IARE
INSTITUTE OF
AERONAUTICAL ENGINEERING

HIGH IMPACT PRACTICES [HIPS]

CORNERSTONE PROJECTS: POWER SYSTEMS

INFORMATION PACKET

2025-2026

INSTITUTE OF AERONAUTICAL ENGINEERING

25 YEARS 2000 2025

I appreciate IARE students who are showing interest in the Power Systems Life Cycle Project Program at the Institute of Aeronautical Engineering.

A cornerstone project (CoP) is typically introduced during the early or middle stages of an academic program at the Institute of Aeronautical Engineering. It focuses on helping students build foundational skills and understand how to apply basic concepts to real-world scenarios. These projects are usually smaller in scope, moderately complex, and designed to strengthen practical understanding of core subjects.

To successfully complete a cornerstone project, students need to become proficient in using simulation and modelling tools. Software like MATLAB/Simulink, ETAP, and Dig SILENT Power Factory are industry-standard platforms that allow for detailed system analysis and visualization of power flow, fault currents, and control strategies. Learning these tools helps students to validate their designs virtually before any physical implementation, reducing errors and improving accuracy. Moreover, the experience gained with these tools makes students more attractive to employers, as practical knowledge of simulation software is highly valued in the power engineering field.

Cornerstone Project (CoP) teams are:

- Collaborative Project – This is an excellent opportunity for students who are committed to working towards social developments and emerging needs.
- Project Activity – The project coordinator listed current working areas for offering cornerstone projects with a team size of at least two students. The coordinator allotted mentors based on the work area and facilitated exclusive project laboratories for selected cornerstone project (CoP)students. This cornerstone project (CoP)bridges the gap between academic learning and real-world social applications. It helps enhance the professional development
- Short-term - Each undergraduate student may participate in a project for an assigned period.

The primary goal of Cornerstone Projects in the Department of Electrical and Electronics Engineering (EEE) is to integrate foundational engineering knowledge with practical, real-world problem-solving to foster innovation, critical thinking, and hands-on technical skills.

- Apply theoretical concepts from circuits, electronics, control systems, embedded systems, and signal processing.
- Encourage team-based design thinking and interdisciplinary collaboration.
- Promote awareness of sustainable and socially relevant solutions aligned with global challenges (such as the UN Sustainable Development Goals).
- Prepare students for industry, entrepreneurship, and advanced research through experiential learning.
- Strengthen skills in circuit design, embedded systems, signal processing, IoT, power systems, and control engineering.
- Encourage students to design original solutions to engineering problems using creative approaches and emerging technologies.
- Cultivate the ability to work effectively in interdisciplinary teams, reflecting real-world engineering environments.
- Provide opportunities to work with tools and platforms like MATLAB, Arduino, Raspberry Pi, LabVIEW, and simulation software.
- Align project outcomes with social, environmental, or community needs—often by mapping them to the **UN Sustainable Development Goals (SDGs)**.
- Inspire students to explore deeper concepts, conduct experiments, and pursue independent or faculty-guided research.

The research theme of this AI based projects also focuses on the challenges presented by the Sustainable Development Goals (SDGs).

IARE Sustainability Development Goals (SDGs) highlighted with Blue Colour Font	
SDG #1	End poverty in all its forms everywhere
SDG #2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
SDG #3	Ensure healthy lives and promote well-being for all at all ages
SDG #4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG #5	Achieve gender equality and empower all women and girls
SDG #6	Ensure availability and sustainable management of water and sanitation for all
SDG #7	Ensure access to affordable, reliable, sustainable and modern energy for all
SDG #8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG #9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
SDG #10	Reduce inequality within and among countries
SDG #11	Make cities and human settlements inclusive, safe, resilient and sustainable
SDG #12	Ensure sustainable consumption and production patterns
SDG #13	Take urgent action to combat climate change and its impacts
SDG #14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
SDG #15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG #16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
SDG #17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

The following research domains are recommended for HIPs-Power Systems Projects, and selected students should find the research gap and frame the problem statements from any one of the themes below**.**

1. Real-Time Fault Detection Using AI in Power Systems **(SDG#7, SDG #9, SDG#11, SDG #12)**
2. Development of IoT-Based Home Automation Using Edge Computing **(SDG#7, SDG #9, SDG#11)**
3. Cybersecurity Frameworks for Smart Grids and SCADA Systems **(SDG#7, SDG #9, SDG#11)**
4. AI-Based Load Forecasting in Smart Power Distribution Networks **(SDG#7, SDG #9, SDG#11)**
5. Development of Self-Healing Electrical Networks Using AI **(SDG#7, SDG #9, SDG#11)**
6. Augmented Reality (AR) Integration in Smart Grid Control Room for Real-Time Monitoring **(SDG#4, SDG #7, SDG#9, SDG #11)**
7. Smart Energy Metering and Real-Time Billing Using Blockchain **(SDG#7, SDG #9, SDG#11)**
8. Hybrid Energy Storage System (HESS) Management Using AI **(SDG#7, SDG #9, SDG#11)**

