SCEMS 2025

CATALOG

About

Conference Details

HISTORY OF THE IEEE SCEMS

SCEMS 2018

The 1st SCEMS
Dec. 14-16, 2018
Huzhou, China

SCEMS 2019

The 2nd SCEMS
Nov. 1-3, 2019
Busan, Korea

SCEMS 2020

The 3rd SCEMS
Dec. 4-6, 2020
Jinan, China

SCEMS 2021

The 4th SCEMS
Dec. 1-3, 2021
Huzhou, China

SCEMS 2022

The 5th SCEMS
Nov. 24-26, 2022
Busan, Korea

SCEMS 2023

The 6th SCEMS
Dec. 7-9, 2023
Huzhou, China

SCEMS 2024

The 7th SCEMS
Nov. 6-8, 2024
Macao, China

SCEMS 2025

WELCOME MESSAGE

Ji-Hoon Han

IEEE SCEMS 2025 General Chair

We are very pleased to welcome you to the 2025 IEEE 8th Student Conference on Electric Machines and Systems (IEEE SCEMS 2025), which is organized by the KIEE EMECS Student committee and will be held in Pusan, South Korea on November 20-22, 2025, both onsite and online.

IEEE SCEMS is a student conference that offers a platform for researchers, scientists, and engineers to present their research results, exchange academic ideas, and expand their networks. The forums cover a range of topics, including the latest research and development in power systems, electrical machines, power electronics, and multi-energy systems. Whether one is interested in academic research or wishes to communicate with peers, they will find their own opportunities and value in IEEE SCEMS. It is hoped that every attendee will gain valuable knowledge and experience from this conference.

Pusan, located in the southeastern part of South Korea, is a vibrant city known for its beautiful beaches, rich cultural heritage, and modern infrastructure. The city is famous for landmarks such as Haeundae Beach, the impressive Gamcheon Culture Village, and the iconic Jagalchi Fish Market. With a perfect blend of urban energy and natural beauty, Pusan offers an exciting environment for both work and leisure.

We look forward to meeting you in Pusan!

COMMITTEES

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Prof. Hongxun HUI	University of Macau
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Mr. Jong-Seok Seon	Konkuk University

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Hyun-Ho Ha	Pusan National University
Seung-Ju Baek	Pusan National University

CONFERENCE VENUE

Busan, Korea

Busan is a key center for scientific research and technological innovation in South Korea, particularly in marine sciences, renewable energy, and advanced logistics. The city hosts cutting-edge research facilities and universities specializing in ocean engineering, shipbuilding, and climate resilience, driving advancements in offshore wind energy, smart port systems, and eco-friendly ship design. Busan is also pioneering sustainable urban development with initiatives like the Eco-Delta Smart City, integrating IoT, renewable energy, and advanced water management technologies. Additionally, its universities and research institutes collaborate globally in fields such as artificial intelligence, big data, and robotics, furthering innovation and knowledge exchange through international conferences and exhibitions. With a focus on technological progress and environmental sustainability, Busan plays a vital role in tackling global challenges and fostering regional and international innovation.

Information for The Pusan National University

Pusan National University (PNU), a representative national university in Korea established in 1946, is making leading achievements in high-tech and medical research such as nanomaterials, artificial intelligence, and big data. It is participating in national projects such as Eco Delta Smart City, leading sustainable urban development, and contributing to the development of the global marine industry with marine engineering and renewable energy technology. In addition, it has established itself as a research-oriented university that is recognized at home and abroad through international joint research and regional specialized industrial development.



KIEE EMECS STUDENT Committee

The KIEE EMECS Student Committee began its activities in 2022. Through active communication among student researchers in various specialized fields such as electric machines and power conversion, we are creating a new vision for the future.

산학연이 함께 에너지 미래를 준비하는
대한전기학회

CONFERENCE TIPS

Banquet

ASHLEY QUEENS

Address: 6th Floor, NC Department Store, 2 Busandaehak-ro 63beon-gil, Geumjeong-gu, Busan

On-site staff members will guide you.

PNU CAMPUS MAP

Busan Campus

2, Busandaehak-ro 63beon-gil, Geumjeong-gu, Busan, 46241

1

101 MEMS/NANO Clean Room Bldg.
102 Information Technology Bldg.
103 Engineering Bldg. #12
105 Engineering Bldg. #3 (Integrated Mechanical Engineering)
106 Hyowon Hall
107 Engineering Bldg. #8 (Aerospace Engineering)
108 Engineering Bldg. #9 (Electronics)
109 Engineering Central Lab
110 Laboratory of Energy Systems Division
111 Waste Disposal Facility

2

201 Engineering Bldg. #6 (Computer Engineering)
202 Woon Jook Jung
203 Liberty Yard
204 Liberty Yard Underground
205 Main Administration Bldg.
206 Engineering Bldg. #11 (Naval Architecture & Ocean Engineering)
207 Engineering Bldg. #10 (Specialized Engineering)
208 Mechanical Technology Center
209 Sangnam International Bldg
210 Language Education Institute
211 Comprehensive Childcare Center

3

301 Engineering Testing Bldg.
302 Geotechnical Engineering Bldg.
303 Mechanical Engineering Bldg.
306 Humanities Bldg.
307 Faculty Office Bldg.
308 Physics Bldg. #1
309 Physics Bldg. #2
310 Moonchang Hall
311 Research & Lab Bldg. #2
312 Core Research Facilities
313 Research & Lab Bldg.
314 Information Technology Education Center
315 Jayoo Hall A (Dormitory)
316 Jayoo Hall B (Dormitory)
317 Child Care Center
318 Jayoo Parking Lot

4

401 Building of Construction
402 Junghak Hall
403 10.16 Memorial Hall
404 Indeokgwan Parking Lot
405 Engineering Bldg. #2 (Material Engineering)
406 Engineering Bldg. #7 (Chemical Engineering)
407 Pusan National University Model Basin
408 Engineering Bldg. #5 (Organic Materials)
409 Professors' Hall
410 Impact Load & Research Bldg.
412 PNU Museum A
413 PNU Museum B
414 Earth Science Bldg.
415 Saetbeol Hall
416 Biology Bldg.
417 Education Bldg. #1
418 Faculty Office Bldg. #2
419 Geumjeong Hall
420 SaeByeokBeol Library
421 Social Sciences Bldg.
422 Seonghak Bldg.

5

501 High-tech Science Bldg
503 New Pharmacy Bldg.
506 Hyowon Industry-University Cooperation Bldg.
507 Indeok Hall
508 Industry-Academia Cooperation Bldg.
509 PNU Museum (Annex)
510 Central Library
511 Gymnasium
512 Tennis Courts
513 Parking Lot (A)
514 Business Bldg.
515 Central Library, Office of Information Technology & Services
516 Economics and International Trade Bldg.

6

601 Arts Bldg.
602 Human Ecology Bldg.
603 Human Ecology Laboratory Bldg.
605 PNU ROTC
606 Chemistry Bldg.
607 Mathematics·Research Complex Bldg
608 Law Bldg. #2
609 Law Bldg.

