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- **Randell Mills**, Brilliant Light Power, Inc., Cranbury, NJ

PLENARY PRESENTATIONS

Cyberattack Detection in Grid-Connected PV Inverters Using Irradiance-Driven Natural Watermarking

Chris Mi

San Diego State University, San Diego, CA

The rapid adoption of inverter-based resources (IBRs), such as solar energy, has expanded the attack surface of the power grid, increasing its vulnerability to cyberattacks. Consequently, there is an urgent need for distributed attack detection methods that locally integrate with IBRs without disrupting normal system operation. Natural watermarking, which leverages inherent DC link voltage fluctuations caused by the variability of renewable energy sources, has emerged as a promising solution for attack detection. However, this approach has yet to be demonstrated under realistic conditions. This study addresses this gap by implementing a natural watermarking scheme in both a hardware-in-the-loop (HIL) simulation of a three-phase grid-tied photovoltaic (PV) inverter and a fully hardware-based system. A Texas Instruments C2000 F280049C LaunchPad is used both to control the inverter and to implement real-time state-space estimations, which form a digital twin of the inverter. This digital twin is then used to detect abnormal inverter behavior by identifying discrepancies between predicted and measured system outputs. Validation results confirm the effectiveness of the proposed approach in detecting noise-injection and replay attacks in both testbeds. Additionally, unpredictable DC link voltage fluctuations arising from variations in irradiance enable the detection of model-based attacks that would otherwise remain undetectable. This study thus demonstrates the practical viability and robustness of natural watermarking as a locally implementable, non-intrusive cybersecurity measure for inverter-based power systems.

Notes

Heat Transfer with Thermal Waves and Resonance

Liqiu Wang

The Hong Kong Polytechnic University, Hong Kong

As humanity transitions from an era of abundant fossil fuels to one defined by pressing energy sustainability challenges, the efficient management and transfer of heat have emerged as critical imperatives. Over 80% of global energy production involves the generation, conversion, or utilization of heat, underscoring the urgent need to engineer advanced thermal transport media capable of addressing the terawatt-scale demands of the future.

Among the four fundamental heat-transfer modes—conduction, convection, radiation, and thermal wave/resonance—the latter stands apart due to its unique mechanism and transformative potential. Unlike conventional modes, which rely on temperature gradients to drive heat unidirectionally from high- to low-temperature regions, thermal wave/resonance arises from cross-coupling between transport processes within a medium. This enables isothermal heat transfer or even heat propagation against thermal gradients, offering unprecedented control over energy flow. Characterized by spatiotemporal wave-like distributions of temperature or its derivatives, this mode exhibits tunable dynamics that can be optimized through tailored cross-coupling, granting it superior efficiency in specific applications compared to traditional methods.

This presentation delves into the origins and manipulation of thermal waves and resonance, highlighting their capacity to revolutionize heat-transfer systems. Experimental demonstrations of their unique features—such as enhanced thermal conductivity, directional control, and non-diffusive energy transport—will be showcased to illustrate their practical advantages. Additionally, the talk will address the complexities inherent in numerically simulating these phenomena, including challenges in modeling wave interference, resonance tuning, and multi-physics interactions. By bridging theoretical insights, experimental validations, and computational hurdles, this work aims to advance the development of next-generation thermal management technologies, paving the way for sustainable solutions to humanity's escalating energy demands.

Notes

Role of Innovation in the global quest to achieve Net Zero Carbon Emissions

D. Yogi Goswami

The Hong Kong Polytechnic University, Hong Kong

As the global leaders grapple with their stated goals to achieve Net Zero Carbon Emissions (NZE) by 2050 or 2060, one must take a serious look at the trends and what needs to be done in the future. Despite all the trends in the right direction, both International Renewable Energy Agency (IRENA) and International Energy Agency (IEA) project that we will fall woefully short of achieving the NZE2050 or limiting the global temperature rise to 1.50C if we continue with the current policies of the countries.

While IEA and IRENA, project future estimates of energy based on the present technologies and some incremental improvements, they are not in a position to foresee what innovative new scientific developments and technologies will be available in the future, which might completely change our predictions. As an example, about 25% of all the energy used in the U.S. is for cooling of buildings. Although that percentage is lower for the rest of the world, it is rapidly increasing. Since buildings are cooled exclusively by electrical power, at present we can only hope to replace that electricity with power from renewable energy. However, a very promising innovation on the horizon in scientific and engineering research is to develop coatings for building skins that will emit long wavelength infra-red radiation in the atmospheric window (8–13 mm wavelength) to deep space, which is at a temperature close to absolute zero. The technology known as plasmonic cooling, when developed, will cool the buildings simply by transferring the heat from the buildings to the outer space by radiation. When this technology becomes practical and commercially available, there might not be any need for mechanical cooling of buildings in many parts of the world. Just as we have seen developments in computer and information technologies in the last two decades that we could not even imagine 30 years back, we will see developments in solar and ambient energy space that we can barely imagine today.

The presentation will describe some of the transformative developments, including plasmonic cooling that we expect to see in the future.

