Titles & Abstract

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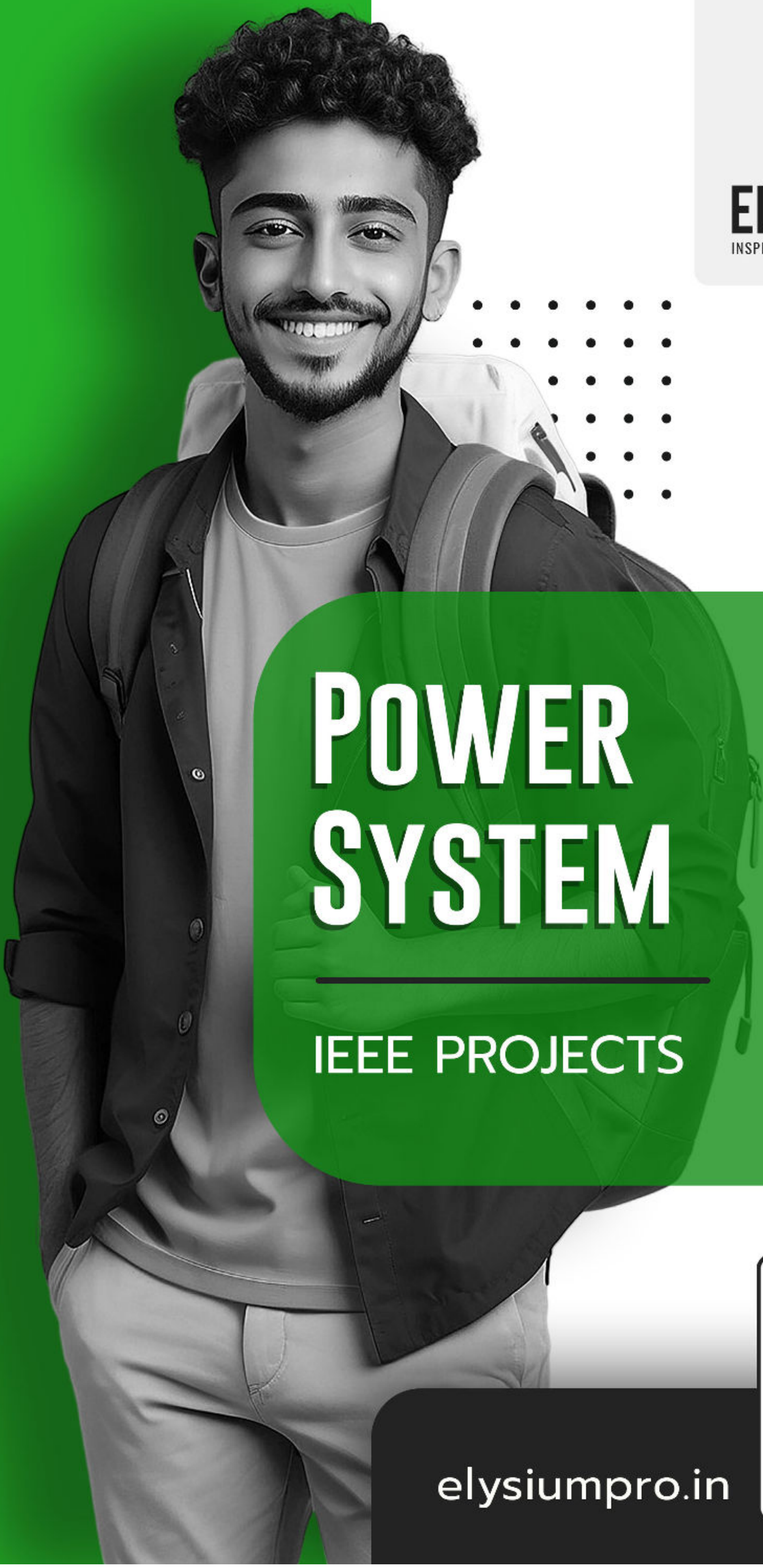

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EPRO-PS-001

PowerFlowMultiNet: Multigraph Neural Networks for Unbalanced Three-Phase Distribution Systems