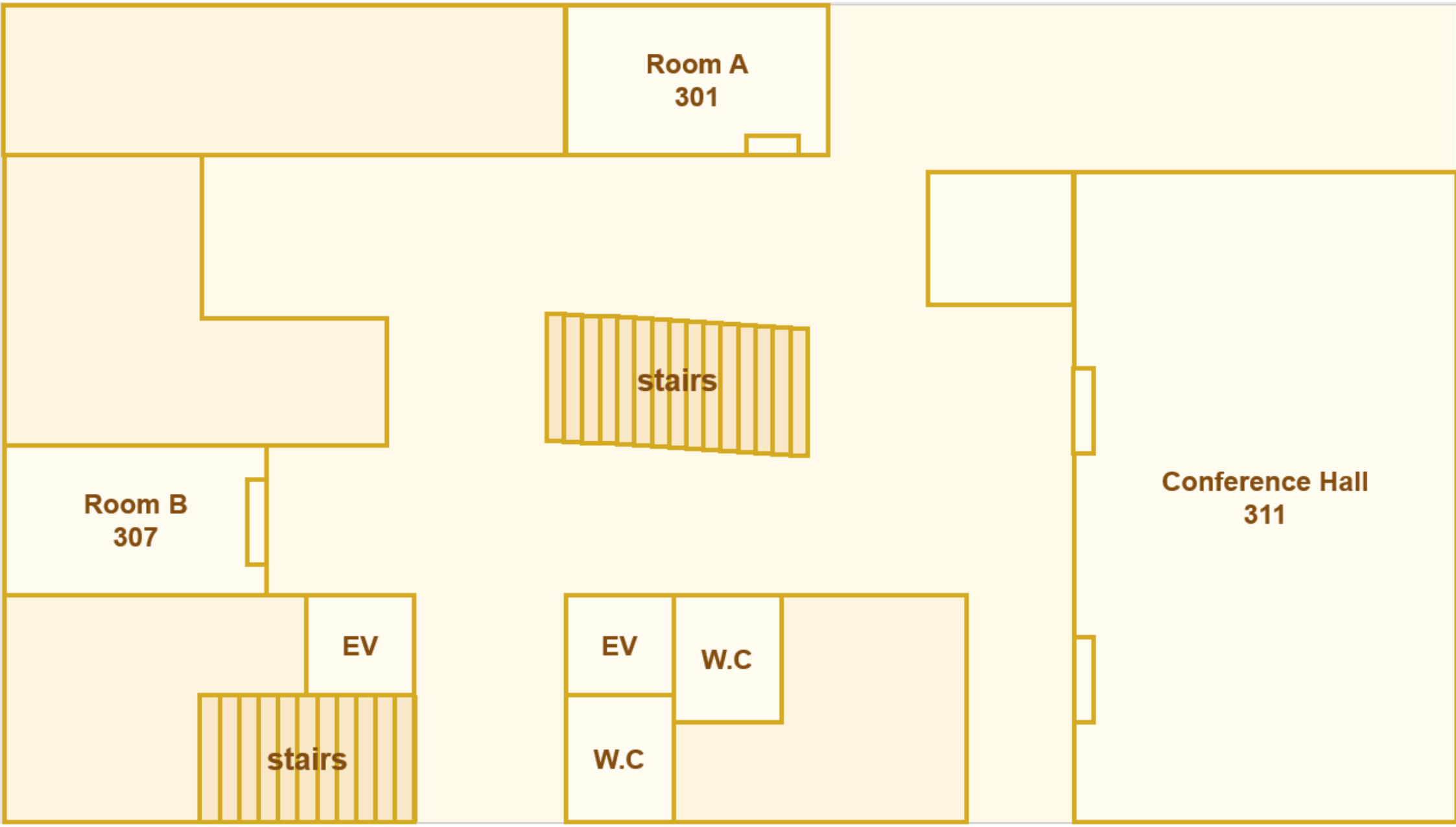
7

701 Education Bldg. #2
702 Fine Arts Bldg. #2
703 Fine Arts Bldg.
704 Plastic Arts & Design Bldg.
705 Kyung-Ahm Gymnasium Faculty Research Center
706 Kyung-Ahm Gymnasium
707 Music Bldg.
708 Student Union Bldg.
709 Science & Technology Bldg.
710 Sports Complex
711 Hyowonjae (Dormitory)
712 Woongbee Hall A (Dormitory)
713 Woongbee Hall B (Dormitory)
714 Jilli Hall Management Bldg. (Dormitory)
715 Jilli Hall Ga (Dormitory)
716 Jilli Hall Na (Dormitory)
717 Jilli Hall Da (Dormitory)

Etc.

K05 Substation
K08 Engineering 2nd Annex

Floor plan
(Main Administration Building (205), 3F)



CONFERENCE DETAILS

IEEE 8th Student Conference on Electric Machines and Systems

PROGRAM AT A GLANCE

Time: November 20-22, Thursday-Saturday, 2025

Venue: Busan National University, Main Administration Building (205), 3F

Date	Time	Activity	Venue
Nov.20 (Thu.)	14:00- 18:00	Registration	Lobby
Nov.21 (Fri.)	10:00- 10:15	Opening Ceremony	Auditorium
	10:15- 10:30	Keynote Speeches	Auditorium
	10:30-10:40	Tea break	Lobby
	10:40- 12:00	Oral Session 1	ROOM A
	12:00- 13:20	Lunch	
	13:30- 14:20	Poster Session 1	ROOM B
	14:20-14:30	Tea break	Lobby
	14:30- 15:20	Poster Session 2	ROOM B
	15:30-17:00	Oral Session 2	ROOM A
	17:10-17:30	Award	Auditorium
	17:30-17:50	Keynote Speeches	Auditorium
	17:50-18:00	Closing Ceremony	Auditorium
	18:30-	Banquet	
Nov.22 (Sat.)	09:00-18:00	Technical Tour	

TECHNICAL PROGRAM OVERVIEW

November 21 (Friday)				
	Auditorium	Lobby	Room A	Room B
10:00- 10:15	**Opening Ceremony**			
10:15- 10:30	**Keynote Speeches**			
10:30-10:40		**Tea break**		
10:40- 12:00			**Oral Session 1**	
12:00- 13:20	**Lunch** Please pick up your lunch in the lobby			
13:30- 14:20				**Poster Session 1**
14:20-14:30		**Tea break**		
14:30- 15:20				**Poster Session 2**

TECHNICAL PROGRAM OVERVIEW

November 21 (Friday)				
	Auditorium	Lobby	Room A	Room B
15:30-17:00			**Oral Session 2**	
17:10-18:00	**Closing Ceremony & Keynote Speeches**			
18:30-	**Banquet**			

PRESENTATION GUIDELINES

Oral Presentations

1. Each oral presentation will be given 15 minutes including Q&A.
2. Session rooms will be ready with laptop computers installed with MS PowerPoint, which the speakers are encouraged to use for their presentations in order to avoid delays in schedule. (It is not recommended to bring your own laptop computer (especially MacBook) unless your presentation requires any special software and/or hardware)
3. The speakers are advised to bring their PowerPoint presentation files on USB memory sticks and be also ready with a backup version of their presentations.
4. Please transfer the file to the laptop computer in the session room during the break before the sessions
5. Presentation slides should be prepared in 16:9 ratio.
6. Speakers are expected to arrive at the session room 15 minutes BEFORE the start of their sessions to report to the session chair.

Poster Presentations

1. The poster will be printed in A0 portrait format (1189mm height x 841mm width).
2. Title, author's information and the poster number must be included in the poster.
3. To prepare for the next presenter, please take down your poster within 5 minutes after the poster session ends.
4. The poster presentation will be conducted in a relaxed and informal atmosphere, and each presentation will be evaluated by at least one session chair for possible recommendation as an outstanding paper.

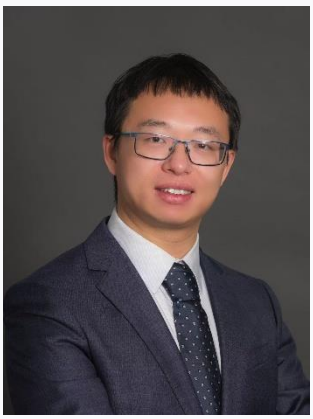
"No-show" papers will not be published in the conference proceedings or IEEE database!

KEYNOTE SPEECHES

Novel Asymmetric Interior Permanent Magnet Machines: Torque Enhancement and Torque Ripple Suppression

Abstract

Permanent magnet (PM) synchronous machine is a key technology for numerous market sectors, including industrial drives, domestic appliances, and electrified transportation such as electric vehicles, fast trains, and electric aircrafts. Interior PM (IPM) machines with embedded PMs inside rotor cores shows advantages including utilization of reluctance torque with less PM usage, mechanical robustness, and demagnetization withstand capability. This presentation will focus on the research developments in novel asymmetric IPM (AIPM) machines utilizing magnetic-field-shifting techniques with enhanced torque density and torque ripple suppression simultaneously. Artificial intelligence-assisted data-driven design optimization methods to address the complicated structure and multi-physics design requirements will be discussed. Worked examples will be given to illustrate the development of the novel research concept and the impact on successful commercial applications.



Dr. Yang Xiao

University of Leicester

Biography

Dr. Yang Xiao received the B. Eng and Ph.D. degrees from Huazhong University of Science and Technology, Wuhan, China, and University of Sheffield, Sheffield, UK, in 2013 and 2021, respectively, all in electrical engineering. From 2021 to 2023, he was a senior research engineer with Dyson Technology Ltd., Malmesbury, UK. Since 2023, he has been a Lecturer (Assistant Professor) with the School of Engineering, University of Leicester, Leicester, UK, and currently serve as Deputy Director of MEng/BEng Electrical & Electronic Engineering.

