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Improved Efficiency and Reliability of a Single-Stage Solar Water Pumping System

PROJ24018

This paper presents a cost-effective and efficient single-stage standalone solar water pumping system (SWPS) integrating perovskite solar cells (PSCs) and an interior permanent magnet synchronous motor (IPMSM). The design process considers critical factors such as solar cell degradation (approximately 1% per year) and temperature effects to ensure long-term reliability. To optimize system performance, an improved control strategy combining maximum power point tracking (MPPT) for the PV panels and advanced motor control techniques—field-oriented control (FOC) and maximum torque per ampere (MTPA)—is implemented. The control strategy also accounts for degradation impacts to maintain efficiency. Simulation studies in MATLAB/Simulink validate the proposed system, demonstrating superior technical and economic performance. Results indicate that the MPPT algorithm's effectiveness depends on DC capacitance, while proper voltage controller gain design minimizes power fluctuations in steady state. The control approach achieves maximum power point tracking within 1.4 seconds, including motor startup time, making it highly suitable for sustainable agricultural water pumping applications.

A Novel MoCo Based Self-Supervised Learning Framework for Solar Panel Defect Detection

PROJ24019

Defect detection in solar panels is challenged by manual labeling constraints and inefficiencies in traditional inspection methods, especially with large, high-resolution images. This study introduces a novel self-supervised learning approach using the Momentum Contrast (MoCo) framework to overcome these limitations without requiring annotated datasets. By leveraging MoCo's powerful feature extraction combined with K-Nearest Neighbors (KNN) clustering, the proposed method accurately identifies defects while eliminating dependence on labeled data. Evaluated on the ELPV dataset, the approach achieved 96.95% accuracy, surpassing existing unsupervised methods such as KDAD, SAOE, DRA, and BGAD-FAS, and outperforming some supervised models including Adapted VGG19, Adapted VGG16, and ShuffleNet. Further testing on the EL dataset resulted in 99.44% accuracy, demonstrating robustness and adaptability across varied conditions. This framework provides a scalable, automated solution for image-level defect detection, significantly improving inspection efficiency and reducing the need for manual intervention in industrial solar panel monitoring.

Improving Power Quality Problems of Isolated MG Based on ANN Under Different Operating Conditions Through PMS and ASSC Integration

PROJ23389

This paper presents an effective Power Management System (PMS) for an AC microgrid (MG) integrating a diesel generator (DG), permanent magnet wind generator (PMWG), and solar photovoltaic (PV) panel. The PMS employs an adaptable Artificial Neural Network (ANN) whose weights are optimized using the Enhanced Bald Eagle Search (EBES) algorithm to ensure system stability, energy balance, reduced DG fossil fuel consumption, and voltage stability throughout operation. To enhance power quality, an adaptive series shunt compensator (ASSC) with an integrative PID controller is introduced, with its gains self-tuned via EBES for adaptive performance under varying MG conditions. The ASSC effectiveness is demonstrated through harmonic mitigation, dynamic voltage stabilization, reactive power control, and power factor correction. A comprehensive case study based on the Zafarana region, Suez Gulf, Egypt, evaluates the PMS considering realistic weather-driven renewable generation variability, actual load profiles, and transient faults. Results confirm the proposed system's robustness and suitability for improving MG stability and power quality under real-world conditions.

Control of multi-level quadratic DC-DC boost converter for photovoltaic systems

PROJ23390

This paper presents a type-2 fuzzy logic controller (T2FLC) for maximum power point tracking (MPPT) in a high-gain three-level quadratic DC-DC boost converter (TLQDC-DCBC) tailored for photovoltaic (PV) systems. The TLQDC-DCBC efficiently steps up low PV voltages, minimizing power losses and enhancing system efficiency. The proposed T2FLC overcomes limitations of traditional MPPT methods, such as oscillations near the maximum power point in incremental conductance (IC) algorithms and reduced accuracy of type-1 fuzzy logic controllers under uncertain conditions. By integrating interval type-2 fuzzy logic and type-reduction techniques, the controller achieves improved robustness, precision, and adaptability to fluctuating irradiance and temperature. MATLAB simulations demonstrate consistent tracking efficiency exceeding 99.5% across irradiance levels of 700–1000 W/m^2 and temperatures of 25–45°C. Comparative results show T2FLC improves tracking efficiency by up to 5.2% over type-1 fuzzy logic and 7.5% over IC, with faster convergence, lower steady-state error, and enhanced stability. This highlights its potential for optimizing energy extraction in dynamic PV environments.