Notes

KEYNOTE PRESENTATION

Enabling Energy Efficiency: From Advanced Materials Invention to Scalable Building Solutions

Elise Strobach

AeroShield Materials, Inc., Waltham, MA

Buildings are one of the largest contributors to global energy use and emissions, yet adoption of energy-saving materials remains slow and fragmented. This talk will explore the critical role of next-generation materials—like transparent aerogels—in transforming the energy performance of windows and building envelopes. The recent development of transparent silica aerogels for high-efficiency windows demonstrates how fundamental material science innovation can help bridge the gap between performance and practicality in the built environment. Dr. Elise Strobach will share lessons from AeroShield's journey—from early-stage research to startup formation and industry partnerships—highlighting both the technical innovations and active research areas behind the material and the business strategies required for scaling. This discussion will explore the intersection of material science, product design, and market adoption, highlighting how these elements must align to drive meaningful progress toward more energy-efficient buildings.

Notes

Harnessing Distributed Energy Resources to Address the AI Power Supply Gap

Neil Auerbach

Hudson Sustainable Group, Miami, FL

In an era of accelerating AI-driven data center demand (projected to drive 53–90 GW of incremental U.S. load growth by 2030) regional grids such as PJM and ERCOT face mounting transmission constraints and capital bottlenecks. This presentation examines how distributed energy resources (DERs), structured through innovative homeowner incentives and virtual power plant (VPP) frameworks, can function as scalable grid infrastructure rather than supplemental capacity.

Beyond traditional reliance on Section 48E tax incentives, this framework evaluates market-based mechanisms to incentivize widespread solar-plus-storage adoption, enabling load-serving entities to optimize battery charging during peak solar production and dispatch power during high-demand periods to mitigate congestion. Data centers, equipped with redundant storage capacity, can further integrate into this distributed architecture, absorbing excess generation and releasing stored energy strategically to enhance grid stability.

By aligning capital markets, distributed ownership structures, and load-management strategies, this approach offers a pathway to improve resiliency, reduce infrastructure costs, and accelerate renewable integration without sole dependence on large-scale transmission expansion. Complementary solutions, including microgrids, demand aggregation, and long-duration storage, are evaluated as part of a diversified portfolio approach to stabilize grids under rapid electrification and digitalization pressures. This framework reframes distributed energy as a core infrastructure asset class essential to sustaining long-term energy security and economic growth.

Notes

Nanomaterials: Improved Energy for Implantable Sensors

Thomas J. Webster

Hebei University of Technology, China

Nanotechnology has certainly revolutionized numerous fields over the past several decades. This presentation will provide information concerning devices that use nanomaterials to generate energy to power implant sensors. Specifically, carbon nanotubes have been used to transform today's medical devices into sensors that can sense and identify cell presence on implants (such as bacteria, inflammatory cells, and/or cells that produce tissue) as well as generate power to communicate such information to a hand held device. Such implantable sensors have been tested in animal models showing the ability to measure early indicators of infection and respond accordingly to offset infection. Moreover, data will be presented from clinical studies with over 45,000 patients in which such nanotextured implants have ensured implant success and have not failed.

Notes

Cost and Benefit of Replacing All Fossil Fuel Power Generation

Wolfgang Bauer

Michigan State University, East Lansing, MI

Our climate has reached a tipping point. The planetary albedo has been reduced measurably because of human activity, primarily the unfettered burning of fossil fuels for transportation, electricity generation, home heating, and industrial activity. Renewable power generation needs to be deployed at global scale to avoid catastrophic global warming. This presentation will explore how much this can be expected to cost and what the return of investment time will likely be for this global energy transition.

Notes

Reinventing Electrolysis with Nanostructured Electrode Architectures for Scalable, Low-Cost Hydrogen

Shule Yu

Envision Energy, Burlington, MA

Among water electrolysis technologies, proton exchange membrane electrolyzer cells (PEMECs) stand out for their high energy density, rapid dynamic response, and low-temperature operation—features essential for coupling with intermittent wind and solar power. However, the high cost and limited catalyst utilization of conventional membrane electrode assemblies (MEAs) remain critical barriers to large-scale deployment.

A transformative electrode and electrolysis design strategy that redefines PEMEC architecture. We developed a novel thin liquid/gas diffusion layer (LGDL) with tunable pore morphology that dramatically reduces interfacial, ohmic, kinetic, and mass-transport losses. Reducing LGDL thickness from hundreds to tens of micrometers lowers stack weight and volume while enhancing performance. By integrating a transparent PEMEC with high-speed micro-visualization, we reveal that electrochemical reactions and multiphase transport occur predominantly near catalyst regions adjacent to highly conductive pathways. Building on these insights, we introduce thin-film catalyst-coated LGDLs and an ink-free integrated dual electrode assembly (IDEA) fabricated via facile electroplating. This architecture constructs electron/proton "nanohighways," maximizes triple-phase boundaries, and significantly enhances both oxygen and hydrogen evolution reactions. The IDEA reduces fabrication steps from over ten to three, saves more than 80% of noble catalysts, and achieves 6 A cm^{-2} at 1.82 V with excellent stability—offering a scalable, low-cost pathway toward industrial green hydrogen production.