Efficiently solving unbalanced three-phase power flow in distribution grids is crucial for accurate grid analysis and simulation. Traditional methods and existing deep learning approaches predominantly focus on balanced networks, neglecting the complexities inherent in unbalanced systems. This paper introduces PowerFlowMultiNet, a novel multigraph Graph Neural Network (GNN) framework explicitly designed for unbalanced three-phase power grids. PowerFlowMultiNet models each phase separately within a multigraph structure, effectively capturing the asymmetry of unbalanced grids. Utilizing a graph embedding mechanism with message passing, the framework captures spatial dependencies within the power system network. The dataset is preprocessed with normalization and label encoding, followed by visualizations to understand data distribution and correlations.

EPRO-PS-002

Reclosers Modeling for Temporal Simulation of Distribution Networks in Simulink/Matlab

Over the past few years, Brazils increasing dependence on electricity has caused a continuous growth in demand and, therefore, the need to guarantee long-term energy supply to costumers. Hence, studying the devices that are responsible ensuring this continuity is critical since the improper operation of this equipment can reduce the reliability of the electrical energy distribution system, therefore requiring detailed study that incorporates simulations, modeling, and analysis of response capacity in the face of real loads. Simulink/Matlab is one of the most widely used software programs in academia. However, it does not have readymade templates for protection system equipment such as relays, fuses, and reclosers. Herein, the aim is to model the digital recloser using the S-function block of Simulink/Matlab. The proposed model for the recloser follows the configurations required by Brazilian electricity distribution companies, i.e. four operations divided into fast and slow, the latter one being responsible for permanently opening the section of the system on fault. To validate the modeled device, the IEEE 34-bar system was used, in which several operational cases were considered.

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EPRO-PS-003

Multi-Micro Grid System Reinforcement Across Deregulated Markets, Energy Resources

Multi-agent based small scaled smart grid reinforcement scheme is proposed to manage energy resources by enhancing resilience to supply power to critical loads in peak demand by leveraging demand side management (DSM) for smoothing load profile and optimal energy storage system (ESS) scheduling in response to grid cost. Interconnected microgrids comprise diverse energy resources that allow sharing energy to balance fluctuation by deploying a market that rewards cheap energy. Three stages are defined in this proposed scheme. In the first stage, without DER, consumption charges are reduced to 7.1% through DSM, but customer comfort is compromised. In the second stage, microgrids comprise RER; energy consumption-related charges are reduced to 92.2% by the feed-in tariff (FIT) Program. In the final stage, the inclusion of energy market for trading among microgrids (ESS, diesel and RER) resulting in reduced charges greater than charges incurred from the grid is defined by 122.1%.

EPRO-PS-004

Passivity and Decentralized Stability Conditions for Grid-Forming Converters

We prove that the popular grid-forming control, i.e., dispatchable virtual oscillator control (dVOC), also termed complex droop control, exhibits output-feedback passivity in its large-signal model, featuring an explicit and physically meaningful passivity index. Using this passivity property, we derive decentralized stability conditions for the transient stability of dVOC in multi-converter grid-connected systems, beyond prior small-signal stability results. The decentralized conditions are of practical significance, particularly for ensuring the transient stability of renewable power plants under grid disturbances.

EPRO-PS-005

Quantitative Stability Conditions for Grid-Forming Converters With Complex Droop Control

– In this article, we consider a dc microgrid composedof distributed generation units (DGUs) trading energy amongeach other, where the energy price depends on the total currentgenerated by all the DGUs. We then use a Cournot aggregativegame to describe the self-interested interaction among the DGUs,where each DGU aims at minimizing the deviation with respectto the given reference signals and maximizing the revenue from the sale of the generated power. Thus, we design afully distributed continuous-time equilibrium-seeking algorithmto compute the generalized Nash equilibrium (GNE) of thegame. We interconnect the designed decision-making algorithmwith the dynamics of the microgrid in a passive way, and,by leveraging passivity theory, we prove theconvergence of theclosed-loop system trajectory to a feasible operating point thatis also a Nash equilibrium of the collective aggregative game.Finally, we present extensive simulation results that validate the proposed distributed optimal control scheme, showing excellentperformance.