Dr. Xiao has authored more than 40 technical papers and is the inventor of more than 20 patents. He received 4 paper awards from international conferences. He is an editor in IEEE Trans. Energy Conversion. He led a tutorial in ISSIE 2024 and served as special session organizers in ECCE Euro 25 and ICEM 24. His current teaching and research interests include advanced electrical machine design and drive for renewable energy generation, electrified transportation, and humanoid robots, and AI-assisted data-driven design, optimization and control of electrical machine systems.

Oral Session 1

Time: 10:40 -12:00, November 21 (Friday) Room A: 301

Topics	Power System Power Electronics and Motor Drives Electric Machine Design and Analysis
Committee	Session Chair: Seung-Ahn Cheo Session Organizer: Jong-Honn Park Conference Staff: Ji-Hoon Yoo, Jun-Hyuk Choi

Paper ID 17

Federated Learning-Based Identification of Multi-Operating-Point Impedance Models in Heterogeneous Multi-VSC Systems

Huihwa Lee, Seokjun Kang, Chiwon Seo, Deokki You and Gilsoo Jang

The rapid growth of voltage-source converters (VSCs) has introduced instability mechanisms such as phase-locked loop (PLL) vulnerabilities, harmonic interactions, and converter-grid resonances that couple classical angle, frequency, and voltage stability domains and heighten the need for small-signal stability assessment. Existing impedance-based approaches can characterize converter-grid interactions, but practical deployment across many operating points is limited by measurement burden, noise sensitivity, crucially, privacy and confidentiality barriers to centralized data pooling. This paper presents a federated learning (FL) framework for identifying multi-operating-point admittance models in heterogeneous multi-VSC systems without sharing raw data. An operating-point dependent state-space model captures PLL, outer power and voltage loops, inner decoupled dq current control, and measurement lags, and generates labeled admittance samples. Linearization-based data are validated against electromagnetic transient simulations via root-locus and time-domain checks. Case studies with three grid-connected VSCs of heterogeneous parameters and data availability show that FL consistently outperforms local only training and achieves accuracy close to centralized learning across the frequency band, benefiting both data-rich and data-scarce clients while avoiding raw data transfer. These results indicate that the proposed approach provides a data efficient, privacy preserving path to impedance identification and supports near real-time small-signal stability assessment in converter dominated grids.

Paper ID 23

Two-Stage Robust Planning for Urban Distribution System with Heatwave Seasonal Imbalance and Progressive Intensification

Zhenwei Zhang and Hongxun Hui Chao

Irreversible global warming is intensifying urban heatwave events, leading to surges in cooling demand and reductions in generation efficiency, which pose severe source–load imbalance challenges for distribution systems. Hence, this paper proposes a two-stage robust planning model that incorporates the multi-timescale evolution of heatwaves. First, a hybrid meteorological modeling framework based on Seasonal Autoregressive Moving Average and Long Short-Term Memory Networks is developed to capture both short-term seasonal fluctuations and long-term evolving trends. Furthermore, a compound uncertainty set is constructed by integrating multiple meteorological factors. Second, the dynamic source–load response model is established for renewable generators and building cooling loads, reflecting the impacts of weather conditions on generation efficiency and thermal processes. Then, a two-stage robust planning model is formulated, where the first stage determines investment decisions for distributed resources, while the second stage evaluates worst-case operational costs under all admissible climate scenarios. To address high-dimensional uncertainty, a Benders decomposition approach is employed to improve computational tractability. Finally, Numerical studies on an urban distribution system demonstrate the effectiveness of the proposed model in balancing investment cost, operational performance, and robustness under compound heatwave stress.

Paper ID 11

Amplitude-Invariant αβ Transformation for FCS-MPC of 8/6 SRMs: A Torque Ripple Reduction Approach

Franklin Sánchez, Maria Milanes, Enrique Romero and Cristian Garcia

The Switched Reluctance Motor (SRM) has emerged as a promising candidate for high-performance industrial drives and electric vehicle (EV) propulsion, owing to its robust magnet-free construction and inherent fault tolerance. However, the nonlinear magnetic characteristics of the SRM result in pronounced torque ripple and acoustic noise, which remain key barriers to its widespread adoption. In recent years, Finite Control Set Model Predictive Control (FCS-MPC) has been investigated as a potential solution to mitigate these challenges. Nevertheless, for 8/6 SRMs, conventional implementations employ an αβ transformation that does not preserve amplitude invariance, leading to non-uniform vector distributions in the control plane. This paper proposes the use of an amplitude-invariant αβ transformation, which generates a novel set of voltage vectors, thereby reducing torque ripple and improving the dynamic behavior of the drive system. The proposed strategy is validated on the MATLAB/Simulink platform, with detailed comparisons against the conventional method. Simulation results show a reduction in torque ripple and an improvement in acceleration time. These findings highlight the strong potential of the proposed approach to enhance SRM performance in demanding applications.

Paper ID 34

Optimal Design of SPMSM for Robot Joints Using Extra Random Trees-Based Surrogate Modeling and Genetic Algorithm

Min-Su Kwon and Dong-Kuk Lim

This paper proposes an optimization framework that integrates extra random trees (ERT) with a genetic algorithm (GA) to achieve efficient and high-performance motor design for robot joint applications. Conventional finite element method (FEM)-based analysis requires excessive computational resources when handling large-scale design samples, motivating the use of surrogate modeling. Compared with random forest (RF), which reduces variance through bootstrap aggregation and deterministic feature splits, ERT employs fully randomized cut-points and feature selection, yielding lower variance, faster training, and improved generalization for nonlinear electromagnetic problems. Based on 2000 FEM samples generated entirely through Latin hypercube sampling (LHS) without additional refinement, the ERT surrogate achieves superior predictive accuracy and robustness relative to RF and other machine learning methods. The originality of this work lies in applying ERT to motor design optimization, where the surrogate significantly reduces FEM computation time while preserving prediction fidelity, thus enabling practical large-scale analysis. The target motor is a surface-mounted permanent magnet synchronous motor (SPMSM). The optimization process maximizes average torque while reducing torque ripple, iron loss, and phase back electromotive force total harmonic distortion (P-BEMF THD). Comprehensive hyperparameter tuning of ERT ensures high prediction fidelity, which in turn allows a well-established and widely adopted optimization method, GA, to achieve effective design convergence. The integration of GA with the ERT surrogate yields an optimal SPMSM design with tangible improvements: average torque increases by 6.84%, torque ripple decreases by 59.13%, P-BEMF THD decreases by 80.46%, core loss decreases by 16.76%, and efficiency is maintained at a high level with a slight 0.25% improvement. For robot joint applications, reduced P-BEMF THD directly translates to improved control precision, while maintain high electromagnetic performance underscores the practicality of the proposed method. Overall, this study advances motor design methodologies by combining ERT and GA for efficient large-scale optimization. Demonstrated improvements across multiple performance indices highlight the potential of the ERT-GA framework as a powerful and efficient tool for next-generation robot joint motor development.

Virtual conference program for oversea presenters

ZOOM Meeting Link:

The virtual conference link will be posted again on the conference website.

Paper ID 8

Zero-Sequence Current Suppression for Open-End Winding High-Speed PMSM with Common DC Bus

Zhuo Chen, Yuhao He, Dan Shi, Yun-Chong Wang and Jian-Xin Shen

In open-end winding permanent magnet synchronous motor (OEW-PMSM) with a single DC bus, zero-sequence current (ZSC) caused by zero-sequence voltage (ZSV) will induce torque ripple and power loss of the whole system. However, since the discretization methods are incorrect, the ZSC suppression methods at present only focused on applications where the carrier ratio is relatively high. In this paper, a ZSC suppression strategy for high-speed PMSM with OEW topology is proposed, which can maintain excellent ZSC reduction under a relatively low carrier ratio in the full speed range. By comparing three continuous and discrete domain models, the discrete domain model is selected since it eliminates exponential term in s-domain, which is more suitable for digital controller design. The digital resonant controller for ZSC suppression based on discrete domain model is illustrated, and then the poles assignment method in z-plane is presented to improve the stability of ZSC control loop. The effectiveness of the controller and compensator are verified through simulation.

Virtual conference program for oversea presenters

ZOOM Meeting Link:

The virtual conference link will be posted again on the conference website.