In order to participate in Power Systems Projects, you must formally apply and be accepted by the project coordinator. To proceed, please mail to the project coordinator, Dr. Damodhar Reddy, Professor and Head, Dept. of EEE, Email Id: dr.damodharreddy@iare.ac.in. This will bring up all available open positions tagged as Power Systems projects. When submitting a project document and an updated résumé, include a statement regarding why you are interested in working with the team to which you are applying. Please note that participation by the power electrics project team requires registration for the accompanying research statement from any of the specified domains. More information will be provided to all selected power systems project applicants who have been offered a position. If you have any questions about a particular team, please contact the team's faculty mentor(s). We encourage you to contemplate this fascinating new opportunity. We look forward to receiving your application submission.

Real-Time Fault Detection Using AI in Power Systems

GOALS

The primary goal is to develop an intelligent system capable of quickly and accurately detecting, classifying, and locating faults in electrical Power Systems as they occur, using Artificial Intelligence techniques. This enables timely corrective actions to minimize system downtime, prevent equipment damage, and ensure stable and reliable power delivery.

Early Fault Identification: Detect faults such as short circuits, line-to-ground faults, or equipment failures in real time to reduce response time.

Accurate Fault Classification: Use AI algorithms (e.g., neural networks, support vector machines) to classify the type of fault based on system signals.

Fault Localization: Pinpoint the exact location of faults on the power grid for efficient maintenance.

Reduce False Alarms: Improve system reliability by minimizing incorrect fault detections.

Integration with Smart Grid Systems: Enable the AI-based fault detection to work seamlessly with automated grid management and protection schemes.

Enhance System Resilience: Strengthen the power system's ability to recover quickly from faults and maintain continuous operation.

Power Systems are complex and critical infrastructure. Real-time fault detection powered by AI helps utilities maintain high reliability, safety, and efficiency, especially as grids become more dynamic with renewable energy and smart devices.

METHODS & TECHNOLOGIES

Methods

- **Data Collection:** Real-time voltage/current data from sensors and SCADA systems
- **Preprocessing:** Filtering, normalization, and feature extraction
- **Model Training:** Supervised machine learning using labelled fault data
- **Fault Classification**: Using AI models (e.g., neural networks, SVMs)
- **System Integration:** Real-time deployment with microcontrollers or embedded platforms

Technologies & Tools

- **Machine Learning Algorithms:** CNNs, RNNs, SVM, Random Forest
- **AI Platforms:** TensorFlow, PyTorch, Scikit-learn
- **Data Acquisition:** PMUs (Phasor Measurement Units), IoT sensors
- **Simulation Tools:** MATLAB/Simulink, ETAP, PowerWorld
- **Hardware:** Raspberry Pi / Arduino (for prototypes), DSPs
- **Communication:** MQTT, Modbus, SCADA systems

MAJORS & AREAS OF INTEREST

The **relevant academic programs and technical domains** that provide the foundational knowledge and skill sets needed to understand, build, and improve real-time AI-based fault detection systems in electrical power grids.

Electrical Engineering: provides the essential principles of power system operation, fault types, system stability, and protection mechanisms. The theory of power system analysis, including symmetrical components and relay coordination, forms the backbone of understanding how faults behave and propagate through electrical networks.

Artificial Intelligence and Computer Science: contribute through learning theory, data structures, real-time computing, and machine learning algorithms. These disciplines introduce models such as artificial neural networks, support vector machines, and deep learning frameworks, which enable intelligent fault classification, prediction, and automated decision-making.

Electronics and Communication Engineering: supports this system through signal processing theory and digital communication protocols, enabling the accurate sensing and transmission of fault data from the power grid to intelligent control centers. Embedded system theory allows for the integration of AI models into real-time hardware platforms like microcontrollers and DSPs.

Data Science: grounded in statistical learning theory and time-series analysis, provides techniques for analysing large sets of power system data, detecting anomalies, and forecasting potential system failures. These approaches enhance the system's ability to prevent faults and reduce response time.

Instrumentation and Control Engineering: draws from control theory and automation principles to enable monitoring, regulation, and self-healing responses in smart grids. The integration of SCADA systems and feedback control loops ensures real-time fault detection is not only identified but also acted upon.

The convergence of these majors reflects an **interdisciplinary theoretical approach**, where knowledge from multiple domains interacts to produce reliable, efficient, and intelligent Power Systems. This alignment mirrors modern educational theories such as constructivism and experiential learning, where real-world problems are solved through collaborative, applied, and cross-disciplinary knowledge building.

