections will reside with 20% of the systems. With the inspection and loss data generated management can then make informed decisions to prioritize repairs based on the impacts on the portfolio as a whole. String and system level defects, with large losses, can be addressed first. Lower priority items can be scheduled based on location and availability of a repair crew sometime in the future. Or groups of geographically adjacent systems can be bundled together and bid out for repair with reduced deployment costs. Regardless, management can now make informed decisions on how to approach these issues.
Residential solar installation costs have remained stubbornly high due primarily to non-hardware “soft” costs. We address one soft cost contributor, installation labor, by investigating the use of adhesives to attach conventional PV modules to asphalt shingled residential roofs. In addition to simplifying the installation process, (thus reducing cost) adhesive mounting eliminates roof penetrations and the associated risk of leaks. The project team has developed a non-penetrating adhesive mounting system for conventional framed c-Si modules for residential steep-slope asphalt shingled roofs. A substructure is adhered to the roof, and the PV modules are mounted to these substructures with traditional mounting clamps. The substructure transmits and distributes the module loads, including wind uplift, to the shingles. By distributing the force (and thus reducing stress) over the full area of the module, the integrity of the load-path between module and roof is maintained, ensuring that the system can meet uplift requirements. Adhesive mounting reduces residential solar LCOE by simplifying the installation process as compared with traditional mounting approaches. The labor associated with locating the rafters and flashing the penetrations is eliminated. Training and skill requirements are thus reduced, opening the PV installer labor force to a larger labor pool. Data from several studies will be presented: 1. Mechanical Load Study: Mechanical load tests (MLT) following both UL2703 section 41 and UL1703 section 21, 2. Yield Study: The impact of the reduced module-roof gap on module temperature and module performance was studied. The adhesive mounting system was compared to a reference system on a test roof-deck in Albuquerque, NM. The study determined the yield loss associated with adhesive mounting, 3. Fire testing: UL 1703 fire tests: ‘Spread of Flame’, and ‘Burning Brand’, and 4. Installation Process Assessment: A Time and Motion (TM) study was performed on an adhesively mounted system and an equivalent reference system. A professional installation crew performed both installs. The comparison indicates the labor savings associated with adhesive mounting. All current mounting approaches require roof penetration and associated flashing, which puts a time, cost and complexity floor on installation cost. In addition, rail-based mounting is heavy, has a high part-count and a complex installation process. Adhesive mounting represents a potential paradigm shift. By simplifying the installation process and removing the need for roof penetration substantial savings are possible.
panels, in real operating conditions. PV manufacturers promise that, we want to help developers get there!).

**SE15: NEC 2017 ARTICLE 690: COST EFFECTIVE DESIGNS**

**Presenter:** Van Nguyen, Process and Specialty Engineer, Fluor

Prior to NEC 2017, the common practice for PV string sizing is to calculate the voltage gain caused by ambient temperature gradient from the rated 25°C. The calculation starts from the PV module rated open circuit voltage which is measured at 1,000 W/m² and 25°C cell temperature. In addition, the calculation of short circuit current, which has a direct impact on DC cable and combiner box sizing, has a safety factor of 1.25 to account for irradiance greater than full sun. NEC 2017 introduces alternative methods in calculating the open circuit voltage and short circuit current that consider both ambient temperature and irradiance. In many cases, these alternative methods result in lower string Voc and Isc, bringing cost savings in balance of system equipment and bulk material. This paper discusses key considerations when selecting the irradiance and coincident ambient temperature profile to ensure safe and cost effective plant design. The paper will also present two case studies in different locations to contrast the design improvements and cost saving opportunities when designing solar plant using NEC 2017, Article 690 versus the previous code revision.

**SE16: UNCERTAINTY IN PV SYSTEM PERFORMANCE ESTIMATES: HOW TO ASSESS TECHNICAL RISK**

**Presenter:** Anastasios Golnas, Technology Manager, US Department of Energy

The value of a PV system to its prospective owner depends, among other factors, on the estimation of its future performance. Any such calculation carries with it some uncertainty whose magnitude also affects the value of the system as it represents a measure of risk. It is important for all stakeholders in the solar industry to understand the root causes of uncertainty, the ways it is measured, and the methodologies used to calculate a system-wide value of uncertainty. Transparency is a good precondition for standardization, which itself can be used to reduce risk. This presentation will propose a number of actions that can guide an industry-wide discussion towards these goals, ensuring that PV systems are valued fairly and accurately based on best practices for measuring uncertainty and real-world performance.