Oral Session 2

Time: 15:30 -17:00, November 21 (Friday) Room A: 301

Topics

Power Electronics and Motor Drives
Electric Machine Design and Analysis

Committee

Session Chair: Min-Su Kwon
Session Organizer: Jong-Hoon Park
Conference Staff: Ji-Hoon Yoo, Jun-Hyuk Choi

Paper ID 28

Pipeline Position and Orientation Estimation from Magnetic Fields Generated by Current Injection

Seungju Baek and Gwansoo Park

To overcome the operational limitations of conventional In-line Inspection (ILI) methods, extensive research is now focused on developing technologies for external pipeline defect detection and maintenance. A critical prerequisite for the effective application of such external-based approaches is the precise determination of the target pipeline's three-dimensional position and orientation. This paper, therefore, proposes and validates a method for localizing a pipeline by injecting a current and analyzing the resulting magnetic field from the exterior. Specifically, the pipeline's relative orientation angle is derived from the ratio of the horizontal magnetic field components, while the distance to the pipeline's central axis is calculated from the magnitude of the horizontal vector sum at the zero-crossing point of the vertical component. Validation via Finite Element Method (FEM) simulations demonstrates the high accuracy and reliability of the proposed method, with maximum errors of less than 0.06% for orientation estimation and less than 0.01% for distance estimation. By providing rapid and precise location data without complex computations, this technology can serve as a key enabling technology for the successful implementation of future non-contact inspection and maintenance systems utilizing external robotics.

Paper ID 31

Average Torque Calculation of Surface-Mounted Permanent Magnet Motors with Extended Stator Tooth Tips Using Magnetic Network

Ze-Cheng Li, Dan Shi and Jian-Xin Shen

Surface-mounted permanent magnet (SPM) motors in humanoid robot lower limb joints require high torque density and strict volume constraints. Overhanging magnets on rotor can increase the motor torque density, but also causes severe end flux leakage. An extended stator tooth tip structure is used to reduce the leakage and further improve the torque density. Accurate analysis for such a structure typically requires time-consuming 3-D finite element (FE) simulations. This paper introduces a method combining equivalent magnetic networks with 2-D FE simulations to calculate the average torque, greatly reducing computation time. The method is validated using 2-D and 3-D FE simulations. And the performance of a conventional SPM motor, an overhang SPM motor, and an overhang SPM motors with extended tooth tips is compared.

Paper ID 3

Torque Enhancement and Torque Ripple Suppression of Permanent Magnet Vernier Machine

Rongxin Wang, Bo Wang, Wendong Zhang, Zihan Wei, Wenjun Zhao and Ming Cheng

This paper presents an investigation into the influence of field-modulated harmonics on the torque and ripple characteristics of permanent magnet vernier machines (PMVMs). The magnetic field modulation process is analyzed to identify the mechanisms responsible for average torque generation and torque ripple. To simultaneously improve torque output and suppress ripple, a novel design approach is proposed, incorporating heterotypic stator teeth and arc-shaped permanent magnets. The specially designed stator tooth structure modifies the airgap permeance distribution, while the arc-shaped magnets reduce high-order harmonics in the magnetomotive force. Compared to a conventional uniform split-tooth design, the proposed structure increases the average torque by 33.5% and decreases torque ripple by 46.32%. Finally, a prototype is fabricated and tested to validate the theoretical analysis and finite element simulation results.

Paper ID 36

Design and Analysis of Dual-Rotor Permanent Magnet Synchronous Motor with Dual Helical Winding for Hybrid Electric Vehicles

Jong-Seok Seon, Hyeon-Taek Oh, Cheon-Hwi Park, Hee-Sang Yoon, Su-Hyun Myeong and Han-Kyeol Yeo

Hybrid electric vehicle traction motors require high torque density and efficiency within limited space. This study proposes a dual helical winding (DHW) configuration for a dual-rotor permanent magnet synchronous machine (DR-PMSM). The winding forms a three-dimensional current path that combines the compactness of a teeth-concentrated winding (TCW) with the flux-distribution characteristics of a distributed winding (DW), achieving short end turns and an inherent skew effect. A quasi-3D finite element method (Q3D FEM) is developed to compare the electromagnetic characteristics of TCW, DW, and DHW topologies under different rotor skew angles. The DHW shows the lowest back-EMF THD and torque ripple while maintaining or improving average torque, effectively overcoming the trade-off of TCW and DW. The DHW configuration with a 3.75° rotor skew, designed based on Q3D analysis, was validated by full 3D FEM, showing deviations within 5% and a computation time reduction by more than 99.37 %. These results verify the effectiveness of the proposed DHW design and Q3D FEM approach for DR-PMSMs operating under space constraints.

Paper ID 29

Quasi-Direct Gradient Descent Method-Based Sensorless Control of IPMSM with Enhanced Robustness

Peiyi Li, Zhang-Hao Huang, Yong Xu, Dan Shi, Shun Cai, Jian-Xin Shen and Yunchong Wang

In the gradient descent method (GDM)-based sensorless control, rotor speed and position are simultaneously estimated by minimizing a cost function, which is derived from the motor voltage equations. However, this approach ignores the inherent kinematic relationship between the speed and position, and is highly sensitive to parameter variations. In this paper a sensitivity analysis is presented, to quantify the influence of parameter perturbations on the estimation accuracy. To enhance robustness and precision, a quasi-direct GDM-based estimation method is proposed. In the proposed method, the initial estimations of the speed and position are obtained through optimization and subsequently refined with a phase-locked loop (PLL), which enforces the kinematic consistency and mitigates the parameter-induced deviations. Simulation results under various parameter disturbances validate the effectiveness of the proposed approach.

Poster Session 1

Time: 13:30 -14:20, November 21 (Friday) Room B : 307

Topics	Power System, Multi-Energy System Power Electronics and Motor Drives Electric Machine Design and Analysis
Committee	Session Chair: Ji-Hoon Han Session Organizer: Jong-Hoon Park Conference Staff: Ji-Hoon Yoo, Jun-Hyuk Choi

Paper ID 4

Data-Driven Model-Free Predictive Control for Dual Three-Phase PMSM Based on Virtual Vector Pair Optimization

Zhihan Wu, Jiaqiang Yang and Liang Yan

Aiming to address the current ripple suppression problem of dual three-phase permanent magnet synchronous motor (DTP-PMSM), this paper proposes a data-driven predictive control (DD-PC) scheme with spatial virtual vector pair (VVP) optimization. A current prediction model based on an improved autoregressive time series structure is given, and the virtual vector pairs with optimal amplitudes in the x-y subspace are obtained using adaptive filtering. The results of the simulation demonstrate the feasibility of the strategy. In comparison with the conventional method, the proposed method extends the voltage domain and improves the modulation accuracy with smaller current ripple and higher stability.

Paper ID 5

SVM Strategy for Matrix Converters Under Unbalanced Input Voltages With Enhanced Input Power Factor

Huu-Nhan Nguyen, Sung-Kuk Ahn, Jae-Yoon Park, Van Quang Binh Ngo and Quoc Hoan Tran

This paper presents a space vector modulation (SVM) strategy for matrix converters (MCs) to achieve optimal compensation of the input power factor (IPF) under unbalanced input voltage conditions. In this study, an improved SVM method is proposed based on the analysis of the LC input filter using space vector theory. The proposed method dynamically determines the optimal duty cycles for switching states to compensate for the displacement angle caused by the filter and maintain the highest achievable IPF across a wide range of voltage transfer ratios. A switching pattern is also introduced to ensure system stability and high-quality input/output waveforms. Simulation results are provided to validate the effectiveness of the proposed strategy.

Paper ID 6

A Multi-Objective Two-Step Predictive Voltage Control Strategy for Three-Level T-Type NPC Inverters With L–C Output Filters

Quoc Hoan Tran and Huu-Nhan Nguyen

This paper presents a two-step model predictive voltage control (MPVC) strategy for a three-phase, three-level T-type neutral-point-clamped (NPC) inverter equipped with an L–C output filter. The proposed control method addresses three critical objectives: (i) accurate sinusoidal output voltage tracking, (ii) DC-link capacitor voltage balancing, and (iii) common-mode voltage (CMV) suppression. A discrete-time model of the inverter–filter system is employed to predict the output voltages, DC-link capacitor voltages, and CMV over a two-step prediction horizon for all feasible switching states. These predictions are incorporated into a multi-objective cost function with appropriately tuned weighting factors to achieve simultaneous optimization of the control objectives. The effectiveness of the proposed approach is verified through detailed PSIM simulations under various load conditions, including resistive, resistive–inductive, and nonlinear diode-rectifier loads. The results demonstrate that the proposed method achieves low total harmonic distortion (THD), minimal tracking error, balanced capacitor voltages, and significant CMV reduction.