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PARTNERS & SPONSORS

None

Development of IoT-Based Home Automation Using Edge Computing

GOALS

The phrase "**Development of IoT-Based Home Automation Using Edge Computing"** refers to the process of designing and implementing a smart home system where Internet of Things (IoT) devices are used to monitor and control household appliances, and edge computing is applied to process data locally, near the source of data generation (within the home), rather than sending all data to the cloud. This approach is grounded in the theory of distributed computing and intelligent systems, where computational resources are moved closer to the physical devices (sensors, controllers, actuators) to achieve faster response times, reduced latency, and enhanced data privacy. It combines IoT architecture principles, which emphasize connectivity and interoperability of devices, with edge computing models, which promote decentralized data processing.

- Making the home **intelligent and automated** through connected devices.
- Using **edge computing** (e.g., Raspberry Pi, ESP32) to **process data locally**, reducing delay and enhancing security.
- Creating systems that are **efficient, responsive, and privacy-aware** by avoiding the need to send all data to external servers.

METHODS & TECHNOLOGIES

Methods (Process & Approach)

The development of this system involves several key methods:

- **System Design & Architecture Planning** Defining the IoT network layout, identifying devices to be controlled (e.g., lights, fans, sensors), and choosing edge computing nodes.
- **Device Integration & Communication** Connecting sensors (temperature, motion, humidity, etc.) and actuators (relays, motors) through protocols like **GPIO**, **I2C**, or **SPI**.
- **Edge Computing Deployment** Processing data locally using microcontrollers or single-board computers. Logic for automation, control, and decision-making is executed at the **edge**, not in the cloud.
- **Local Network Setup** Using **Wi-Fi** or **Bluetooth** to enable device-to-device communication within the home.
- **User Interface Development** Creating a mobile/web app or dashboard for user control and real-time monitoring of devices.
- **Testing & Optimization** Evaluating system performance, response time, energy efficiency, and adjusting automation rules as needed.

Technologies Used

- **Edge Devices**:
  Raspberry Pi (as a central edge hub)
  ESP32 / ESP8266 (for smart sensing and control)
- **Sensors & Actuators**:
  PIR motion sensors, DHT11/DHT22 (temperature & humidity), gas sensors, LDR, IR sensors.
  Relays, LEDs, servo motors, and other output devices
- **Communication Protocols**:
  MQTT – Lightweight messaging for IoT
  HTTP/REST API – For local server access
  Wi-Fi / Bluetooth – For wireless communication
- **Programming Languages**:
  Python (for Raspberry Pi logic and server)

C/C++ (for ESP32 firmware using Arduino IDE)

- **Software Platforms**:
  Node-RED or Home Assistant (for logic flow and automation)
  Arduino IDE (for microcontroller programming)
  Blynk / MIT App Inventor / Flutter (for mobile app interfaces)
- **Databases / Storage**:
  Local SQLite / lightweight JSON files.
  Optional integration with cloud platforms (Firebase, AWS IoT) for backup.

MAJORS & AREAS OF INTEREST

The development of IoT-based home automation systems using edge computing is an interdisciplinary field that integrates concepts and skills from several academic majors and technical domains. This project primarily involves **Electrical Engineering**, **Electronics and Communication Engineering**, **Computer Science and Artificial Intelligence**, **Instrumentation and Control Engineering**, and **Information Technology**.

Electrical Engineering contributes foundational knowledge of Power Systems, circuits, and sensor interfacing, which are crucial for designing the hardware infrastructure of home automation devices.

Electronics and Communication Engineering focuses on signal processing, wireless communication protocols such as Wi-Fi and Bluetooth, and embedded system design, enabling seamless connectivity and control among IoT devices.

Computer Science and Artificial Intelligence bring expertise in programming, software development, and the implementation of intelligent algorithms that process data locally at the edge, facilitating real-time automation and decision-making. This includes knowledge of network security to protect user data and maintain privacy within the home network.

Instrumentation and Control Engineering provide the theoretical and practical frameworks for measurement, monitoring, and automation of physical systems, ensuring reliable system control and feedback.

Information Technology supports system integration, cloud services (if used), and user interface development, offering platforms for users to interact with and manage their smart home environments.

Collectively, these majors and areas of interest encompass both hardware and software perspectives, highlighting the interdisciplinary nature of modern home automation systems and the importance of edge computing to create efficient, responsive, and secure smart homes.

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PARTNERS & SPONSORS

None

Cybersecurity Frameworks for Smart Grids and SCADA Systems

GOAL

To design, develop, and implement robust cybersecurity frameworks that protect Smart Grids and SCADA (Supervisory Control and Data Acquisition) systems from cyber threats, ensuring secure, reliable, and resilient operation of modern power infrastructure.