EPRO-PS-006

Distributed Control of Islanded DC Microgrids: A Passivity-Based Game Theoretical Approach

The intermittency of renewable energy sources (RESs) leads to the incorporation of energy storage systems into microgrids (MGs). In this article, a novel strategy based on model predictive control is proposed for the management of a wind–solar MG composed of RESs and a hydrogen energy storage system. The system is involved in the daily and regulation service markets, characterized by different timescales. The long-term operations related to the daily market are managed by a high-layer control, which schedules the hydrogen production and consumption to meet the load demand, maximizes the revenue by participating in the electricity market, and minimizes the operational costs. The short-term operations related to the real-time market are managed by a low-layer control (LLC), which corrects the deviations between the actual and forecasted conditions, by optimizing the power production according to the participation in the market and the short-term dynamics and constraints of the equipment. In addition, the LLC is in charge of smoothing the power provided to the grid. Numerical simulations demonstrate that the strategy effectively operates the MG by satisfying constraints and energy demands while minimizing device costs. Moreover, when compared to other strategies, the controller yields fewer state

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EPRO-PS-007

A Coordinated Multitimescale Model Predictive Control for Output Power Smoothing in Hybrid

The intermittency of renewable energy sources (RESs) leads to the incorporation of energy storage systems into microgrids (MGs). In this article, a novel strategy based on model predictive control is proposed for the management of a wind–solar MG composed of RESs and a hydrogen energy storage system. The system is involved in the daily and regulation service markets, characterized by different timescales. The long-term operations related to the daily market are managed by a high-layer control, which schedules the hydrogen production and consumption to meet the load demand, maximizes the revenue by participating in the electricity market, and minimizes the operational costs. The short-term operations related to the real-time market are managed by a low-layer control (LLC), which corrects the deviations between the actual and forecasted conditions, by optimizing the power production according to the participation in the market and the short-term dynamics and constraints of the equipment.

EPRO-SP-008

PowerFlowMultiNet: Multigraph Neural Networks for Unbalanced Three-Phase Distribution Systems

Efficiently solving unbalanced three-phase power flow in distribution grids is pivotal for grid analysis and simulation. There is a pressing need for scalable algorithms capable of handling large-scale unbalanced power grids that can provide accurate and fast solutions. To address this, deep learning techniques, especially Graph Neural Networks (GNNs), have emerged. However, existing literature primarily focuses on balanced networks, leaving a critical gap in supporting unbalanced three-phase power grids. This letter introduces PowerFlowMultiNet, a novel multigraph GNN framework explicitly designed for unbalanced three-phase power grids. The proposed approach models each phase separately in a multigraph representation, effectively capturing the inherent asymmetry in unbalanced grids. A graph embedding mechanism utilizing message passing is introduced to capture spatial dependencies within the power system network. PowerFlowMultiNet outperforms traditional methods and other deep learning approaches in terms of accuracy and computational speed. Rigorous testing reveals significantly lower error rates and a notable hundredfold increase in computational speed for large power networks compared to model-based methods

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EPRO-PS-009

FaultSSL: Seismic Fault Detection via Semi-supervised learning

The prevailing methodology in data-driven fault detection leverages synthetic data for training neural networks. However, it grapples with challenges when it comes to generalization in surveys exhibiting complex structures. To enhance the generalization of models trained on limited synthetic datasets to a broader range of real-world data, we introduce FaultSSL, a semi-supervised fault detection framework. This method is based on the classical mean teacher structure, with its supervised part employs synthetic data and a few 2D labels. The unsupervised component relying on two meticulously devised proxy tasks, allowing it to incorporate vast unlabeled field data into the training process. The two proxy tasks are PaNning Consistency (PNC) and PaTching Consistency (PTC). PNC emphasizes the feature consistency of the overlapping regions between two adjacent views in predicting the model. This allows for the extension of 2D slice labels to the global seismic volume. PTC emphasizes the spatially consistent nature of faults.