**SE17: CABLE SYSTEM COMMISSIONING UPDATE**

**Presenter:** Charles Shannon, Senior Application Engineer, IMCORP

Previously at Solar Power International a unique approach to cable commissioning was presented. This paper is a follow up describing performance of those cables and an additional 60,000 field cable assessments by Power Frequency Partial Discharge (PD) testing at utilities, renewable energy facilities and industrial sites. As many renewable developers, owner operators, and utilities refocus on large scale solar they are finding opportunities to enhance cable system commissioning. The performance of cable systems under various commissioning test techniques across the world will be presented. Test comparison case studies, defect dissection results, and performance data will be provided demonstrating the benefits of using industry factory quality standards in the field for maximum cable system reliability.

**SE18: SOLAR CELL RECYCLING**

**Presenter:** Ajith Weerasinghe, Associate Professor, Fresno State

A novel chemical recycling method for Si-solar panel without the use of HF is proposed. The key component of recycling solar cells is the repurposing of the individual components of each cell. Silicon is recovered in a high enough purity to be reused in the production of new solar cells and the metallic components are to be sold off as commodities. Chemicals required for an etching process to remove metallic components include HCl and HNO3. The results show after one iteration that around 93.3% of Al and 61.5% of Ag was recovered for polycrystalline Si cell (p: Si) and 93.5% of Al and 61.3% of Ag was recovered for monocrystalline Si cell (m: Si). The experimentation method is scalable environmentally friendlier than a process involving HF.

**SE19: RECYCLING PV MODULES**

**Presenter:** Thomas Felder, Principal Investigator, DuPont Photovoltaic and Advanced Materials

The number of solar panels in the world is growing rapidly, according the IEA, 70,000 solar panels are being deployed every hour. Recycling needs will rise exponentially to relieve landfill load and recover materials for re-use. Legislation is currently most advanced in Europe, where the Waste Electrical and Electronic
Equipment Directive (WEEE) was established in 2003, and, with subsequent directives, requires module manufacturers to provide disposal of panels. Research on recycling methods is very active in Europe, where recycling energy consumption is declining and recycling efficiency is improving. Recycling will become more profitable as volume grows, but currently subsidies are needed to cover costs. This presentation will review current recycling methods and improvements under development.
POSTER PRESENTATIONS:

T09: A NEW COST-EFFECTIVE APPROACH TO SAFELY INTERCONNECT LARGE SCALE SOLAR PV

Presenter: Nachum Sadan, President & Chief Executive Officer, GridEdge Networks

OBJECTIVE:
Enabling high penetration of large-scale PV by reducing interconnection cost and time

METHODS:
DER installed on distribution feeders can operate reliably while connected to the utility. But when this connection is broken, the circuit may remain energized by the remaining DER. IEEE 1547 requires DER to disconnect from such islands within 2 seconds. But this becomes difficult when a wide DER variety (manufacturers of various DER types employing different detection methods at multiple physical locations) is spread across the island. Therefore, large scale DER installations may need an overarching communications-based protection system. The most common is Direct Transfer Trip (DTT). In this system, a central controller monitors feeder midline reclosers and then sends trip signals to appropriate disconnecting devices. A new DTT alternative is the subject of this presentation. Named “Distributed Generation Permissive” (DGP), this new method continuously monitors the continuity of the connection between utility and DER. DGP uses power line communications to continuously send a multi-frequency digital message across this path. Loss of this message means the path is broken and an island has likely formed. DERs will then be automatically tripped, based on the message no longer getting through.