Identify Cyber Threats and Vulnerabilities: Analyse common attack vectors (e.g., malware, DDoS, spoofing, unauthorized access) targeting smart grid communication networks and SCADA systems.

Develop a Multi-Layer Security Framework: Implement security measures at various layers – physical, network, application, and data – to ensure end-to-end protection.

Ensure Real-Time Intrusion Detection and Response: Design or integrate Intrusion Detection Systems (IDS) and Anomaly Detection methods that operate in real-time within SCADA and smart grid environments.

Incorporate Cryptographic and Authentication Protocols: Use encryption, digital signatures, and secure key management to protect control data and user access.

Establish Policy and Compliance Standards: Align the framework with industry standards such as NIST, IEC 62443, or ISO/IEC 27001 to ensure compliance and interoperability. Simulate and Test Threat Scenarios: Create testbeds to simulate attacks and evaluate the effectiveness of the proposed framework under real-world conditions.

Support Resilience and Recovery: Design protocols for quick system restoration and continuity of service in the event of a cyber-attack.

Smart grids and SCADA systems are becoming increasingly interconnected and digtal, making them prime targets for cyberattacks.

METHODS & TECHNOLOGIES

Proactive Security Architecture

Emphasizes preventive rather than reactive measures—focusing on real-time detection, access control, and early threat identification.

AI & ML-Driven Monitoring

Prefers the integration of artificial intelligence and machine learning to build adaptive systems that can detect anomalies, zero-day attacks, and evolving threats with minimal human intervention.

Layered Security (Défense-in-Depth)

Adopts a multi-layered protection strategy across network, data, application, and physical layers—ensuring redundancy and minimizing single points of failure.

Secure and Redundant Communication Protocols

Utilizes secure industrial protocols like IEC 62351, DNP3-SA, and TLS/IPSec to ensure data confidentiality, integrity, and authentication in real-time power grid operations.

Standards and Framework Compliance

Aligns with international standards (e.g., NIST, NERC-CIP, IEC 62443) to ensure interoperability, auditability, and best practices in infrastructure protection.

System Resilience and Recovery Planning

Prefers strategies that ensure not just defence, but also rapid recovery from cyberattacks, maintaining power system continuity and integrity.

Testbeds, Simulations, and Penetration Testing

Favors rigorous testing environments to simulate cyberattacks, train defence mechanisms, and validate system robustness under controlled conditions.

MAJORS & AREAS OF INTEREST

Comprehensive Défense-in-Depth: Emphasizes multiple layers of security controls—from physical security of devices, network segmentation, secure software development, to user access controls—to minimize risk exposure at every point in the system.

Advanced AI and Machine Learning Integration: Prefers leveraging cutting-edge AI/ML algorithms for anomaly detection, predictive threat analytics, and automated incident response to enhance the speed and accuracy of cybersecurity operations.

Strict Compliance with Industry Standards: Strongly aligns with globally recognized cybersecurity frameworks and standards such as NIST Cybersecurity Framework, IEC 62443 for industrial automation security, and NERC CIP for critical infrastructure protection, ensuring interoperability and regulatory adherence.

Robust Secure Communication Protocols: Utilizes encryption and authentication standards tailored to smart grid environments like IEC 62351 and DNP3 Secure Authentication to safeguard data integrity and confidentiality in control and monitoring communications. **Real-Time Monitoring and Incident Response:** Prefers deploying Security Information and Event Management (SIEM) systems and real-time Intrusion Detection Systems (IDS) to detect, analyse, and respond to threats promptly, minimizing operational disruptions.

Resilience and Rapid Recovery Planning: Prioritizes designing systems with redundancy, failover capabilities, and comprehensive disaster recovery plans to maintain uninterrupted power system operation even under cyberattack scenarios.

Continuous Testing and Validation: Advocates for frequent penetration testing, red team exercises, and cyber range simulations to identify vulnerabilities proactively and strengthen system defences.

Interdisciplinary Collaboration: Encourages cooperation among experts in electrical engineering, cybersecurity, data science, control systems, and regulatory compliance to develop holistic and practical security solutions.

User Awareness and Training: Supports ongoing education and training programs for operators and engineers to maintain high security awareness and reduce human factor risks.

Scalable and Future-Proof Solutions: Prefers cybersecurity frameworks that can evolve with emerging threats, technological advances (e.g., quantum computing), and expanding smart grid architectures.