Notes

New Nuclear Reactors to Combat Global Warming

Wolfgang Bauer

Michigan State University, East Lansing, MI

Last year nuclear power plants globally generated approximately 7 TWh of electricity. Since nuclear reactors have capacity factors close to 1 and are not plagued by intermittency problems, they are seen as a valuable component in the portfolio to replace the 140,000 TWh of energy generated from fossil fuels worldwide. New technologies promise safer and less expensive reactors, and this presentation will give an overview of the current state of the art.

Notes

Photon Recycling via Harvesting Indoor Lights for Energy Generation via Photovoltaic and Photothermal Thin Films

Donglu Shi

University of Cincinnati, OH

This work brings together several complementary approaches for capturing energy from indoor and low-light settings, aiming toward truly energy-neutral buildings. We show that everyday LED lighting can do more than illuminate a room—when combined with semitransparent CdTe or silicon photovoltaic (PV) panels, it can also generate useful electrical power. Even at low irradiance, optimized PV configurations deliver substantial output, with photon-recycling efficiencies above 30% and projected annual savings in the hundreds of thousands of dollars for large commercial buildings. Alongside this, we present a transparent photothermal radiator based on plasmonic Fe_3O_4@Cu_2-xS thin films, which absorb diffused UV and IR light and convert it into heat, reaching temperatures above 50 °C in an indoor test environment. Together, these optical and photonic strategies demonstrate how ambient indoor light can be repurposed into both electricity and heat, offering practical and scalable routes to reduce grid reliance and improve building sustainability.

Notes

Exposing the Novel Properties of Nanoscale Energy Materials via in-situ Studies and Optical Simulations

Oomman K. Varghese

University of Houston, TX

Revealing the unique properties and the potentials of nanostructured energy materials is key to bringing paradigm shifts in the energy field. Numerical simulations are commonly used to cover a large sample space of parameters for accelerated materials discovery. Various in situ materials characterization tools emerged in recent years offer unprecedented opportunities for achieving this goal via experiments. Using numerical simulations and in situ heating transmission electron beam studies, we discovered certain distinct optical and structural properties of vertically aligned titania nanotubes. This material, synthesized using electrochemical anodization, has been recognized as promising for solar energy applications such as solar cells and solar fuel generation. While the in-situ study revealed that the material could retain its tubular morphology at temperatures exceeding 950 °C, the numerical simulations showed its tunable photonic characteristics. This talk provides the details of these studies.

Notes

Advancing the Assessment of Climate Polarisation Using Joint Shannon Entropy of Temperature and Precipitation Fields

Bernard Twarog

Cracow University of Technology, Poland

This study introduces a novel approach to analysing the polarisation of climate phenomena through the application of Shannon information entropy to the bivariate distribution of monthly temperature and precipitation. Departing from previous catchment-based analyses, the study employs a uniform global grid at 0.5° × 0.5° resolution, enabling consistent and spatially detailed assessment across regions. Leveraging updated long-term datasets from NOAA, spanning over a century of monthly observations, both traditional trend-based indicators and entropy-based metrics are evaluated. The joint entropy metric captures the spatial complexity and mutual variability of temperature and precipitation, revealing patterns of climate polarisation that may elude classical trend analyses. Statistical testing is supported by the Mann-Kendall and Pettitt tests for trend identification, while the entropy-based framework provides a complementary perspective on climate variability. The results uncover previously unrecognised clusters of high entropy, indicating regions of increased climatic instability. These findings offer deeper insight into the spatial dynamics of climate change and support the integration of entropy-based diagnostics into adaptive planning and sustainability-oriented climate policy.

Notes

Hydrophilic Microporous Matrix Hosting a Symbiotic Microbial Consortium for Crop Resilience Enhancement

Teresa M. Victor

ISPTEC, Angola

This work introduces a novel hydrophilic microporous matrix, synthesized via High Internal Phase Emulsion (HIPE) polymerization, uniquely engineered to host a living symbiotic microbial consortium of endophytes and PGPR. Unlike conventional polymeric HIPE materials, which are typically inert, this matrix is specifically designed to preserve microbial viability, enable colonization, and support direct plant–microbe interactions in soil environments.

The process integrates chemical reaction engineering principles kinetic modelling, emulsion thermodynamics, and semi continuous reactor operation with microbial compatibility constraints, representing an uncommon and innovative convergence between polymer engineering and agricultural biotechnology. Controlled shear emulsification and residence time optimization were critical to maintaining matrix porosity while protecting embedded microorganisms.

SEM imaging provides direct evidence of novelty, revealing microbial colonization within the matrix, root hair penetration into the porous structure, and migration of endophytes from the matrix into plant tissues. Field trials across five crops (coffee, banana, Miscanthus, palm oil, maize) demonstrated consistent improvements in growth, biomass, chlorophyll retention, and reduced symptoms associated with Fusarium oxysporum.

By coupling the matrix with the Symbiotic Rhizosphere Simulated (SRS) system, this work establishes a new integrated platform for agro process intensification, offering a scalable, biologically active material for next generation sustainable agriculture.

Keywords: Hydrophilic microporous matrix; HIPE polymerization; PGPR; endophytes; rhizosphere engineering; process intensification; sustainable agriculture; SRS system; crop resilience; Fusarium suppression.