Reduced switches multilevel inverter with optimized harmonic elimination for photovoltaic system

PROJ23391

The best switching angles are chosen in this study with Artificial Bee Colony (ABC), Genetic algorithms (GA), and Gray wolf algorithm (GWO), slime moiled algorithm (SMA), Whale optimization algorithm (WOA). These angles are selected according to the lowest total harmonic distortion of output load voltage from reduced switches multilevel inverter. These algorithms are used in a hybrid method to solve the transcendental equations for determining switching angles. A 27-level inverter fed by isolated unequal PV panel as DC sources with reduced switches and sources is chosen for this study. Theoretical analysis and Simulation are accomplished using Matlab/Simulink for 27 level reduced switches multilevel inverter. The simulated results validated the practical outcome

Enhanced Inverse Model Predictive Control for EV Chargers: Solution for DC–DC Side

PROJ23392

This article proposes an enhanced control strategy for the DC-DC stage of electric vehicle (EV) chargers using inverse model predictive control (IMPC). IMPC combines the advantages of model predictive control (MPC) with reduced computational complexity, making it well-suited for handling nonlinear, multi-objective, and constrained power converter systems. However, conventional IMPC's performance heavily relies on an accurate dynamic model, making it vulnerable to uncertainties and disturbances. To overcome this, the proposed approach integrates an adaptive estimation technique based on a recursive least squares algorithm for real-time dynamic model identification. This adaptive model enables IMPC to predict optimal switching states more reliably. The control scheme supports constant power, constant current, and constant voltage operation modes with smooth transitions. Validation through simulations and experimental tests on a dual active bridge (DAB) converter demonstrates improved robustness and reliability. This adaptive IMPC approach offers a promising solution for high-performance and dependable EV charging applications under varying operational conditions.

A Comparative Study of Cutting-Edge Bi-Directional Power Converters and Intelligent Control Methodologies for Advanced Electric Mobility

PROJ23393

This study explores various bidirectional converters (BDCs) used in electric vehicles (EVs), focusing on their efficiency, energy density, and cost characteristics. Key types of BDCs, including flyback, forward, and push-pull converters, are reviewed to determine the most suitable options for EV applications. The research also examines control methods such as pulse width modulation (PWM) and hysteresis control, analyzing their impact on output voltage and current regulation. Advantages and disadvantages of each control strategy are discussed in relation to converter performance. Comparative assessments highlight trade-offs between efficiency, cost, and energy density among the converter types. The paper also offers recommendations for selecting appropriate bidirectional converters and control techniques tailored to EV requirements. By consolidating existing research and identifying current challenges, this work provides valuable insights and guidance for future advancements in bidirectional power converter design and control, supporting the development of more efficient and reliable electric mobility solutions.

Multilevel Inverters Design, Topologies, and Applications

PROJ23394

Multilevel inverters (MLIs) have become vital in modern energy conversion, serving low to high-power applications due to their efficient and optimal performance. MLIs address critical challenges such as high total harmonic distortion (THD), switching losses, low fault tolerance, poor output voltage quality, device rating, and switching frequency limitations. These factors lead to diverse MLI classifications tailored to specific applications. However, existing literature often lacks comprehensive coverage of control strategies, design methodologies, and mathematical analyses. This paper presents a detailed review of various MLI topologies, focusing on their structural design, synthesis, mathematical modeling, control techniques, and practical applications. Key features such as switching losses, configuration complexity, cost, load management, and voltage interfacing are systematically examined. The study also compares this review with other prominent works, highlighting its broad scope on MLI evolution, design methods, and utilization. This comprehensive analysis underscores the significance of MLIs in advancing energy conversion technologies across multiple sectors.