Paper ID 7

Safe Multi-Critic Reinforcement Learning-based Energy Management and Volt-Var Control in Active Distribution Networks

Hyung Joon Kim and Dam Kim

With the increasing integration of inverter-based distributed energy resources, energy management and Volt-Var Control (EM-VVC) is essential for reliable operations of active distribution networks (ADNs). While deep reinforcement learning (DRL) shows promise, single-critic actor-critic DRL methods struggle to address multiple objectives—voltage regulation, loss minimization, and peak reduction—due to their differing mathematical properties. In addition, penalty- and constraint-based safety mechanisms also often fail to ensure full compliance with operational limits. To overcome these limitations, this paper proposes a safe multi-critic soft actor-critic (SAC) framework for EM-VVC in ADNs. In the proposed safe DRL, multiple critics independently approximate each objective, reducing learning complexity, while an iteration-based safe exploration module ensures operational safety during training. Comparative studies on modified IEEE 33-bus networks demonstrate improved learning efficiency, complete voltage violation elimination, and significant loss and peak load reductions compared to existing methods.

Paper ID 19

PMaSynRM High-Fidelity Modelling considering Spatial Harmonics and Magnetic Saturation

Antoine Dupont, Geoffrey Postal and Johan Gyselinck

This article presents a real-time runnable permanent-magnet-assisted synchronous reluctance machine model that accounts for spatial harmonics and magnetic saturation and cross-saturation. It is based on offline evaluations of a finite-element model that represents the geometry of the machine with great accuracy, over a grid of current and rotor position values. The collected current - flux-linkage data are then fitted with one polynomial function per rotor position. The coefficients of the polynomials are then stored and used for time-based simulations. The model is first validated statically by analysing the regression error over the training dataset. Secondly, a dynamic simulation is performed to compare it with a lookup-table-based model in realistic conditions.

Paper ID 10

Decision-Focused Learning-based Prediction Interval for Renewable Energy Curtailment Strategy

Jeuk Kang and Yun-Su Kim

With the increasing penetration of renewable energy sources, curtailment strategies have become indispensable for maintaining both system reliability and economic efficiency. Nevertheless, the uncertainty associated with renewable generation and electricity demand frequently undermines the effectiveness of such strategies. Prediction intervals provide a promising means of quantifying forecast uncertainty, yet traditional methods do not guarantee decision quality, as even small forecast errors can result in suboptimal curtailment outcomes. This paper proposes a decision-focused learning framework for renewable energy curtailment that directly integrates prediction intervals into operational decision-making. The framework employs a mixture density network to produce distributional forecasts from which prediction intervals are derived. A weighted negative log-likelihood surrogate loss is introduced to align predictive uncertainty with downstream decision performance, enabling end-to-end training even in non-differentiable optimization environments. Simulation results on a microgrid with photovoltaic generation and conventional units show that the proposed approach consistently outperforms existing methods.

Paper ID 14

Twin-Delayed Deep Reinforcement Learning for Coordinated Virtual Inertia and Droop Control in Energy Storage-Based Primary Frequency Response

Xiaoyan Lyu, Ding Li, Jiaming Wang and Xuzhi Luo

With the increasing penetration of renewable generation, modern power systems are exposed to fast frequency deviations and reduced inertial support. Energy storage has the capability of rapid response, yet conventional frequency regulation strategies, such as fixed virtual inertia or static droop control—struggle to simultaneously suppress transient frequency swings and restore steady-state deviations. This paper introduces a coordinated control method that leverages Twin-Delayed Deep Deterministic Policy Gradient (TD3) to dynamically allocate the contributions of virtual inertia and virtual droop control in energy storage units. By taking system frequency deviation and its rate of change as state inputs, the TD3 agent learns to determine optimal sharing coefficients, thereby ensuring smooth transitions between control modes and avoiding abrupt output variations. Compared with traditional reinforcement learning algorithms, the TD3 framework improves stability and convergence through delayed policy updates and a double critic structure, reducing overestimation errors during training. Simulation studies on a regional power grid model under both abrupt renewable disturbances and continuous wind power fluctuations demonstrate that the proposed method significantly reduces maximum frequency deviation, lowers frequency root-mean-square error, and shortens out-of-limit durations, while maintaining balanced state-of-charge trajectories and prolonging battery life. These results indicate that the TD3-based approach offers a promising pathway for enhancing frequency security and supporting large-scale renewable integration.

Paper ID 15

Investigation into the Multi-Frequency Range Influence of Key Parameters of High-Inertia Energy Storage Synchronous Condensers on System Impedance

Hui Wang, Jishen Li, Qiyang Zhang and Taiying Zheng

In the context of power grids with a high penetration of renewable energy, the continuous decline in grid inertia and damping poses a severe challenge to system stability. As a novel phase-shifting equipment, the High-Inertia Energy Storage Synchronous Condensers (HIESSC) can provide reactive power support, inertia support, and short-circuit current support. Although the HIESSC exhibits unique dynamic behaviors during grid disturbances due to its lack of a prime mover and substantial moment of inertia, the precise, quantitative impact of its internal control and system parameters on system impedance across different frequency ranges remains unclear. To address this, this paper establishes an impedance model for the HIESSC and proposes a quantitative analysis method to characterize the frequency ranges affected by parameters. This study analyzes the quantitative influence mechanisms and trends of HIESSC control and system parameters on system impedance characteristics across multiple time scales. Based on the impedance model, the variation trends of the motor's impedance model with respect to each system parameter are plotted. The curves are then superimposed on the impedance-frequency plane, and the frequency ranges primarily influenced by each parameter are analyzed using the metric of Frequency-Domain Bundle Width(FDBW). The results show that power loop parameters dominate the sub-synchronous to fundamental frequency response, current loop parameters regulate high-frequency characteristics, PLL parameters exhibit a dual-peak effect around low and fundamental frequencies, and the moment of inertia provides high positive damping in the low-frequency range. The research provides a theoretical basis for the optimized design of the HIESSC.

Paper

ID **16**

Common Mode Voltage-Free Model Predictive Control for Dual Three-Phase PMSM Driven by NPC Three-Level Inverter

Cheng Li, Lijian Wu, Tao Wang and Pingyue Song

In a dual three-phase permanent magnet synchronous machine (DTP-PMSM) control system, two negative effects are commonly concerned, those are, the common mode voltage (CMV) that may harm the bearings and the harmonic currents in the z1-z2 subspace that cause extra power loss. However, these two issues can hardly be addressed at the same time for DTP-PMSMs driven by conventional two-level inverters limited by the control degrees of freedom. In this paper, a DTP-PMSM driven by neutral-point-clamped three-level inverter is considered, whose additional control degrees of freedom are fully utilized to achieve both zero-CMV (ZCMV) and z1-z2 subspace harmonic suppression. In the proposed strategy, all the basic voltage vectors that can achieve ZCMV are identified first, which are then used in pairs to synthesize virtual vectors (VV) that have zero voltage component in the z1-z2 subspace. Based on these synthesized ZCMV-VVs, a finite control set model predictive control algorithm is implemented. Simulation results validate that the proposed strategy achieves fast dynamic response speed, ZCMV, and effective harmonic suppression.

Paper

ID **18**

Relative Permeance-Based Airgap Flux Density Analysis of SPMSM Considering Slotting Effect and Tooth-Tip Flux Concentration

Donggeon Lee, Jaesung Choi and Gilsu Choi

This paper addresses the limitation of conventional relative permeance–based models in analyzing the slotting effect of surface-mounted permanent magnet synchronous motors (SPMSMs). Traditional models often fail to adequately capture the flux concentration at the tooth tips, resulting in significant errors. To overcome this issue, a modified relative permeance model is proposed, incorporating slot geometry effects through conformal mapping and introducing a tooth-tip flux concentration term formulated using a cosine window function. Comparative analysis with existing models shows that the proposed model reduces estimation errors of the airgap flux density distribution by up to 52% under no-load conditions and up to 71% under loaded conditions, achieving substantially improved accuracy. These results confirm that the proposed analytical approach enhances the reliability of airgap flux density prediction, particularly useful in the early stages of SPMSM design.