Notes

Thermo-Mechanical Stress Analysis of Wellbore Integrity in CO_2 Storage Wells: A Case Study from the Tubåen Formation, Snøhvit Field, Norway

Jawad Ali Khan

PetroND Energy Solutions, Grand Forks, ND,

A fully coupled thermo-mechanical–poroelastic analysis of wellbore integrity during CO_2 injection in the Tubåen Formation of the Snøhvit Field. Using field data and the Drucker–Prager plasticity model, the study captures how evolving temperature and pressure redistribute stresses in the casing, cement, and formation, driving risks such as debonding, tensile failure, and microannulus development. The results are rigorously cross-validated with established literature as well as the mathematical model developed in this work, offering a strong and practical framework for predicting integrity challenges and improving CO_2 storage well design.

Notes

Comparing Wind-Hydrogen and Solar-Hydrogen System Performance and Cost for Reliable Microgrid Operation

Jack Cimorelli

University of Massachusetts Lowell, Lowell, MA,

Understanding the available resource availability at a given location is crucial in developing clean and effective microgrid systems. Wind turbines and solar panels can provide zero-emission electricity supply but are hindered by intermittency. Pairing renewable energy sources with an energy storage medium such as compressed hydrogen offers a potential solution to meet energy demand for remote installations. However, the attributes of wind and solar resource profiles make the design of these solutions a challenge. This presentation highlights the integration of wind energy and solar energy in a remote microgrid for direct power generation and hydrogen-based energy storage. A techno-economic modeling tool is used to size and analyze the different components of the hybrid microgrid systems. The tool provides insight into identifying the best solution based on a given power supply, power demand, and location. A naval base off the coast of southern California is used as a case study. This naval base would greatly benefit from a well-designed hybrid energy storage system, leading to increased self-sufficiency and decreased reliance on fossil fuels. Initial results indicate that due to the nature of the location's wind and solar resource profiles, a wind-hydrogen microgrid system is more cost-effective than a solar-hydrogen microgrid from a long-term cost perspective. This research helps support the design of microgrids looking to transition away from fossil fuels and incorporate renewables; and is applicable to other remote sites having no grid connection.

Notes

Co-optimization of Cost and Curtailment in Hybrid Wind-Hydrogen Powered Microgrids: Understanding the Impact of Overbuilding

Victor Eniola

University of Massachusetts Lowell, Lowell, MA

Energy storage systems address wind resource intermittency challenges, but they come with high operational costs and have not yet reached technological maturity. This study explores hydrogen energy storage as a potential cost-effective strategy. Using a rule-based energy management scheme (EMS), an overbuilding factor (OBF) is introduced to study its effect on techno-economics and performance of a wind power-hydrogen storage system. In addition, the model is integrated with a multi-objective genetic algorithm (MOGA) to perform a cost and curtailment co-optimization. The study results suggest that, for a microgrid at San Nicolas Island in Southern California, overbuilding wind capacity by 61-75% represents an optimal design range for hybrid wind-hydrogen microgrids. A capital cost below US$9.1 million and a curtailment rate not exceeding 18% balances economic and technical objectives, efficiently utilizing excess wind capacity while minimizing wasted energy, and making the design suitable for sustainable and resilient energy systems. The results reveal that the numerical model and optimization can provide insight into system balance for wind-hydrogen powered microgrids. The results also highlight system design trends; increasing the OBF reduces the required electrolyzer capacity which significantly reduces hydrogen storage costs. This study demonstrates how OBF as a design strategy to counteract wind variability, can improve system performance, and achieve cost-effective energy solutions, providing critical insights for both autonomous microgrids and large-scale renewable energy infrastructure.

Notes

Quantitative Assessment of Vibration-Induced Drill String Wear Failure in Ultra-Deep Oil Wells

Liming Dai

University of Regina, Canada

Vibration-induced wear failure of drill strings poses serious challenges to scientists and engineers, particularly in ultra-deep oil wells, where vibration attenuation becomes less effective and dynamic stress propagation is significantly amplified. Although extensive efforts have been made to investigate wear failure mechanisms and to quantitatively characterize drill string degradation in ultra-deep wells, existing studies predominantly focus on vibration behavior in a single direction.

In this study, an innovative dynamic model of a drill string used in ultra-deep oil wells is developed by comprehensively incorporating multi-physical field coupling effects, including drilling fluid–structure interaction, drill string–wellbore contact and collision, bit–rock interaction, as well as temperature and pressure influences. In addition, a wear model based on energy transfer theory is established to effectively predict wear depth and service life. Using the proposed models, the wear failure behavior of drill strings subjected to multi-nonlinear vibrations during ultra-deep well drilling is quantitatively analyzed.

The dynamic responses of the drill string under coupled longitudinal, lateral, and torsional vibrations are evaluated and validated using field and experimental data obtained in this study. The results indicate that drill string vibrations exhibit pronounced nonlinear characteristics, with instability phenomena such as drill string jumping and stick–slip readily occurring under critical operating conditions. These findings provide direct guidance for the selection and optimization of drill string parameters in ultra-deep well drilling (>10,000 m), thereby enhancing drill string safety and operational reliability during the drilling process.