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PARTNERS & SPONSORS

None

AI-Based Load Forecasting in Smart Power Distribution Networks

GOAL

The goal of this research is to develop **an intelligent, secure, and resilient self-healing power grid by leveraging advanced AI technologies integrated with traditional power system models**. It aims to enhance fault detection, diagnosis, and recovery through physics-informed hybrid AI, ensure data privacy and security using federated learning, and build operator trust with explainable AI. The research further seeks to enable decentralized, cooperative fault management using multi-agent reinforcement learning, improve prediction accuracy through advanced sensor fusion, and simulate effective recovery strategies via real-time AI-driven digital twins. Additionally, it aims to ensure secure coordination among distributed agents using blockchain and achieve low-latency, scalable performance through cloud-edge hybrid computing architectures.

METHODS & TECHNOLOGIES

Multimodal Data Integration: Prefers leveraging diverse data types beyond load and weather including social behaviour analytics, economic indicators, and grid asset health data to improve forecast accuracy.
Hybrid Physics-Informed AI Models: Prefers combining classical power system models (e.g., load flow, state estimation) with AI techniques to enhance interpretability and reliability.
Graph Neural Networks (GNNs): Prefers exploiting grid topology and spatial dependencies via GNNs for superior spatiotemporal load forecasting**.**
Transfer Learning & Domain Adaptation: Prefers approaches that adapt pre-trained models from one region or grid segment to another, reducing data needs**.**
Reinforcement Learning (RL): Prefers RL methods for adaptive demand-side management based on load forecasting outputs.
Federated Learning & Privacy-Preserving AI: Prefers decentralized model training directly on edge devices (smart meters, substations) to protect customer privacy while maintaining accuracy.
Uncertainty Quantification: Prefers Bayesian deep learning and ensemble techniques that provide confidence intervals around forecasts, enabling risk-aware grid operations.

MAJORS & AREAS OF INTEREST

Frontier Engineering & Technology Disciplines

- **Advanced Power Electronics and Grid Integration** Prefers specialization in power converters, solid-state transformers, and advanced inverter controls supporting dynamic load management and forecasting accuracy.
- **Neuromorphic Computing & Brain-Inspired AI** Prefers exploration of biologically inspired AI architectures for ultra-efficient, low-latency forecasting and adaptive grid intelligence.
- **Edge AI & Distributed Intelligence** Prefers deploying decentralized AI models running on resource-constrained edge devices to enable near real-time localized forecasting and control.

Emerging Interdisciplinary Domains

- **Synthetic Data Generation & Augmented Reality for Grid Operations** Prefers generating realistic synthetic load profiles for robust AI training and employing AR to visualize complex grid states for operator training.
- **Energy Informatics & Computational Social Science** Prefers integrating consumer behavior, social network analysis, and policy impacts with technical load forecasting models for socially aware energy management.

- **Human-Centered AI & Participatory Sensing** Prefers designing AI systems incorporating human feedback loops and crowd-sourced sensing for enhanced forecasting reliability.

Application-Driven & Industry-Integrated Areas

- **Decentralized Energy Systems & Peer-to-Peer Trading** Prefers studying blockchain-enabled energy markets with AI-driven forecasting for optimized peer-to-peer energy transactions.
- **Resilient and Adaptive Grid Design** Prefers integrating AI forecasting with resilient grid topologies designed for rapid recovery from disruptions and climate-induced events.
- **Energy Storage and Demand Flexibility** Prefers coupling load forecasting with predictive management of battery storage, EV charging, and flexible demand response resources.

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PARTNERS & SPONSORS

None

Development of Self-Healing Electrical Networks Using AI

GOAL

This research aims to **enable a resilient, intelligent, and secure self-healing power grid by integrating advanced AI techniques with power system engineering**. It focuses on hybrid AI models that combine physics-based simulations with data-driven learning to enhance the accuracy and interpretability of fault diagnosis and network reconfiguration. Federated learning is employed to support collaborative intelligence across distributed grid nodes while preserving data privacy and security. Explainable AI ensures transparency in decision-making to build operator trust and support regulatory compliance. Multi-agent reinforcement learning facilitates decentralized, cooperative control for dynamic fault isolation and restoration. Real-time digital twins, integrated with AI, allow continuous monitoring and simulation of recovery strategies. The approach leverages sensor fusion for early anomaly detection, blockchain for secure and tamper-proof agent coordination, and cloud-edge hybrid computing to deliver fast, scalable responses to grid disturbances.