EPRO-SP-010

Convex Optimal Power Flow Based on Power Injection-based Equations and Its Application in

Optimal power flow (OPF) is a fundamental tool for the operation analysis of bipolar DC distribution network (DCDN). However, existing OPF models based on current injection-based equations face challenges in reflecting the power distribution and exchange of bipolar DCDN directly since its decision variables are voltage and current. This paper addresses this issue by establishing a convex OPF model that can be used for the planning and operation of bipolar DCDN. As a novel OPF model, the power flow characteristics of bipolar DCDN are revealed through power injection rather than current injection, ensuring its applicability and convenience in power optimization problems. Furthermore, the original OPF model based on power injection-based equations is introduced, and for the first time, second-order cone programming (SOCP) is utilized to relax the non-convex terms within it. Notely, McCormick envelopes are used to restrict the feasible region of the convex model, thereby reducing the influence of SOCP relaxation. To enhance the tightness of the feasible region of the convex model, the refined sequence bound tightening algorithm (SBTA) is employed to adjust the boundaries within McCormick envelopes.

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EPRO-PS-011

PowerFlowMultiNet: Multigraph Neural Networks for Unbalanced Three-Phase Distribution Systems

Efficiently solving unbalanced three-phase power flow in distribution grids is pivotal for grid analysis and simulation. There is a pressing need for scalable algorithms capable of handling large-scale unbalanced power grids that can provide accurate and fast solutions. To address this, deep learning techniques, especially Graph Neural Networks (GNNs), have emerged. However, existing literature primarily focuses on balanced networks, leaving a critical gap in supporting unbalanced three-phase power grids. This letter introduces PowerFlowMultiNet, a novel multigraph GNN framework explicitly designed for unbalanced three-phase power grids. The proposed approach models each phase separately in a multigraph representation, effectively capturing the inherent asymmetry in unbalanced grids. A graph embedding mechanism utilizing message passing is introduced to capture spatial dependencies within the power system network.

EPRO-SP-012

An_Energy-Based_Model_of_Four-Switch_BuckBoost_Converter

The four-switch buck–boost (FSBB) topology is widely used alongside isolated converters to enhance voltage range capabilities. In these applications, independent control of the duty-cycles of the FSBB's two legs and phase shifting are employed to shape the inductor current ripple, enabling zero voltage switching. This presentation introduces a novel nonlinear average model and its corresponding linearized small-signal model for the FSBB, accounting for the dynamics of phase shift and duty-cycles. The inductor energy-based approach accurately describes these dynamics. The proposed models demonstrate excellent alignment with simulation results and are validated through experimental measurements.

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EPRO-PS-013

Centralised Multimode Power Oscillation Damping Controller for Photovoltaic Plants With Communication Delay Compensation

Low-frequency oscillations are an inherent phenomena in transmission networks and renewable energy plants should be configured to damp them. Commonly, a centralised controller is used in PV plants to coordinate PV generators via communication channels. However, the communication systems of PV plants introduce delays of a stochastic nature that degrade the performance of centralised control algorithms. Therefore, controllers for oscillation damping may not operate correctly unless the communication channel characteristics are not considered and compensated. In this article, a centralised controller is proposed for the oscillation damping that uses a PV plant with all the realistic effects of communication channels taken into consideration. The communication channels are modelled based on measurements taken in a laboratory environment, considering its stochastic nature. The controller is designed to damp several modes of oscillation by using the open-loop phase shift compensation.

EPRO-SP-014

Decentralized_Dynamic_Power_Sharing_Control_for_Frequency_Regulation_Using_Hybrid_Hydrogen_Electrolyzer_Systems

Hydrogen electrolyzers are promising tools for frequency regulation of future power systems with high penetration of renewable energies and low inertia. This is due to both the increasing demand for hydrogen and their flexibility as controllable load. The two main electrolyzer technologies are Alkaline Electrolyzers (AELs) and Proton Exchange Membrane Electrolyzers (PEMELs). However, they have trade-offs: dynamic response speed for AELs, and cost for PEMELs. This paper proposes the combination of both technologies into a Hybrid Hydrogen Electrolyzer System (HHES) to obtain a fast response for frequency regulation with reduced costs. A decentralized dynamic power sharing control strategy is proposed where PEMELs respond to the fast component of the frequency deviation, and AELs respond to the slow component, without the requirement of communication. The proposed decentralized approach facilitates a high reliability and scalability of the system, what is essential for expansion of hydrogen production. The effectiveness of the proposed strategy is validated in simulations and experimental results.