Notes

Voltage Profile Enhancement in Critical Feeders Using Feedback Controlled Dynamic Voltage Restorers

Manuel Dario Jaramillo Monge

Salesian Polytechnic University, Ecuador

In this article, power quality issues in distribution systems are investigated, and a mitigation strategy based on a Dynamic Voltage Restorer (DVR) equipped with a feedback Phase-Locked Loop (PLL) control scheme is proposed. The proposed approach effectively compensates voltage fluctuations, enhances voltage stability, and mitigates potential disturbances affecting critical feeders. The PLL-based control system is implemented in MATLAB/Simulink, where each functional block is fully parameterized to compute the required compensation voltages for the IEEE 34-bus test system. To evaluate the dynamic performance of the DVR, an exponential load variation is applied to emulate severe voltage drops that may lead to instability in critical buses and feeders. The network voltages and load currents are provided as inputs to the DVR module, where a linear feedback control algorithm determines the appropriate compensation strategy by regulating the injection of active power and the absorption or supply of reactive power. The DVR is installed at bus 27, between the distribution network and the sensitive load, and operates continuously to maintain bus voltages within acceptable operational limits. 3rdDiego Carrion Electrical Engineering Department Universidad Polit´ecnica Salesiana Quito, Ecuador during operation. The DVR technology is used to prevent voltage sags and swells. It uses PLL feedback control logic to maintain the frequency of each phase at values close to zero. Voltage regulators also improve energy quality and stabilize the distribution system. They protect end users' loads and prevent the overloading of critical feeders in case of any disturbance during operation.

Notes

Production of Zeolite Y From Kaolin Conversion for Energy Applications

Teresa M. Victor

ISPTEC, Angola

The increasing demand for efficient and sustainable energy processes has intensified interest in zeolite-based catalysts due to their structural stability and high catalytic activity. This study reports the production of Y-type zeolites from kaolin via conversion methods, adapting the International Zeolite Association (IZA) standard synthesis route. Kaolin tailings were selected as the raw material over hydrogel synthesis, offering improved product stability, efficiency, and cost-effectiveness while valorizing local resources. The synthesized zeolite Y exhibits a crystalline framework with well-defined pores, making it suitable for energy-related applications such as fluid catalytic cracking (FCC) and emerging clean energy technologies. A process design was developed, including block diagrams and mass balance, with a nominal production capacity of 1,225 tons/day. Economic viability analysis demonstrated an annual revenue of 6.7 billion USD, with positive indicators (NPV, IRR, TL, Payback) confirming the feasibility of establishing a production facility in Angola. These findings underscore the potential of kaolin-derived zeolites as strategic catalysts for energy applications, combining local resource utilization with industrial and economic sustainability.

Keywords: Heterogeneous catalyst, FCC process, zeolite y, kaolin.

Notes

Green hydrogen Production from Alternative Water Resources and Waste Plastic Feedstocks

Huiyao Wang

New Mexico State University, Las Cruces, NM

Photocatalytic water splitting and photo-reforming provide sustainable pathways for green hydrogen production by utilizing only sunlight and alternative water sources or plastic waste as feedstocks, offering the potential for a negative carbon footprint. In this work, various photocatalysts—including Au/TiO_2, Pt/TiO_2, Zn/TiO_2, and Ag/G/TiO_2—were synthesized and evaluated. Among them, Pt/TiO_2 and Ag/G/TiO_2 atom-nanocomposites demonstrated the highest efficiency for hydrogen generation. By optimizing pretreatment processes and reaction parameters, hydrogen production was significantly enhanced, achieving an estimated cost of $1.1–1.5 per kilogram under optimal conditions. The photocatalysts developed in this study can be recycled, regenerated, and reused. Future progress in achieving more uniform single-atom deposition is expected to further reduce precious-metal usage, lower overall production costs, and improve catalytic performance.

Notes

Predictive Model for Energy Efficiency in Peru Using Data Mining to Reduce CO_2 Emissions

Reynaldo Jose Cervantes Bravo

National Agrarian University, Peru

This study shows the transition to a low-carbon economy in Peru by creating an energy matrix prediction model, using renewable energy and natural gas, and predicting the energy efficiency and emissions of CO_2 by 2035 to enable the Peruvian government to implement better energy use, thus reducing the emissions from a focus on the Energy Trilemma: Energy Security, Energy Equity, and Environmental Sustainability.

The model is based on the macroeconomics and energy model using data from 1970 to 2024 to determine energy intensity and emissions of CO_2 per year and GDP projections from 2025 to 2035 from the Central Reserve Bank. Energy intensity reduction scenarios are considered: pessimistic (annual reduction of 1%), conservative (annual reduction of 1.5%), and optimistic (annual reduction of 2%). These scenarios define the total energy consumption in 2035 in million tons of oil equivalent (Mtoe) and the energy matrix distribution in 2025 and 2035.

The technology of data mining is used for monitoring the energy efficiency and compliance with the international commitments by year in real time. The model allows evaluating the impact on the emissions of greenhouse gases of an energy project using the Environmental Pollution Index (CIX) and access to carbon credits under the Kyoto Protocol. The study allows knowing the commitment of Peru to COP 28, since it allows calculating the maximum cumulative budget of emissions to ensure that the temperature does not increase by more than 2°C by the year 2100 and ensure energy security and equity in vulnerable areas.