METHODS & TECHNOLOGIES

Explainable AI (XAI) Algorithms: Prefers AI models that offer transparent decision-making processes to facilitate operator trust and regulatory approval in self-healing actions.
Federated and Distributed Learning: Prefers privacy-preserving, decentralized machine learning methods to collaboratively train models across multiple grid segments without data sharing risks.
Hybrid Physics-Informed Machine Learning: Prefers combining physical laws of electrical networks with data-driven models for improved accuracy, interpretability, and generalization.
Meta-Learning & Transfer Learning: Prefers AI techniques that adapt rapidly to new fault scenarios or network configurations by leveraging prior learning.
High-Density Sensor Networks with Multi-Modal Data Fusion: Prefers integrating electrical, thermal, acoustic, and vibration sensor data for comprehensive fault detection.
Synchronized Phasor Measurements & Wide-Area Monitoring Systems (WAMS): Prefers utilizing PMU data streams for system-wide situational awareness and predictive analytics.
Drone-Enabled Remote Sensing: Prefers aerial drones equipped with sensors and cameras to inspect and monitor hard-to-reach grid infrastructure in real time.

MAJORS & AREAS OF INTEREST

Power Systems Engineering with Emphasis on Smart Grids: Prefers students and researchers with strong fundamentals in power generation, transmission, distribution, and modern grid technologies.
Control Engineering with Focus on Adaptive and Distributed Control: Prefers expertise in advanced control theories, especially those enabling decentralized and real-time adaptive responses in electrical networks.
Computer Engineering Specializing in Embedded Systems and Real-Time AI: Prefers knowledge in designing hardware-software co-designed AI solutions for latency-sensitive grid applications.
Electrical and Computer Communications Engineering: Prefers skills in designing robust, secure communication infrastructures that support critical smart grid operations.
Applied Machine Learning with Emphasis on Graph Neural Networks & Reinforcement Learning: Prefers cutting-edge ML techniques tailored to modelling complex network topologies and autonomous decision making.
Explainable AI and Trustworthy AI Research: Prefers researchers focused on making AI decisions interpretable and verifiable in safety-critical power system contexts.
Distributed and Federated AI Systems: Prefers expertise in decentralized model training and inference that preserves data privacy and ensures scalability.

Big Data Analytics and Streaming Data Processing: Prefers familiarity with handling and deriving insights from large-scale real-time sensor and operational datasets.
Cyber-Physical Systems Engineering: Prefers expertise in integrating computing, networking, and physical processes with rigorous timing and safety constraints.
Internet of Things (IoT) and Edge Computing: Prefers research in scalable, secure deployment of sensor networks and AI inference at the edge.
Cybersecurity with Focus on Critical Infrastructure Protection: Prefers specialization in threat detection, mitigation, and resilient system design for smart grid environments.
Renewable Energy Systems and Grid Integration: Prefers understanding of renewable energy variability and its impact on self-healing grid strategies.
Digital Twin and Simulation Sciences: Prefers experience in creating high-fidelity virtual models for real-time system monitoring and AI training.
Smart Grid and Microgrid Technologies: Prefers proficiency in modern grid management, demand response, energy storage, and distributed energy resources (DERs).
Embedded AI and Real-Time Systems Engineering: Prefers expertise in designing AI that meets strict latency, reliability, and energy consumption requirements.
Systems Engineering and Technology Management: Prefers skills in overseeing complex, multi-disciplinary projects ensuring successful deployment and operation.

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PARTNERS & SPONSORS

None

Augmented Reality (AR) Integration in Smart Grid Control Room for Real-Time Monitoring

GOAL

The goal of this research is to **design and implement an augmented reality (AR)-enhanced interface for power grid operations that improves situational awareness, decision-making, and response times in real-time control environments**. It aims to provide seamless, multi-layered visualization of grid data—such as load flow, fault status, and topology—directly within the operator's workspace using spatially accurate AR overlays. The research further seeks to reduce cognitive load through intuitive visual cues and contextual filtering, enable interactive control via gesture, voice, and gaze, and support collaborative decision-making through multi-user AR sessions. Additional goals include integration with existing grid management systems (e.g., SCADA, EMS), real-time fault detection and visualization, scalable deployment across diverse control environments, and immersive operator training for rare fault conditions—all while ensuring compliance with cybersecurity and data privacy standards.

METHODS & TECHNOLOGIES

Augmented Reality Development Frameworks: Use advanced AR SDKs and platforms such as Microsoft HoloLens SDK, ARCore (Google), ARKit (Apple), or Unity3D with Vuforia for building immersive AR applications tailored to control room environments.
3D Spatial Mapping and Environment Modelling: Implement simultaneous localization and mapping (SLAM) algorithms to create accurate 3D representations of control rooms, enabling precise overlay of virtual elements on physical objects.
Real-Time Data Integration: Develop middleware systems to stream real-time smart grid data (e.g., from SCADA, EMS, PMUs) into the AR application using protocols like MQTT, OPC-UA, or REST APIs.
Sensor Fusion: Combine data from multiple sources such as electrical sensors, cameras, GPS, and environmental monitors to enhance the contextual relevance and accuracy of AR visualizations.
User Interaction Techniques: Employ multi-modal interfaces such as hand gestures, voice commands, eye tracking, and haptic feedback for intuitive and non-disruptive control of AR content.