Poster Session 2

Time: 13:30 -14:20, November 21 (Friday) Room B : 307

Topics	Power System, Multi-Energy System Power Electronics and Motor Drives Electric Machine Design and Analysis
Committee	Session Chair: Jong-Seok Seon Session Organizer: Jong-Hoon Park Conference Staff: Ji-Hoon Yoo, Jun-Hyuk Choi

Paper ID 20

Comparative Study of Online Signal-Based Fault Detection Methods for PMSMs with Interturn Short-Circuit Faults

Maxence Bouzin, Geoffrey Postal, Antoine Dupont and Johan Gyselinck

This paper compares two online signal-based fault detection algorithms for permanent magnet synchronous machines (PMSMs) with interturn short-circuit faults under closed loop operation. The first method analyzes the harmonic content of dq-axis voltage components, while the second focuses on the negative-sequence component of the three-phase voltage, as most fault-induced distortions appear in voltage signals during closed
loop control. Both algorithms are implemented in MATLAB Simulink and validated through simulations and experiments on a 1 kW PMSM test bench, using both an ideal voltage source with no high-order switching harmonics and a voltage-source inverter with high-order switching harmonics. Results show that both methods effectively detect interturn short-circuit faults in both supply scenarios, with the negative-sequence approach being more robust to waveform distortion. These findings support the use of signal-based techniques for real-time fault monitoring in industrial PMSM applications. The main contribution of this paper is a rigorous evaluation of how high-frequency switching harmonics affect the fault detection algorithms, along with an experimental comparison on the same PMSM.

Paper ID 21

Research On The Design Of New Energy Vehicle Owner Satisfaction Maximization Under the V2G Model

Jingchi Zhang, Qiyang Zhang, Guyu Pan, Dongwen Li, Shangyi Cui, Taiying Zheng and Huan Yang

With the widespread popularity of electric vehicles (EVs), vehicle-to-grid (V2G) technology, as an emerging mode of energy interaction, can significantly improve the stability and flexibility of the power grid while providing potential economic benefits for EV users. However, designing V2G charging strategies to maximise user satisfaction is an important topic that needs to be addressed by academia and industry at present. In this paper, we construct an overall satisfaction model in V2G mode that integrates charging cost satisfaction and travel satisfaction, and optimise it using a mutually evidence-based genetic algorithm, aiming to design personalised charging strategies to meet different user needs. The feasibility and effectiveness of the model are verified through simulation experiments. The results show that the strategy can flexibly adjust the parameters according to the user's personal situation, effectively reducing the charging cost while ensuring that the travel is satisfied, and yielding better economic benefits compared to methods such as disordered charging and discharging strategies. Additionally, users can take the initiative to participate in grid frequency regulation by adjusting the weighting parameters, which provides strong support for energy storage and grid stability. The research results presented in this paper provide a solid theoretical foundation and practical guidance for promoting and applying V2G technology.

Paper

ID 22

Enhancing Disturbance Robustness through TD3 based Adaptive Bandwidth Control

Taeyeon Kim, Minhyuk An, Changoh Woo and Jae Suk Lee

With the widespread popularity of electric vehicles (EVs), vehicle-to-grid (V2G) technology, as an emerging mode of energy interaction, can significantly improve the stability and flexibility of the power grid while providing potential economic benefits for EV users. However, designing V2G charging strategies to maximise user satisfaction is an important topic that needs to be addressed by academia and industry at present. In this paper, we construct an overall satisfaction model in V2G mode that integrates charging cost satisfaction and travel satisfaction, and optimise it using a mutually evidence-based genetic algorithm, aiming to design personalised charging strategies to meet different user needs. The feasibility and effectiveness of the model are verified through simulation experiments. The results show that the strategy can flexibly adjust the parameters according to the user's personal situation, effectively reducing the charging cost while ensuring that the travel is satisfied, and yielding better economic benefits compared to methods such as disordered charging and discharging strategies. Additionally, users can take the initiative to participate in grid frequency regulation by adjusting the weighting parameters, which provides strong support for energy storage and grid stability. The research results presented in this paper provide a solid theoretical foundation and practical guidance for promoting and applying V2G technology.

Paper

ID 24

DMPC-Based Two-Level Cross-Regional Optimization for Power Systems with High Renewable Penetration

Shanke Mou, Nan Yang, Hao Chen, Kai Xia and Xiangwen Wu

High renewable integration promotes cross-regional power exchanges to enhance operational flexibility, but also propagates significant uncertainty across interconnected areas. To address this challenge, this paper proposes a two-level distributed model predictive control framework composed of an upper-level coordinator and lower-level regional operators. At the upper level, the coordinator optimizes tie-line flows and reserve allocations through shadow-price signals to mitigate congestion. Inter-regional consensus is enforced through the alternating direction method of multipliers, which ensures rapid convergence and protects data privacy. At the lower level, each regional operator solves a receding-horizon model predictive control problem subject to DC network limits, unit and ramping constraints, and optional storage dynamics. Boundary tie-line references from the coordinator are tracked, while renewable uncertainty is hedged by embedding a conditional value-at-risk measure into the rolling horizon optimization. This formulation yields a tractable second-order cone program that can be updated with new forecasts at each step. Case studies on the IEEE 118-bus system demonstrate that the proposed framework enhances renewable utilization, lowers cross-regional exchange costs, and strengthens overall operational security, offering a practical pathway for secure and economical coordination under high renewable penetration.

Paper

ID 25

Multi-Time-Scale Coordinated Planning of Transmission System with Heterogeneous Flexibility and Renewable Uncertainty

Nan Yang, Shanke Mou, Hao Chen, Aixia Bao and Jiawei Xiang

The large-scale integration of renewable energy into transmission systems introduces significant variability and uncertainty, necessitating additional flexibility to ensure reliable and economic operation. Heterogeneous flexibility resources (e.g., storage, gas-fired units, demand-side response) distinct temporal and operational characteristics, complicating coordinated planning and operation. Therefore, this paper proposes a multi-time-scale coordinated framework that jointly addresses long-term investment and short-term operation. At the upper level, investment siting and sizing of multiple flexibility resources are optimized to minimize total cost while enhancing renewable accommodation. At the lower level, stochastic operational subproblems are formulated under representative wind, solar, and load scenarios, incorporating unit commitment and network power flow constraints. To manage the computational complexity of large-scale systems with numerous scenarios, a Benders decomposition algorithm is developed. The master problem determines investment decisions, while subproblems evaluate operational feasibility and optimality, with cuts iteratively exchanged until convergence. Case studies on a benchmark transmission system demonstrate that the proposed approach improves renewable integration, reduces system cost, and achieves scalable computational performance.

Paper ID 26

Convergence Region of Phase Angle Difference: On the Stability Analysis of Lossy Power Networks

Zhaomin Lyu

This paper investigates the stability of lossy power networks, which has received limited attention in the existing literature. Firstly, with Lyapunov indirect method, the author proposes that the convention for lossless networks—that the equilibrium phase angle difference across each line must remain below $\pi/2$—is prone to failure in ensuring the local stability of lossy systems. Next, the lossy network is modeled as a single machine infinite bus (SMIB) system, and a closed-form expression for the convergence region of the phase angle difference is derived through a modified equal area criterion (EAC). The simulation results validate the theoretical findings and provide a sample of the convergence region. Finally, and of critical importance, the author demonstrates that, the insight about the phase angle difference is highly potential for future extension that designs control strategies for lossy power systems from a novel perspective.

Paper ID 27

An Equivalent-Circuit Method for Fast Computation of Eddy-Current Fields in Rotating Ferromagnets

Ju Hyeok Lee, Seung Ahn Chae and Gwan Soo Park

This paper presents a rapid analysis method for eddy-current magnetic fields generated when a ferromagnetic body rotates within an external magnetic field—a problem directly linked to mitigating magnetic signatures that can threaten the survivability of underwater vehicles. We reformulate the physics in a body-fixed (stationary) frame in which the external field rotates about the body, and we model the conductor with an RL equivalent circuit. After identifying a small set of circuit parameters, the eddy-current response is obtained from the circuit's frequency response, reducing computational cost relative to frequency-by-frequency finite element modeling (FEM). Comparison with FEM is used to assess both the validity and the limitations of the approach. The proposed framework enables fast, first-order prediction of frequency-dependent eddy-current behavior and clarifies the conditions under which equivalent-circuit modeling is applicable to magnetic-signature management.