Notes

Improving the Fatigue Design of Mechanical Systems such as Refrigerator

Seongwoo Woo

Ethiopian Technical University, Ethiopia

To enhance the lifetime of mechanical system such as automobile, new reliability methodology – parametric Accelerated Life Testing (ALT) – suggests to produce the reliability quantitative (RQ) specifications—mission cycle—for identifying the design defects and modifying them [1]. It incorporates: (1) a parametric ALT plan formed on system BX lifetime that will be X percent of the cumulated failure, (2) a load examination for ALT, (3) a customized parametric ALTs with the design alternatives, and (4) an assessment if the system design(s) fulfil the objective BX lifetime. So we suggest a BX life concept, life-stress (LS) model with a new effort idea, accelerated factor, and sample size equation. This new parametric ALT should help an engineer to discover the missing design parameters of the mechanical system influencing reliability in the design process. As the improper designs are experimentally identified, the mechanical system can recognize the reliability as computed by the growth in lifetime, LB, and the decrease in failure rate. Consequently, companies can escape recalls due to the product failures from the marketplace. As an experiment instance, two cases were investigated: 1) problematic reciprocating compressors in the French-door refrigerators returned from the marketplace and 2) the redesign of hinge kit system (HKS) in a domestic refrigerator. After a customized parametric ALT, the mechanical systems such as compressor and HKS with design alternatives were anticipated to fulfil the lifetime – B1 life 10 year.

Notes

Circular Valorization of Metallurgical Slags for Thermal Energy Storage in Concentrated Solar Power Systems and Sustainable Mining Operations

Olumide Ogunmodimu

Pennsylvania State University, University Park, PA

The global mining industry is among the most energy intensive sectors, with operations requiring substantial electrical power for ore extraction, crushing, grinding, flotation, smelting, and refining. Many mining operations are located in remote regions with limited grid infrastructure, high electricity costs, and abundant solar resources, making them ideal candidates for on site renewable energy generation. In the United States, the mining and minerals processing sector consumes approximately 200–300 TWh of energy annually, creating significant opportunities to integrate concentrated solar power (CSP) technologies. Moreover, the valorization of metallurgical slags as thermal energy storage (TES) media offers a circular economy pathway in which industrial byproducts can displace traditional renewable energy storage materials and systems, providing a low cost, high temperature alternative that supports CSP deployment. CSP with thermal storage delivers dispatchable power, aligns well with the continuous operational requirements of mining facilities, and enables nighttime electricity generation or peak demand support. Additionally, TES materials derived from slags could facilitate process heat integration for mineral processing and smelting operations, ultimately enhancing energy security, reducing carbon emissions, and improving the economic sustainability of remote mining sites.

Keywords: Concentrated solar power, thermal energy storage, metallurgical slag, electric arc furnace slag, material characterization, waste valorization.

Notes

Comparative Characterization of Different Metallurgical Slags for Thermal Energy Storage for Concentrated Solar Power

Olumide Ogunmodimu

Pennsylvania State University, University Park, PA

This study aims to comparatively characterize three industrial steel slags, Ladle Metallurgy Furnace (LMF), Basic Oxygen Furnace (BOF), and Electric Arc Furnace (EAF), to evaluate their suitability as cost-effective thermal energy storage (TES) materials. A comprehensive analytical approach was employed, including X-ray fluorescence for elemental composition, scanning electron microscopy with energy-dispersive X-ray spectroscopy for microstructural context and local, thermogravimetric analysis and derivative thermogravimetry for thermal stability and decomposition behavior, differential scanning calorimetry for heat flow and thermal transitions, and X-ray diffraction for identifying crystalline phases. Results indicate that all three slag types are primarily composed of Fe_2O_3, CaO, and SiO_2, a compositional profile favorable for TES applications. EAF slag demonstrated superior thermal stability and possessed the most stable crystalline framework with minimal free lime (f-CaO), making it the most promising candidate for long-term, cyclic high-temperature TES operations. Its microstructure offers a favorable baseline for TES, combining Fe-rich pathways for heat conduction with limited, closed porosity. Conversely, LMF slag, while exhibiting a balanced composition dominated by periclase and silicate phases that contribute to high thermal stability and heat capacity, also shows significant decomposition at lower temperatures and is detectable, suggesting the need for specific design accommodations or pre-treatment. BOF slag, rich in heat-conductive iron oxides and silicates, exhibited significant f-CaO and portlandite, which can impair volumetric stability and thus require pretreatment to ensure dimensional stability during cyclic thermal operation. Once conditioned, its RO/wüstite-reinforced framework can provide durable, conductive contacts for TES.

Notes

Technical Practices and Upgrading Paths of New-Generation Coal Fired Power for Low- Carbon and Efficient Development

Chen Xinyue

Shanghai Shenergy Power Technology Co., LTD., Shanghai, China

Under China's "dual carbon" goals, coal power is transitioning from baseload to flexible support for renewable integration. The Implementation Plan for the Special Action on the Upgrading of New-Generation Coal-Fired Power (2025-2027) prioritizes flexibility: three of its four core indicators—deep peak-shaving, load change rate, and start-stop flexibility—directly enable this role, while the fourth, wide-load (especially low-load) efficiency, ensures the transition does not drive up coal power's own emissions.