Hardware Platforms:
Utilize AR headsets (e.g., Microsoft HoloLens, Magic Leap), wearable smart glasses, or tablet-based AR devices designed for industrial use with high-resolution displays and spatial audio.
Cloud and Edge Computing:
Leverage edge computing to process and analyse large volumes of grid data near the control room, minimizing latency, complemented by cloud services for heavy analytics and long-term storage.
Real-Time Analytics and AI:
Integrate AI-driven analytics for anomaly detection, predictive maintenance, and decision support, enabling the AR system to highlight critical events proactively.
3D Visualization and Rendering Engines:
Use advanced rendering engines like Unity or Unreal Engine to produce high-fidelity 3D models, animations, and dynamic visual effects representing grid status and alerts.
Cybersecurity Technologies:
Implement end-to-end encryption, secure authentication mechanisms, and network security protocols to protect AR communications and control room data from cyber threats.
Collaboration Tools:
Incorporate multi-user AR collaboration platforms that support remote participation and real-time annotations, enabling distributed teams to jointly manage grid operations.

MAJORS & AREAS OF INTEREST

The ideal candidate should have a solid foundation in smart grid operations, including **power system dynamics, SCADA, and grid automation, to ensure AR solutions align with real-world control room needs**. Strong capabilities in real-time software development, system integration, and distributed computing are essential for building reliable, mission-critical AR applications. Expertise in augmented and mixed reality, particularly in spatial computing and immersive interface design, is key to transforming operator interaction with complex grid data. A background in control systems, fault-tolerant automation, and **low-latency industrial communication (e.g., 5G, IIoT) supports responsive and resilient AR operations**. Proficiency in human-computer interaction (HCI) and UX design is critical to minimize cognitive load and improve situational awareness under high stress. Familiarity with **AI/ML for anomaly detection and decision support, cybersecurity compliance (e.g., NERC CIP), and GIS-based geospatial visualization is also important**. Additional strengths include experience with edge-cloud architectures, real-time sensor data fusion, and AR-integrated training and simulation environments, including digital twins, to support both operational excellence and continuous learning.

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PARTNERS & SPONSORS

None

Smart Energy Metering and Real-Time Billing Using Blockchain

GOAL

The primary goal is to develop a **secure, transparent, and efficient energy metering and billing system** using **blockchain technology**. This system aims to improve the accuracy, reliability, and speed of real-time energy transactions and billing while minimizing fraud and data manipulation. **Real-Time Metering**: Implement **IoT-based smart meters** to collect accurate energy consumption data from users in real time. **Blockchain Integration**: Utilize **blockchain technology** to securely process and store billing transactions, ensuring transparency and reducing the risk of tampering. **Fraud Prevention**: Leverage the immutable nature of blockchain to prevent manipulation of meter readings and unauthorized access to billing data. **Instant Billing**: Enable **real-time billing** based on consumption data stored on the blockchain, ensuring immediate and accurate transactions for customers.

METHODS & TECHNOLOGIES

Blockchain Development Platforms:
Use advanced blockchain frameworks such as **Ethereum**, **Hyperledger Fabric**, or **Corda** to build secure, decentralized energy billing systems with support for smart contracts and distributed ledgers.
Smart Contract Implementation:
Deploy smart contracts to automate energy billing, enforce usage-based pricing models, and trigger real-time payment settlements without manual intervention.
Real-Time Data Acquisition from Smart Meters:
Integrate IoT-enabled smart energy meters for continuous monitoring and secure transmission of consumption data using protocols like **MQTT**, **CoAP**, or **LoRaWAN**.
Data Encryption and Secure Transactions:
Implement end-to-end encryption, digital signatures, and secure hashing (e.g., **SHA-256**) to protect user identity, ensure data integrity, and prevent tampering or fraud.
Edge and Cloud Computing for Data Processing:
Leverage **edge devices** to preprocess meter data close to the source, reducing latency, and utilize **cloud platforms** (e.g., AWS, Azure) for scalable billing analytics and historical data storage.

Hardware Platforms:
Utilize smart meters with built-in communication modules, IoT gateways, and microcontrollers (e.g., Raspberry Pi, ESP32) to collect and relay data to the blockchain securely.
AI-Driven Consumption Analytics:
Apply machine learning models to detect anomalies, predict usage patterns, and optimize energy pricing dynamically based on real-time consumption trends.
Cryptocurrency & Token Integration:
Integrate digital wallets and tokenized payment systems to support blockchain-based payments, refunds, and incentives for energy-efficient usage.
Cybersecurity and Identity Management:
Use blockchain-based identity solutions and multi-factor authentication to protect user data and control access to meter information and transaction records.
Interoperability with Energy Systems:
Ensure compatibility with existing SCADA systems, AMI infrastructure, and national energy data standards for seamless deployment in live grid environments.