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EPRO-PS-015

Gain and Phase: Decentralized Stability Conditions for Power Electronics-Dominated Power Systems

This paper proposes decentralized stability conditions for multi-converter systems based on the combination of the small gain theorem and the small phase theorem. Instead of directly computing the closed-loop dynamics, e.g., eigenvalues of the state-space matrix, or using the generalized Nyquist stability criterion, the proposed stability conditions are more scalable and computationally lighter, which aim at evaluating the closed-loop system stability by comparing the individual converter dynamics with the network dynamics in a decentralized and open-loop manner. Moreover, our approach can handle heterogeneous converters' dynamics and is suitable to analyze large-scale multi-converter power systems that contain grid-following (GFL), grid-forming (GFM) converters, and synchronous generators. Compared with other decentralized stability conditions, e.g., passivity-based stability conditions, the proposed conditions are significantly less conservative and can be generally satisfied in practice across the whole frequency range.

EPRO-SP-016

Fast and Accurate Non-linear Model for Synchronous Machines Including Core Losses

Over the past few years, Brazils increasing dependence on electricity has caused a continuous growth in demand and, therefore, the need to guarantee long-term energy supply to costumers. Hence, studying the devices that are responsible ensuring this continuity is critical since the improper operation of this equipment can reduce the reliability of the electrical energy distribution system, therefore requiring detailed study that incorporates simulations, modeling, and analysis of response capacity in the face of real loads. Simulink/Matlab is one of the most widely used software programs in academia. However, it does not have readymade templates for protection system equipment such as relays, fuses, and reclosers. Herein, the aim is to model the digital recloser using the S-function block of Simulink/Matlab. The proposed model for the recloser follows the configurations required by Brazilian electricity distribution companies, i.e. four operations divided into fast and slow, the latter one being responsible for permanently opening the section of the system on fault. To validate the modeled device, the IEEE 34-bar system was used, in which several operational cases were considered.

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EPRO-PS-017

Predicting DC-Link Capacitor Current Ripple in AC-DC Rectifier Circuits Using Fine-Tuned Large

This paper presents a fast and accurate state-space model for synchronous machines taking into consideration the machine geometry, material non-linearities and core losses. The model is first constructed by storing the solutions of multiple static finite element (FE) simulations into lookup-tables (LUTs) to express the stator flux linkages as functions of the state variables, i.e., the winding currents and the rotor position. Different approaches are discussed to include the core loss into the model. A novel approach is presented for constructing a pre-computed LUT for the core loss as a function of the state variables and their time derivatives so that the loss can be directly interpolated when time-stepping the state-space model. The Simulink implementation of the proposed core-loss model shows a good match with time-stepping FE results with a 120-fold speedup in computation. In addition, comparison against calorimetric loss measurements for a 150-kVA machine operating under both sinusoidal and pulse-width modulated voltage supplies is presented to validate the model accuracy.

EPRO-SP-018

Capacitor Voltage Balancing Method for the Hybrid Multilevel Converter Considering Grid Voltage Sags

Compared to the traditional modular multilevel converter and alternative arm converter, the hybrid multilevel converter (HMC) exhibits superiority in terms of cost and volume. In the HMC, the pulse width of the direction switch (DS) is conventionally utilized to maintain capacitor voltage balancing (CVB). However, this method has certain limitations, including a restricted range of modulation indices and the inability to support pure reactive power operation. To address these drawbacks, a new CVB method based on the phase angle of the DS is proposed in this article. Compared to the traditional method, the proposed method enables the HMC to achieve a full range of modulation index and four-quadrant operation. Additionally, it demonstrates improved performance in terms of SM capacitance and capacitor voltage ripple, especially under severe grid voltage sags and low power factors. A comparative analysis is conducted between two CVB methods, focusing on the SM number, switch number, and SM capacitance. Furthermore, a unified control strategy considering asymmetrical and symmetrical grid voltage sags is proposed for these two CVB methods. Finally, the effectiveness and superiority of the proposed CVB methods are verified by simulation and experimental testing.