These targets introduce major technical challenges. Deep peak-shaving requires stable combustion at 20% rated load or below, straining boiler stability, SCR denitration, and hydrodynamics. Load change rate must reach 4% per minute, demanding precise trade-offs between fast ramping and mechanical stress. Start-stop flexibility shortens cold-start times while safeguarding thick-walled components like boilers and turbines. Wide-load efficiency suffers because conventional units optimized for rated load lose efficiency sharply under low load—an inherent design constraint.

Our team has implemented proven solutions in commercial projects. For deep peak-shaving, Waigaoqiao No.3, Xuzhou CR Power, and Pingshan Phase-II achieve stable operation at ≤20% load through system-level optimization. Start-stop flexibility is addressed via steam-heated startup and low-speed warm-up systems, which accelerate startups while protecting equipment through precise temperature control. Wide-load efficiency is improved by flexible regeneration, generalized regeneration, and generalized frequency conversion, technologies that sustain high efficiency across the full load range. These applications closely align with national upgrade requirements and provide replicable, actionable pathways for China's flexible and low-carbon coal power transition.

Notes

Role of Energy Efficiency in Energy Transition: A Decomposition Analysis of Energy Use

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The use of energy-efficient technologies tends to reduce the overall energy use of a country. However, a change in energy can occur either due to a change in activity effect, intensity effect, or structural effect. The paper deploys the Logarithmic Mean Divisia Index, known as the LMDI method to examine the impact of energy efficiency policies adopted by India since 1990. The overall energy use between 1990 to 2018 is disaggregated into two different effects for selected energy-intensive sectors. The period from 1990 to 2018 is divided into two phases to examine the impact of deploying energy reforms in 2003. The results reveal that services and the residential sector contribute positively to an increase in energy use. The effect of economic conditions was realized significantly in determining the energy use in the phases. The policies should focus on improvement in energy efficiency in the agriculture sector holds crucial policy implications in the domain of energy efficiency. There is a need for energy saving and conservation policies to reduce energy demand by households. High energy use in the transport sector due to structural change signifies the focus on energy efficiency in the transport sector due to the upcoming perceived large scale electric vehicle deployment. Finally, a sector-specific energy efficiency and energy conservation policy is recommended for efficient policy formulation.

Notes

Production of Ancillary Services with Solar Thermal Energy for Industrial Applications

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Planetary decarbonization depends on the availability of solar resources and the profitability of the proposed solar system. The cost of thermal energy using fossil fuels is 0.0628 USD/kWh. This work conducts a parametric evaluation to minimize the energy cost of ancillary services produced using solar thermal energy: hot water, electricity, and cooling. Electricity is generated using an organic Rankine cycle, and cooling is provided by an NH_3–H_2O vapor absorption system. A sensitivity analysis is performed by varying parameters such as solar thermal temperature, evaporator temperature, and cooling temperature, and their effect on system performance is investigated. The system's LCOE is 0.0579 USD/kWh with a payback period of 5.6 years. This work provides a reference framework for the current competitiveness of solar thermal energy and the challenges of minimizing energy costs.

Notes

Use of Pressure Transient Analysis to Evaluate Fluid Soaking in Multi-Fractured Shale Gas Wells

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Post-fracturing (post-frac) fluid soaking plays a crucial role in enhancing well productivity in shale gas reservoirs by enabling imbibition-driven fracture stimulation. However, determining the optimal soaking duration remains an open challenge. This study applies pressure transient analysis (PTA) to post-frac shut-in data from six multi-fractured shale gas wells in southwest China to evaluate fluid soaking effectiveness in real time. The analysis revealed that pressure derivative data become scattered after one day of shut-in, but the overall trend beyond that point provides critical insight. Two wells demonstrated zero slope (flat) pressure derivatives within one week, indicating sufficient soaking. Four wells exhibited increasing derivative trends, signaling insufficient soaking. These observations correlate with reported Estimated Ultimate Recoveries (EURs), validating PTA as an effective tool for soaking assessment. This work introduces a practical method to evaluate fluid soaking adequacy using real-time shut-in pressure data. The approach empowers operators to make timely data-driven decisions on soaking duration, improving reservoir performance and optimizing well productivity.