An Optimal Energy Dispatch Management System for Hybrid Power Plants: PV-Grid-Battery-Diesel Generator-Pumped Hydro Storage

PROJ23395

This paper proposes a real-time energy management framework for hybrid power plants (HPPs) integrating renewable energy sources (RESs), battery energy storage systems (BESSs), diesel generators (DGs), and pumped hydro storage (PHS). The Energy Dispatch Engine (EDE) uses Mixed-Integer Linear Programming (MILP) and Stochastic Dual Dynamic Programming (SDDP) to optimise energy flows, minimise costs, and manage battery health via State-of-Charge (SoC) constraints. The framework addresses the intermittent nature of RESs and aims to meet daily household energy demands efficiently while reducing carbon emissions. Comparative analysis shows that the SDDP method outperforms MILP, achieving a lower total cost ($180 vs. $219.8 per 24h) and reduced CO2 emissions cost ($8.3 vs. $10.2 per 24h). The results highlight SDDP's effectiveness in optimising discharge/charge profiles and overall HPP operation under various tariff schemes. This study provides valuable insights for cost-effective and environmentally friendly energy management in hybrid systems combining multiple energy sources and storage technologies.

Coordinated Control Strategy-Based Energy Management of a Hybrid AC-DC Microgrid Using a Battery–Supercapacitor

PROJ23396

This paper presents a standalone microgrid (MG) powered primarily by photovoltaic (PV) energy and supported by a hybrid energy storage system (HESS) combining batteries and supercapacitors. The MG supplies both alternating current (AC) and direct current (DC) loads, with batteries and supercapacitors connected in parallel to the DC bus via bidirectional converters. DC loads are directly connected to the DC bus, while AC loads are powered through a DC-AC inverter. A novel control strategy based on Boolean logic analysis is implemented to manage solar irradiation fluctuations and load variations efficiently. This approach simplifies energy management system (EMS) control by translating flowchart logic into Boolean functions, reducing complexity and errors in system operation. Simulation results with a 400 V DC bus and a 6-second low-pass filter demonstrate the system's capability to maintain stable voltage and effectively respond to both AC and DC load demands. The proposed strategy enhances MG reliability while simplifying controller design and implementation.

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Estimation of Energy-Saving Potential Using Commercial SiC Power Converters

PROJ23397

This study evaluates the annual global energy-savings potential of various power electronics applications utilizing commercial silicon carbide (SiC) wide bandgap (WBG)-based power converters. As the first analysis to focus on real market products, our findings reveal that SiC-based converters offer significant energy-saving potential across all examined applications. Additionally, given the substantial yearly growth in installing photovoltaic (PV) systems and electric vehicle (EV) chargers, we project a considerable future energy-saving potential. This research underscores the importance of SiC technology in enhancing energy efficiency and supports its broader adoption in power electronics to achieve global energy savings.

Real-Time Scheduling Optimization of Integrated Energy Systems in Smart Grids based on Approximate Dynamic Programming

PROJ23398

With the large-scale integration of renewable energy (RE) sources and rapid advancements in smart grid (SG) technologies, the efficient integration of diverse energy resources to achieve supply-demand balance and maximize cost-effectiveness has emerged as a research hotspot in the energy sector. This paper addresses the real-time scheduling challenge in integrated energy systems (IES) within the context of SG, emphasizing pivotal factors such as electric and thermal load scheduling, energy storage control, dynamic electricity pricing, carbon emission mechanisms, and demand response (DR). To this end, we propose a comprehensive scheduling model tailored for IES, aiming to minimize the total cost over the dispatch cycle. Furthermore, an optimal scheduling algorithm based on approximate dynamic programming (ADP) was designed to solve this model. Numerical experiments reveal that, while ensuring user comfort, the proposed real-time scheduling scheme, by comprehensively considering the interactions among various system inputs, significantly enhances system flexibility and economic performance. It effectively tackles the uncertainty of RE, thereby improving energy utilization efficiency.