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EPRO-PS-019

Progress in artificial intelligence applicationsbasedon the combination of self-driven sensorsanddeeplearning

In the era of Internet of Things, how to develop a smart sensor system with sustainable power supply, easy deployment and flexible use has become a difficult problem to be solved. The traditional power supply has problems such as frequent replacement or charging when in use, which limits the development of wearable devices. The contact-to-separate friction nanogenerator (TENG) was prepared by using polychotomy thy lene (PTFE) and aluminum (Al) foils. Human motion energy was collected by human body arrangement, and human motion posture was monitored according to the changes of output electrical signals. In 2012, Academician Wang Zhong lin and his team invented the triboelectric nanogenerator (TENG), which uses Maxwell displacement current as a driving force to directly convert mechanical stimuli into electrical signals, so it can be used as a self-driven sensor. Teng-based sensors have the advantages of simple structure and high instantaneous power density, which provides an important means for building intelligent sensor systems

EPRO-SP-020

Effective Application of IoT Power Electronics Technology and Power System Optimization Control

With the development of society, the power system plays an important role in the global energy structure. However, facing increasing energy demand and environmental pressure, improving power system efficiency, reducing costs, and ensuring reliability and safety have become key issues. The Internet of Things (IoT) power electronics technology, as one of the research hotspots, integrates IoT and power electronics technology to achieve intelligent and optimized control of power systems through sensors, communication, and control technologies. In order to meet current and future needs, it is necessary to optimize the operation and management of power systems using IoT power electronics technology. By analyzing the application of Internet of Things power electronics technology and the optimal dispatch of power systems, support vector machine algorithms are used to analyze and process equipment data, and perform data monitoring and anomaly detection to promote energy waste reduction and energy saving, and then start from operation and maintenance respectively. Comparative simulation experiments were conducted in five aspects: efficiency, effectiveness of power load prediction and optimization control, effectiveness of intelligent monitoring, operating costs, and data security.

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EPRO-PS-021

Efficient and Fast Wind Turbine MPPT Algorithm Using TS Fuzzy Logic and Optimal Relation

The output power of an ocean wave energy (WE) system has an intermittent and stochastic characteristic. WE output power can be transferred to the grid without sudden fluctuations when combined with a hybrid energy storage system (HESS) consisting of a battery pack and an ultracapacitor (UC) module. The study presented in this paper identifies the lowest-cost HESS sizing for WE systems by using a genetic algorithm (GA) optimization method. In this study, the system cost was reduced with the HESS cost and sizing study for ocean WE converter systems, and the battery was used effectively for a longer cycle. GA optimization has been applied in the field of HESS in ocean WE systems and has brought innovation to the literature with its optimum cost and sizing study. An optimum design model is presented considering the maximum/minimum voltage and current limits and the energy storage units' temperature and depth of discharge parameters. The series and parallel connection calculations and the required number of battery and UC cells are given in the sizing section.

EPRO-SP-022

Genetic Algorithm-Based Optimal Sizing of Hybrid Battery/Ultracapacitor Energy Storage

The output power of an ocean wave energy (WE) system has an intermittent and stochastic characteristic. WE output power can be transferred to the grid without sudden fluctuations when combined with a hybrid energy storage system (HESS) consisting of a battery pack and an ultracapacitor (UC) module. The study presented in this paper identifies the lowest-cost HESS sizing for WE systems by using a genetic algorithm (GA) optimization method. In this study, the system cost was reduced with the HESS cost and sizing study for ocean WE converter systems, and the battery was used effectively for a longer cycle. GA optimization has been applied in the field of HESS in ocean WE systems and has brought innovation to the literature with its optimum cost and sizing study. An optimum design model is presented considering the maximum/minimum voltage and current limits and the energy storage units' temperature and depth of discharge parameters. The series and parallel connection calculations and the required number of battery and UC cells are given in the sizing section. The GA optimization was performed in MATLAB, and the energy storage rate for the 625-kW system and the power and energy results of the energy storage units were given as a result of the optimum cost analysis.