Paper ID 35

Distributed Coordination of Multi-Virtual Power Plants for Large-Scale EV Integration via Polytope-based Aggregate EV Power Flexibility

Junsang Cha, Chiwon Seo, Gilsoo Jang, Minhan Yoon and Changhee Han

Large-scale integration of heterogeneous electric vehicles (EVs) increases the complexity of distribution network (DN) operation, yet parking windows provide substantial flexibility through controllable charging and discharging with energy carryover across hours. This paper develops a polytope-based inner approximation that preserves time coupling in the aggregate flexibility of many vehicles, and embeds this representation in a distributed coordination scheme that schedules multiple virtual power plants (VPPs) together with a realistic DN model. A homothetic prototype with scaling and translation yields a compact H-representation, while the consensus variables in the consensus alternating direction method of multipliers (ADMM) are updated in closed form via the Karush–Kuhn–Tucker (KKT) optimality conditions, which reduces the computational burden at each ADMM update. Agents exchange only local point of common coupling (PCC) power copies and low dimensional multipliers, thereby preserving privacy, and the coordination enforces network limits on voltage, line current, substation capacity, and losses. On the IEEE-33 bus system, the proposed method reduces total system cost by about 16.11% relative to a box aggregation benchmark under the same coordination procedure, improves substation load flattening, and maintains voltage security. The aggregate schedules also guarantee feasible disaggregation to individual vehicles without constraint violations. These results indicate that the approach achieves economics, network feasibility, and computational efficiency in a single framework for large-scale EV integration.

Paper ID 30

An Impedance-Based Approach for Systematic Stability Assessment of Multi-Bus DC Microgrids

Zhetong Yu, Gengzhe Wang, Huan Yang, Xinmeng Fang and Rongxiang Zhao

DC microgrids have progressively exhibited notable characteristics such as multiple voltage levels, multiple DC busbars, and the integration of numerous power electronic converters. However, this renders the interaction between converters increasingly apparent. To broaden the application of impedance modelling, this paper proposes an impedance-based stability analysis method for multi-voltage-level DC microgrid systems. By developing comprehensive two-port impedance models for key power electronic converters, including voltage-controlled and power-controlled interlinking converters, energy storage systems, and load interfaces, the complex stability assessment is transformed into an equivalent circuit analysis problem through Thevenin's and Norton's theorems. The core contribution lies in establishing three critical equivalent loop gains that enable systematic stability evaluation using Nyquist criterion. Case studies demonstrate that system instability primarily originates from impedance mismatches in low-voltage DC subsystems and improper source-load integration on the high-voltage bus. MATLAB/Simulink simulations under several operational conditions confirm the method's effectiveness.

Paper ID 32

Pre-synchronization Control Strategy for Parallel VSG-Controlled Converters in Island Operation Mode Based on DQ-Axis Voltage

Qibiao Lu, Rujing Zhang, Gengzhe Wang, Jingchi Zhang, Zhetong Yu and Huan Yang

The converter based on virtual synchronous generator (VSG) control has been widely applied in new power systems because it introduces the rotor motion equation and excitation equation of the motor in the control process, endowing power electronic devices with inertia characteristics and damping characteristics. However, in the case of multiple VSG converters being connected in parallel, the traditional pre-synchronization control method based on phase difference will output abrupt compensation changes, resulting in low pre-synchronization efficiency or even failure. In this paper, by establishing a parallel model of the converter, the reasons for the failure of parallel connection caused by the pre-synchronization control method based on phase difference are clarified. And through the analysis of the relationship between the phase and amplitude of different voltages and the magnitude of their dq-axis components, a control method that can directly adjust the dq-axis components of the parallel voltage to achieve pre-synchronization is proposed, which solves the problems of low rate and easy instability in the original synchronization process. On this basis, the influence of the establishment of different dq coordinate systems on the proposed pre-synchronization method was studied in detail, revealing the conclusion that voltage analysis and control must be based on the same dq coordinate system. The simulation results verify the correctness and efficiency of the proposed pre-synchronization method.

Paper ID 33

Fast Training of Physics-Informed Neural Networks Using Analytical Motor Models

Ji-Hoon Han, Jong-Hoon Park and Sun-Ki Hong

Physics-Informed Neural Networks (PINNs) have emerged as a mesh-free alternative to conventional Finite Element Analysis (FEA) for complex structural problems. However, challenges such as hyperparameter selection and high-dimensionality often necessitate incorporating FEA results into the training process. In this paper, a novel approach is proposed, in which outputs from analytical models are used to train PINNs, addressing these challenges. Compared to conventional approaches, improved capability in capturing nonlinear behavior is demonstrated, and the PINN training process is significantly accelerated.

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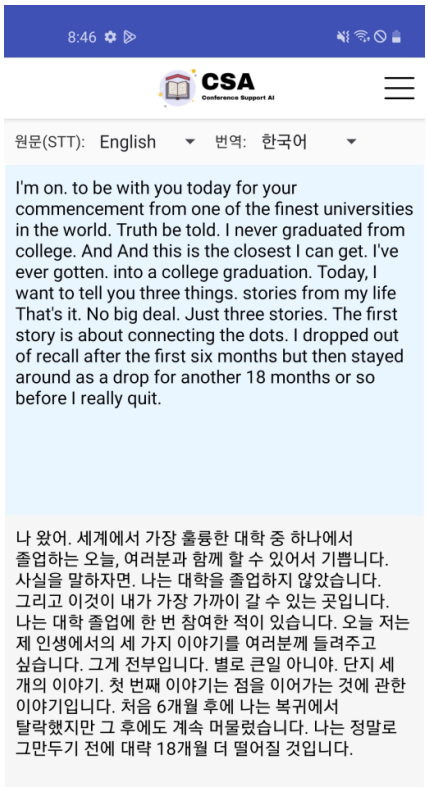

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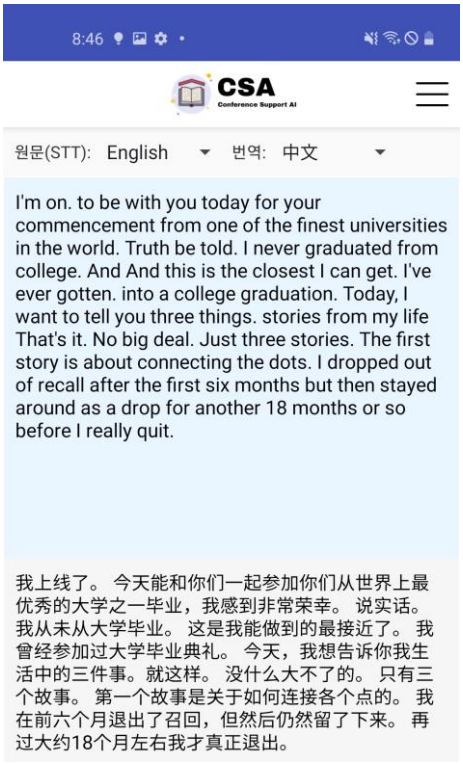

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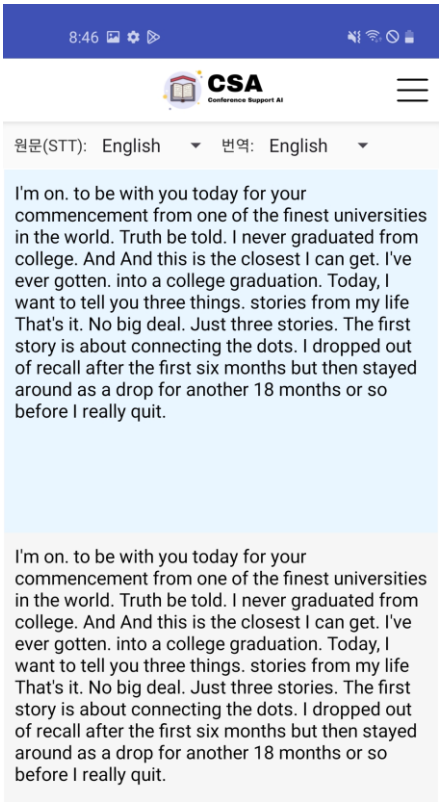

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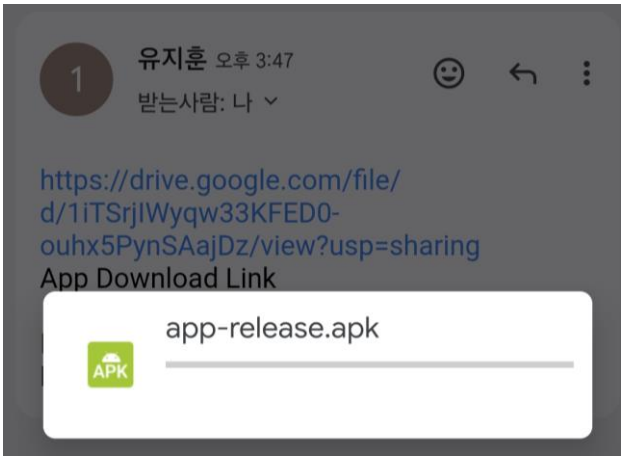