Modeling and Analysis of Power Distribution Networks with HVAC Load Management

PROJ23399

This paper proposes a dynamic multi-scenario modeling approach for air conditioning (AC) cluster loads, integrating occupant behavior, spatiotemporal activity distributions, and meteorological factors. A refined unregulated load baseline is established to better isolate and evaluate the effects of AC usage on overall distribution network loads. Simulation results under various scenarios indicate that the proposed framework accurately captures cluster-level load responses, effectively reflecting the interplay among occupant activities, temperature variations, and regional characteristics. The outcomes demonstrate the model's potential to enhance AC load forecasting and support intelligent demand-side management in smart grids, offering both theoretical and practical insights for future load regulation strategies.

Impact of Coordinated Electric Ferry Charging on Distribution Network Using Metaheuristic Optimization

PROJ23400

The maritime shipping sector significantly contributes to greenhouse gas emissions, especially in coastal areas. Electric ferries powered by renewable energy and supported by battery energy storage systems (BESSs) offer a promising decarbonization solution. This study evaluates the operational impacts of coordinated electric ferry charging on a medium-voltage distribution network at Gladstone Marina, Queensland, Australia. Using DIgSILENT PowerFactory integrated with MATLAB Simulink and a Python-based control system, simulations are conducted for four ferry terminals equipped with BESSs. A dynamic BESS operation model is optimized via a hybrid metaheuristic algorithm combining Genetic Algorithm, Particle Swarm Optimization, and Bacterial Foraging Optimization (GA-PSO-BFO). Under 50% and 80% transformer loading, charge–discharge coordination enhances voltage stability by 1.0–1.5%, reduces transformer loading by 3–4%, and feeder line loading by 2.5–3.5%, while charge-only coordination shows minimal benefits. Quasi-dynamic analysis confirms improved system stability. These results demonstrate the effectiveness of coordinated energy management for electric ferries, supporting sustainable maritime operations.

Advanced MATLAB Simulation of Electric Vehicle DC-DC Buck Converter with Brushless DC Motor Integration

PROJ23401

This study presents an advanced MATLAB simulation framework for an electric vehicle (EV) system integrating a DC-DC buck converter with a Brushless DC (BLDC) motor. The framework aims to improve energy efficiency, motor control accuracy, and overall system performance in EV applications. The buck converter is modeled to regulate voltage effectively, ensuring optimal power delivery to the BLDC motor across varying load and operational conditions. A detailed dynamic model of the BLDC motor captures its electrical and mechanical behaviors, enabling analysis of speed, torque, and efficiency. Additionally, a feedback-based control strategy is implemented to maintain stable and precise motor operation during rapid load changes and voltage fluctuations. This integrated simulation highlights the critical role of power electronics in EV powertrains and offers a versatile platform for testing and optimizing key components. The proposed model provides a valuable foundation for future advancements in EV control strategies and energy management systems.

The Future of Electric Vehicles: Advanced Design, Modeling, and Simulation for Next-Generation Performance Using

PROJ23402

This paper investigates next-generation electric vehicle (EV) performance improvements through advanced modeling and simulation using MATLAB. It focuses on simulating key EV components—electric motors, battery systems, power electronics, and control algorithms—to optimize powertrain efficiency and overall vehicle performance. The MATLAB hybrid vehicle model was validated against ADVISOR's published data, showing strong correlation with minor discrepancies deemed insignificant. Fuel economy comparisons using EPA's New York City Cycle (NYCC) and Highway Fuel Economy Cycle (HWFET) revealed an 8.9% and 14.3% improvement for the hybrid vehicle over conventional models, respectively. Energy consumption and regeneration during assist and braking modes were also quantified, demonstrating effective energy management. The modular and flexible MATLAB/ADAMS platform enables easy customization for diverse vehicle models. This simulation-driven design approach supports enhanced efficiency, extended range, and improved performance, paving the way for sustainable transportation solutions and the continued evolution of electric mobility.

Regenerative Braking System (RBS) MOSFET Switching-Based Drive Cycle for an Electric Motorcycle

PROJ23403

This paper investigates the operation of a regenerative braking system (RBS) for electric vehicles using urban drive cycles, specifically the US60 and NEDC cycles. The study calculates output torque based on vehicle dynamics to identify braking instances where torque is negative, activating regenerative braking and increasing the battery's state of charge (SoC). The RBS design employs four MOSFETs as switching devices to facilitate energy recovery during deceleration. Simulation results reveal that at 50% SoC, the first regenerative event improved performance by 12.22%, with a subsequent gain of 5.96%. At 80% SoC, the first event yielded a 12.55% improvement, while the second showed a 6.19% increase. These increases in SoC demonstrate the system's effectiveness in capturing and storing kinetic energy. The MATLAB-based simulation provides a foundation for future work on regenerative braking control strategies, aiming to enhance energy efficiency and extend battery life in electric vehicle applications.