Notes

Photovoltaic-Thermal Integrated with Shea Butter as Phase Change Material to Enhance Electrical Efficiency and Hot Water Production in Sub-Saharan Africa: Nigeria as Case Study

Kar Richard Awai

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Africa receives the highest annual sunshine hours of any continent, leading to high temperatures for photovoltaic cells that require effective cooling solutions. The widespread use of paraffin wax in current studies is concerning, as it is derived from fossil fuels, making it neither environmentally friendly nor sustainable. This research provides a comprehensive analysis of photovoltaic-thermal (PVT) systems with phase change materials (PCM) in sub-Saharan Africa, specifically adapted to Nigerian climate conditions. It introduces shea butter as a novel PCM for PVT applications, a topic previously unexplored. Shea butter used as a phase change material for cooling photovoltaic (PV) cells proves to be superior to traditional paraffin wax. Shea butter significantly lowers cell temperatures during peak sunlight hours, leading to improved electrical power output and efficiency (peak: 130.53 W versus 109.78 W for traditional PV) and (peak: 11.35% versus 9.10%), respectively. It also offers notable environmental benefits, being renewable, biodegradable, and associated with a lower carbon footprint. Economically, shea butter promotes income generation and empowerment for women in West Africa. Increasing water flow rates (0.5–2.5 LPM) effectively decreases temperatures, with optimal electrical power at 2.0 LPM. The study identifies an ideal shea butter layer thickness of 0.04 m, balancing thermal capacity and heat transfer efficiency. The payback period for the PVT/PCM system was 1 year less than the traditional PV system, and the LCOE US$0.309/kWh and US$0.222/kWh, respectively. Overall, shea butter proves to be a superior PCM for PV cooling, providing significant environmental, economic, and performance advantages over paraffin wax.

Notes

Factors Enabling Access to Affordable, Reliable, Sustainable and Modern Energy in the European Union

Aldona Migala-Warchol

Rzeszow University of Technology, Poland

By 2050, Europe will become the first climate-neutral continent according to the vision of the European Union (EU). To tackle this challenge, the EU has scheduled to accomplish 17 goals of the United Nations's 2030 Agenda, with Goal 7 addressing the energy sector. The role of public policies is fundamental in this case; however, insufficient in some areas, e.g. when adopting green energy technologies. The purpose of the article is to identify the economic factors that are necessary to achieve Goal 7 of Agenda 2030. To realize the aim of the study and identify economic factors which are significant for implementing the targets of Goal 7 of the 2030 Agenda, two statistical methods were used: the Pearson linear correlation coefficient and linear regression modelling with the scatterplot to present the relationships graphically on a chart. The results of the study confirm that in the EU, the possibility of achieving Goal 7 is dependent on the three economic determinants analyzed, i.e. GDP per capita, unemployment rate, gross domestic spending on research and development.

Notes

Optimization of Compressor Station Operations in Natural Gas Transmission Systems Using Machine Learning and Genetic Algorithms

Javier Alexander Ruiz

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This paper presents the implementation of an in-house operational optimization tool for a natural gas transmission pipeline, designed to reduce compressor station operating hours while maintaining system reliability and operational safety. The solution was implemented as part of a corporate analytics initiative and aligns with the company's strategy for digital transformation, continuous improvement, and operational excellence.

The tool integrates data analytics and advanced optimization techniques to support real-time decision-making at the control center. Machine Learning models, implemented in Python, are used to forecast gas demand and arrival pressure at a downstream consumption station. These predictions are combined with a Case-Based Reasoning (CBR) framework and Genetic Algorithms to evaluate multiple operational scenarios and identify the optimal compressor station scheduling. The objective function minimizes compressor operating hours over a 12-hour planning horizon while ensuring a specified arrival pressure at the consumption station.

The solution has been compiled into a Windows executable and fully integrated into the Control Center environment. It is deployed on an administrative workstation used by control room engineers and complements existing real-time monitoring tools, such as online linepack visualization. The tool is executed on demand by the Control Center Engineer during operations, providing actionable recommendations without interfering with core SCADA systems.

Results demonstrate that the tool enhances operational efficiency, supports proactive decision-making, and contributes to energy savings and emission reduction, while preserving system integrity and operational safety.

Notes

Breakthrough Zero-CO2 Distributed Power Source

Randell Mills

Brilliant Light Power, Inc., Cranbury, NJ

Brilliant Light Power, Inc. (BLP) has completed the engineering to develop a commercial prototype of a new, zero-pollution, primary energy source based on a proprietary hydrogen plasma reaction that releases 200 times the energy of burning hydrogen that can be obtained from water. Our SunCell® having a capital cost of less than 1/10th that of solar was invented and engineered to harness this new source of power. Specifically, BLP is operating a SunCell® at commercial scale (>100 kW) producing power levels that, upon finalization of commercial packaging and integration of a dense receiver array PV converter, can power essentially all power applications with no fuels or grid connection, projected $20/kW cap cost, $0.001 kW/h generation cost with no transmission, distribution, or demand charges, no supply chain issues, and zero pollution including CO2. Our global and significant patent portfolio protects our leading technology position and products.

The SunCell® comprises a plasma cell that injects hydrogen and catalyst, and two electromagnetic pumps serve as electrodes by injecting intersecting molten tin streams from corresponding reservoirs wherein the connected streams carry a low voltage, high current to form a Hydrino®-reaction plasma in a reaction chamber. The SunCell® is an optical power source having a dynamic-transparency plasma window. Optical power or radiation transfers power at 10 to 100 times the power per area compared to conduction and convection of combustion and nuclear power plants. The optical power source is mated with a commercial dense receiver array (DRA) comprising an ensemble of concentrator photovoltaics cells (CPV) that operate at 1000 times the light intensity of solar-farm PV cells to produce electrical power for total electrification of essentially all power loads.

Notes

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