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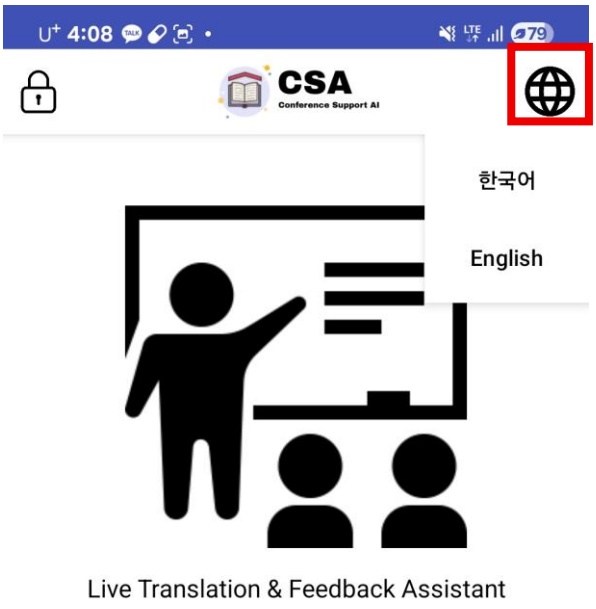

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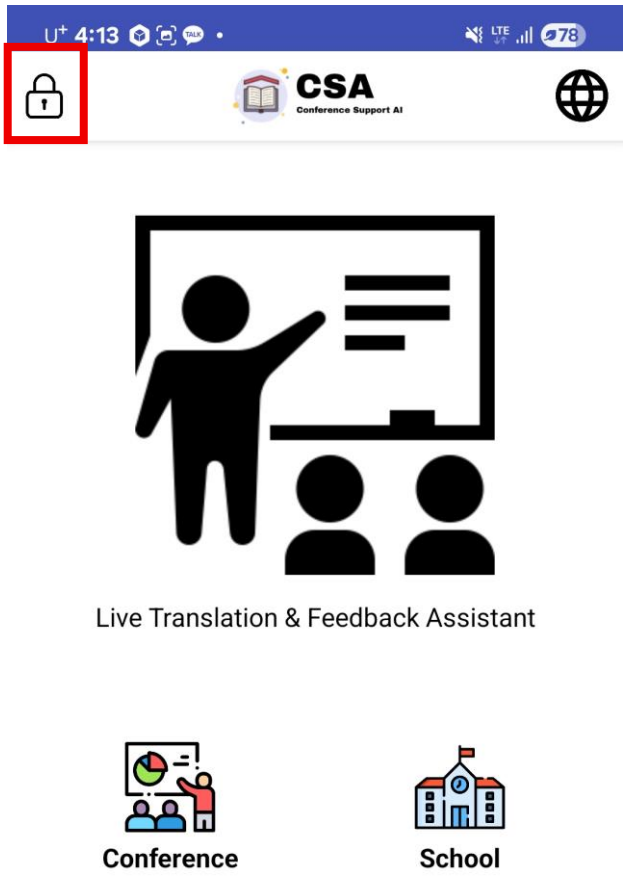

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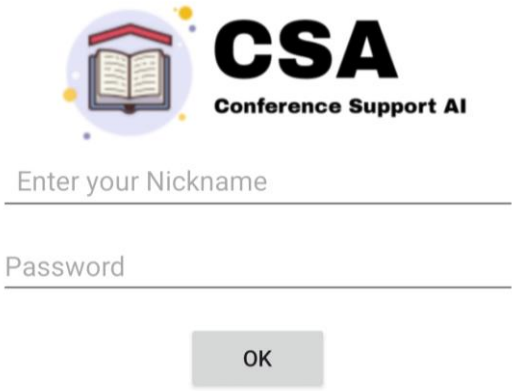

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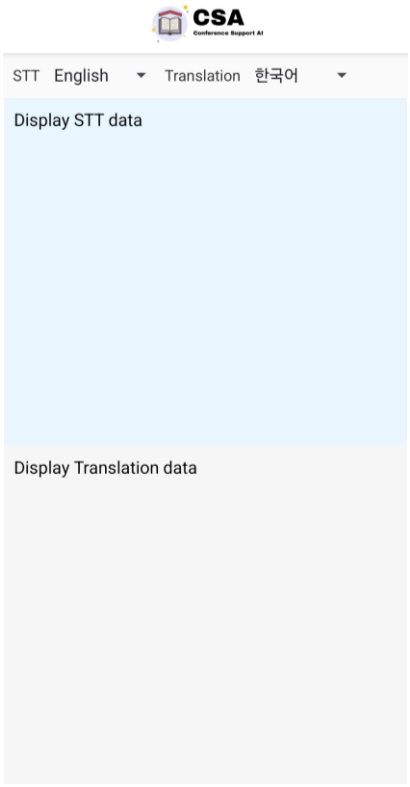

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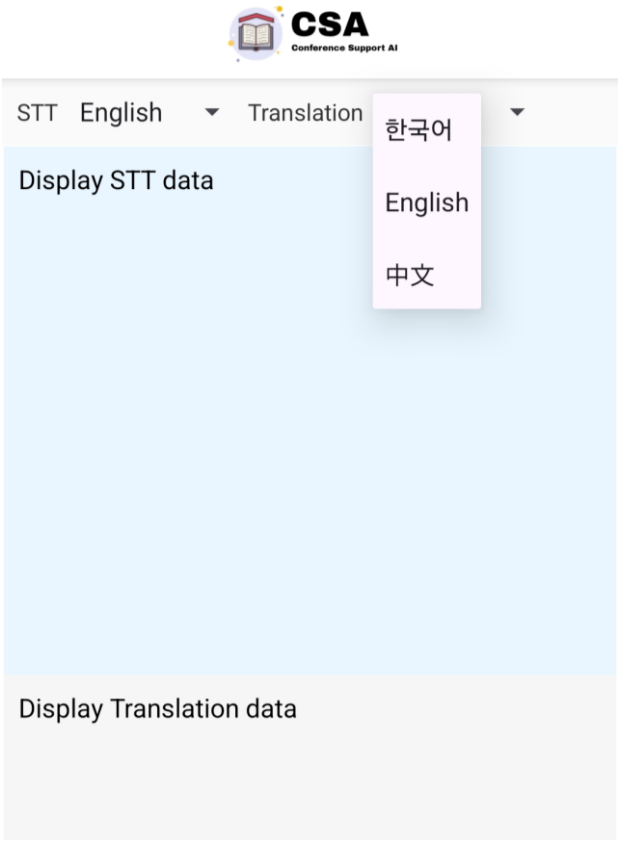

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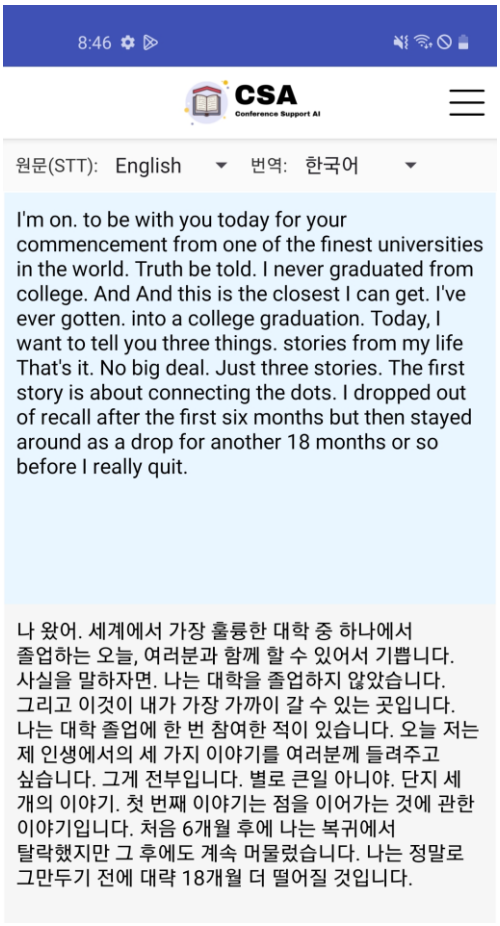

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