Battery, Super Capacitor-Based Hybrid Energy Storage with PV for Islanded DC Microgrid

PROJ23404

This paper investigates a hybrid energy storage system integrated with solar photovoltaic (PV) technology for an islanded DC microgrid. As renewable energy adoption grows due to environmental concerns and fossil fuel depletion, energy storage systems become essential for managing the intermittent and unpredictable nature of solar power. The study models and simulates an islanded DC microgrid using MATLAB Simulink, incorporating solar PV, batteries, and supercapacitors. A two-stage DC converter with Maximum Power Point Tracking (MPPT) optimizes solar energy extraction, while a bidirectional converter regulates the Battery Energy Storage System (BESS) to maintain stable DC bus voltage. The research analyzes both transient and steady-state responses of the hybrid storage system, highlighting its ability to swiftly adapt to sudden load changes. Results demonstrate the effectiveness of combining batteries and supercapacitors in enhancing microgrid stability and performance. This work contributes to advancing reliable, efficient energy management solutions for isolated renewable-powered microgrids.

Adaptive Control of a Hybrid Microgrid With Energy Storage System

PROJ23405

This paper addresses the challenge of reduced inertia in hybrid microgrids (HμGs) caused by the increased integration of Renewable Energy Resources (RER) and Energy Storage Systems (ESSs), which compromises frequency and voltage stability. To enhance dynamic response, a PID-based Model Reference Adaptive Control (MRAC) is applied to the synchronous generator (SG). The study explores the role of ESSs, particularly supercapacitors (SC), to emulate dynamic inertia and support rapid frequency regulation. The adaptive control of the SG enables swift adjustments to maintain optimal frequency, while ESSs stabilize power fluctuations and balance load-supply variations, ensuring steady standalone operation. Advanced metaheuristic optimization techniques are employed to tune the controllers for the SC, battery, and MRAC of the SG, optimizing system performance. Simulation results validate the effectiveness of combining SC-based inertia emulation with adaptive control, demonstrating significant improvements in frequency stability and dynamic performance of the two-area HμGs under standalone conditions.

A learning-based energy management strategy for hybrid energy storage systems with compressed air and solid oxide fuel cells

PROJ23406

This paper addresses the challenges of intermittency and volatility in renewable energy integration by proposing a self-adaptive energy management strategy using deep reinforcement learning (DRL). The system integrates compressed air energy storage, battery energy storage, and solid oxide fuel cells to enhance flexibility and reliability. The study identifies limitations in the basic Deep Deterministic Policy Gradient (DDPG) algorithm, particularly its low sensitivity to environmental changes and capacity mismatches within the hybrid storage system, which can impair optimal charging and discharging decisions. To overcome this, the algorithm is improved through a carefully designed replay buffer that enhances detection of subtle reward function variations. The proposed DRL method is compared with other DRL approaches to validate its feasibility and effectiveness. Simulation results demonstrate that the enhanced algorithm, coupled with the energy management strategy, improves economic performance and system adaptability, offering a promising solution for efficient and resilient renewable energy integration in modern power systems.

Solving optimal power flow problem for IEEE-30 bus system using a developed particle swarm optimization method

PROJ23407

This paper presents a developed Particle Swarm Optimization (PSO) method to solve the Optimal Power Flow (OPF) problem, focusing on minimizing generation fuel costs while satisfying system constraints. The approach targets utility and industrial power systems, optimizing control parameters to reduce fuel costs, active/reactive power losses, and emissions. The developed PSO algorithm is tested on the IEEE 30-bus system and compared against conventional PSO and other advanced algorithms including Backtracking Search Algorithm (BSA), hybrid SFLA-SA, Differential Evolution (DE), Enhanced Genetic Algorithm (EGA), and Monarch Butterfly Optimization (MBO). Results show the proposed PSO achieves a fuel cost of $786.03/h, outperforming others by reducing fuel cost by 4.358% compared to the robust MBO algorithm. The study demonstrates that the proposed method effectively enhances economic and operational efficiency in power system management. MATLAB simulations validate the accuracy and effectiveness of the approach, confirming its potential for practical OPF applications.