RESULTS:
DGP has been installed on dozens of distribution circuits. It has been used to protect DER of many types, including solar PV and energy storage. Accumulated experience now exceeds 5 years and overall reliability after installation and commissioning has been excellent. Of particular relevance is a 23KV distribution circuit with 10 grid-attached PV sites that employ DGP to prevent islanding. This circuit nicely illustrates the high penetration scenario that is becoming increasingly common. The DGP system has now been in service for more than a year and is proving to be both technically and economically superior to DTT. The DGP system offers the flexibility of attaching additional new DER sites to a “DG Ready” circuit anywhere along the feeder at any given time (i.e. as construction is completed and the DG is ready to connect), and the scalability of adding new DER sites with minimal effort and low incremental cost.

CONCLUSION:
The utility found this solution to be less costly than DTT systems employing other communications media. They have found DGP to be both dependable and secure, as they reported in a 2018 T&D World article. With DER penetration predicted to grow rapidly, the continued use of traditional AI methods must now be questioned. DGP offers a proven, more economical and reliable method to deliver AI protection and enable large scale deployments. The DGP platform can also be used to support new modes of operation with smart inverters as required by the new 1547-2018 standard by sending control signals from the utility to DER.

T10: PV MODULE INDEX: HOW TO IDENTIFY THE MOST RELIABLE, HIGHEST PERFORMING, QUALITY PRODUCT

Presenter: Chris Beitel, Head, Business Development, Renewable Energy Test Center

What are the best PV modules and who are the most trusted manufacturing partners? This question is as relevant as ever, as the Solar PV industry continues to pursue advances in technology, and as many different manufacturers offer competing products, while customers and financial services companies work to discern which products are the most reliable, highest performing and best quality. Renewable Energy Test Center (RETC) has spent nearly a decade providing third-party testing of thousands of different solar modules for certification, accelerated reliability characterization and detailed performance analysis. Now, RETC is releasing its first annual “PV Module Index,” a report that uses the company’s database of results from PV module testing to identify the highest-ranking PV modules and their manufacturers, from among 19 of the highest-achieving manufacturers and their modules that RETC tests. The report is the PV industry’s first annual ranking that evaluates module Reliability and Performance, and Quality practices of the manufacturers. RETC’s presentation will summarize the PV Module Index, which shows the results of module tests including: 1. Reliability tests: Damp Heat Performance, Potential Induced Degradation, Thermal Cycling 2. Performance tests: Module Efficiency, Light Induced Degradation, Performance at Elevated (real-world) test conditions, off-angle lighting conditions 3. Quality evaluations: Breadth and Frequency of testing (Product Qualification Program, Thresher Testing methodologies), Randomized Sampling, Factory Audits,
Bill of Material Change Control, implementation of a consistent regiment of testing over multiple samples to assure all modules rolling off manufacturing line conform to specifications. Value to the PV Industry: 1. Previously undisclosed information about important criteria and testing regimens that show which PV modules are the best and why. 2. Information for manufacturers about what tests they should obtain for their modules and how positive test results show the quality of a product. 3. Information for project developers, EPCs, financial institutions and independent engineers about how to obtain a holistic view of a module's depth of performance and reliability. 4. Data sharing on new technologies, such as bifacial and PERC, more recent entrants to manufacturing, and the differences between laboratory testing and real-world field performance and reliability testing. RETC is an independent third-party laboratory specializing in PV product certification, accelerated reliability testing, bankability profiling, advanced engineering design concepts, and module & system design testing. The company is based in Fremont, Calif., and operates test facilities in Nevada, the Philippines, and Chile. Customers include module manufacturers and project developers, EPCs, financial services companies, and independent engineering firms.

**T11: NEW ALGORITHM FOR DELIVERING ALL THE PV ELECTRICAL POWER TO A BATTERY**

**Presenter:** Waseem Roshen, Chief Executive Officer, SS Power Technology

A new constant power algorithm is described for charging a battery. This new algorithm is especially suited for charging a battery from a solar module(s) because it ensures that all the electrical power generated in a solar module is delivered to the battery all the time, irrespective of the charge state of the battery. In order to protect the battery, the current is gradually reduced as the battery voltage rises such that the power going into battery is constant until the full charge state is reached. Once the full charge state is reached, the power to the battery is turned off. The paper would compare the performance of this new algorithm with commonly used algorithms such as MPPTs and PWM algorithms. These commonly used algorithms usually employ constant voltage methods.