Capacitor Placement in Power Distribution Networks for Voltage Profile Improvement and Loss Reduction Using Revolution Optimization Algorithm

PROJ23408

This paper presents a two-stage procedure to identify the optimal locations and sizes of capacitors in radial distribution systems. In first stage, the loss sensitivity analysis using two loss sensitivity indices (LSIs) is employed to select the most candidate capacitors locations. In second stage, the ant colony optimization (ACO) algorithm is investigated to find the optimal locations and sizes of capacitors considering the minimization of energy loss and capacitor costs as objective functions while system constraints are fully achieved. The fixed, practical switched and the combination of fixed

Optimal integration of photovoltaic sources and capacitor banks considering irradiance, temperature, and load changes in electric distribution system

PROJ23409

This paper introduces the Efficient Metaheuristic BitTorrent (EM-BT) algorithm, aimed at optimizing the placement and sizing of photovoltaic renewable energy sources (PVRES) and capacitor banks (CBs) in electric distribution networks. The main goal is to minimize energy losses and enhance voltage stability over 24 h, taking into account varying load profiles, solar irradiance, and temperature effects. The algorithm is rigorously tested on standard distribution networks, including the IEEE 33, IEEE 69, and ZB-ALG-Hassi Sida 157-bus systems. The results reveal that EM-BT outperforms established methods like Particle Swarm Optimization (PSO), Grey Wolf Optimizer (GWO), and Whale Optimization Algorithm (WOA), demonstrating its effectiveness in reducing energy losses and maintaining stable voltage profiles. By effectively combining PVRES and CBs, this research highlights a robust approach to enhancing both technical performance and operational reliability in distribution systems. Additionally, the consideration of temperature effects on PVRES efficiency adds depth to the study, making it a valuable contribution to the field of power system optimization.

Economic Dispatch and Power Flow Analysis for Microgrids

PROJ23410

This study explores economic dispatch and optimal power flow (OPF) in microgrids, focusing on a single-bus islanded and a three-bus grid-tied configuration. The system integrates renewable energy sources (solar PV, wind turbines), battery energy storage systems (BESS), and conventional generators (CHP, diesel, natural gas) to ensure cost-effective and reliable operation. Economic dispatch optimizes resource allocation over daily and weekly periods, maximizing renewable energy use and strategically employing BESS to mitigate intermittency. OPF analysis manages active and reactive power distribution, maintaining voltage stability and meeting operational constraints. Results indicate the microgrid meets load demand with minimal dependence on costly external grid power. For the grid-tied microgrid, dispatch prioritizes low-cost sources, with Bus 1 supplying the majority due to favorable economics. Voltage remains within acceptable limits, though dynamic load changes highlight the need for secondary voltage control. The findings validate the proposed strategies in achieving sustainable, economically efficient, and stable microgrid performance.

Fault Detection and Classification in Ring Power System With DG Penetration Using Hybrid CNN-LSTM

PROJ23411

This paper presents three deep learning models—CNN, LSTM, and a hybrid CNN-LSTM—for fault detection, classification, and location estimation in smart grids integrated with renewable energy sources. These models analyze pre- and post-fault voltage and current signals collected from multiple locations within test networks. The CNN extracts key features from the 1D signal data, which the LSTM then processes to accurately identify and locate faults. The proposed methods were evaluated using simulation data from IEEE 6-bus and 9-bus systems, considering various fault types, locations, and ground fault resistances. The study also accounts for network topology changes and the presence of distributed generators (DGs). Results show that the hybrid CNN-LSTM model outperforms existing approaches in fault detection, classification, and localization accuracy, demonstrating high robustness and reliability. This highlights the effectiveness of advanced deep learning techniques in addressing fault management challenges in modern smart grids with dynamic fault currents from renewable energy sources.