**T12: NEW DYNAMIC METHOD FOR EXTRACTING AND DELIVERING ELECTRICAL POWER FROM SOLAR MODULES TO VARIOUS LOADS**

**Presenter:** Waseem Roshen, Chief Executive Officer, SS Power Technology

A new method for extracting electrical power from a solar module is described. This method ensures that all the electrical power generated in the solar panel is delivered to the load, irrespective of the load value attached to the solar panel. The method employs a high frequency electronic circuit. A comparison of this new method with the existing methods such as various MPPT (Maximum Power Point Tracking) algorithms is presented. It is found that, for a wide range of load types and values, this new method can deliver many times more electrical power to the load than is possible with other algorithms.

**T13: CABLE SYSTEM COMMISSIONING UPDATE**

**Presenter:** Charles Shannon, Senior Application Engineer, IMCORP

Previously at Solar Power International a unique approach to cable commissioning was presented. This paper is a follow up describing performance of those cables and an additional 60,000 field cable assessments by Power Frequency Partial Discharge (PD) testing at utilities, renewable energy facilities and industrial sites. As many renewable developers, owner operators, and utilities refocus on large scale solar they are finding opportunities to enhance cable system commissioning. The performance of cable systems under various commissioning test techniques across the world will be presented. Test comparison case studies, defect dissection results, and performance data will be provided demonstrating the benefits of using industry factory quality standards in the field for maximum cable system reliability.
T14: MANAGING ENERGY STORAGE WITH THE FLEXIBLE LOGIC CONTROLLER

Presenter: Scott Barrington, Business Development Manager, Trimark Associates

A recent study that specifically focused on the current grid and high-penetration PV called energy storage the ‘ultimate solution’ for allowing intermittent sources to address utility baseload needs. The report stated “a storage system capable of storing substantially less than one day’s worth of average demand could enable PV to provide on the order of 50% of a system’s energy.” This paper focuses on incorporating storage as part of the overall ‘systems’ solution. Successful integration into the larger utility grid infrastructure that include PV-Storage systems will provide many operational benefits to utilities and customers. However, performance of the current battery management systems is limited by the on-board embedded systems as the number of battery cells increases in the large-scale lithium-ion (Li-ion) battery energy storage systems (BESSs). A supervisory control and data acquisition system is still required for integration and maintenance of the large-scale BESSs. Trimark working with SCE has created the Flexible Logic Controller (FLC) to act as an intermediate device to interface the BESS Contractor’s proprietary battery management systems with the multiple interfaces, protocols, and associated control, input, and status points, required for the various applications. The FLC contains control mode algorithms for various applications and will control and monitor the ESS by communicating with the battery management system and other ESS devices through simple, high-level control and status points (e.g., P and Q commands). The FLC provides SCE the ability to revise the control mode algorithms, and control, input, and status points, at a future point in time, without needing to make low-level code changes to the proprietary battery management system, and without requiring the FLC to make changes to proprietary low-level code. The FLC provides the following: • Controllable Distributed Energy Resources combining energy storage, and management with solar PV • Improved predictability of solar PV generation through high resolution solar forecasting • Reduced lifetime cost of solar plus storage system cost through reliable integrated smart inverters • Optimum operation of resources and settings of controllers through distribution feeder modeling and impact studies • Making the grid ready for seamless integration of solar plus storage to support customer choice, while optimizing the electric system: technically and economically • Making solar plus storage more operationally integrated, in a cost competitive manner • Improving the value proposition of solar plus storage and other distributed energy resources.

T15: EFFECT OF VARIOUS FINANCING OFFERS AND ENERGY EFFICIENCY BUNDLING ON RESIDENTIAL SOLAR CUSTOMER ACQUISITION

Presenter: Micah Myers, Founder and Chief Executive Officer, Pace Avenue

Pace Avenue is completing a Department of Energy grant project to accelerate solar adoption and reduce customer acquisition costs (CAC) through a disruptive customer acquisition platform that connects homeowners to a marketplace of financing options, product options and various energy efficient home improvement contractors and solar installers.
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