Regulatory Compliance and Auditing:
Design systems to meet energy sector compliance standards (e.g., **ISO 27001**, **GDPR**, **CERC**) and facilitate transparent auditing through immutable transaction logs.

MAJORS & AREAS OF INTEREST

The ideal candidate should have a strong foundation in electrical engineering, particularly in energy systems, **smart grid architecture, and power distribution** to ensure accurate and reliable metering integration. Proficiency in computer science and artificial intelligence is essential for implementing blockchain technology, developing **smart contracts**, and enabling **real-time, secure data processing and fraud prevention**. A background in electronics and communication engineering supports effective use of IoT communication protocols and ensures seamless data transmission from smart meters to blockchain platforms. Data science expertise is important for analyzing consumption trends, detecting anomalies, and **building predictive models** to enhance billing accuracy and customer insights. Additionally, knowledge in instrumentation and control engineering is vital for integrating smart metering systems with existing automation and grid management platforms, enabling efficient energy monitoring and control.

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None

Hybrid Energy Storage System (HESS) Management Using AI

GOAL

The primary goal is to develop an intelligent system for managing Hybrid Energy Storage Systems (HESS) using Artificial Intelligence (AI) to optimize energy storage, increase system efficiency, and support grid stability. The system aims to dynamically control and manage the charging and discharging of both batteries and supercapacitors in hybrid energy systems, based on real-time grid conditions, energy demands, and storage capacity.
Energy Storage Optimization: Maximize energy efficiency by dynamically managing HESS charging and discharging cycles using AI-based algorithms.
Real-Time Control: Implement AI-driven decision-making for real-time control of hybrid energy storage systems, ensuring optimal energy dispatch and storage.
Fault Detection and Prevention: Use machine learning models to identify potential faults or inefficiencies in HESS components, such as battery degradation or overcharging, to prevent costly damage.
Grid Stability Support: Enhance grid resilience by ensuring hybrid energy systems provide support during periods of high demand, integrating renewable sources, and responding to grid disturbances.
AI-Based Predictive Maintenance: Use AI to predict maintenance needs and optimize lifespan for batteries and supercapacitors, reducing downtime and operational costs.
Integration with Smart Grids: Seamlessly integrate AI-based HESS management with existing grid infrastructure and energy management systems (EMS) for real-time coordination and enhanced performance.

METHODS & TECHNOLOGIES

Methods
Data Collection: Real-time data from grid sensors, energy meters, and storage systems (e.g., voltage, current, temperature).
Preprocessing: Data cleaning, normalization, and feature extraction from grid conditions and energy storage components.
Model Training: Supervised and unsupervised machine learning techniques for optimizing energy storage algorithms based on labeled training data.
Storage System Optimization: Use AI to control hybrid energy storage systems' charging/discharging cycles to optimize efficiency, capacity, and lifetime.
Fault Detection & Anomaly Detection: Implement machine learning algorithms (e.g., neural networks, SVM) to predict and prevent faults such as battery degradation, overcharging, and underperformance.**System Integration**: Integration with real-time grid management and energy management systems (EMS), ensuring smooth data exchange and operational coordination.

Technologies & Tools

Machine Learning Algorithms: Neural Networks (NN), Support Vector Machines (SVM), Random Forest, Deep Reinforcement Learning for decision-making.
AI Platforms: TensorFlow, Keras, PyTorch, Scikit-learn for model development and real-time integration.
Energy Storage Systems: Batteries, supercapacitors, and hybrid energy storage systems for energy management and storage optimization.

Data Acquisition: SCADA systems, PMUs (Phasor Measurement Units), IoT sensors, smart meters for real-time monitoring.
Simulation Tools: MATLAB/Simulink for energy system modeling, HESS simulations, and optimization.

Hardware: Raspberry Pi, microcontrollers (Arduino), DSPs for prototype systems; specialized energy storage management hardware.
Communication Protocols: MQTT, Modbus, CAN Bus for communication between smart meters, storage devices, and EMS.

MAJORS & AREAS OF INTEREST

The ideal candidate should have a comprehensive understanding of Power Systems, energy storage technologies, and artificial intelligence to effectively develop and manage **Hybrid Energy Storage Systems** (HESS). A strong background in electrical engineering is essential for understanding grid operations and the integration of storage technologies such **as batteries and supercapacitors**. Expertise in artificial intelligence and computer science is crucial for applying machine learning algorithms, data analytics, and real-time control strategies to optimize storage performance and enable predictive maintenance. Knowledge in electronics and communication engineering supports the use of sensors, communication protocols, and **data acquisition systems to monitor storage systems** in real time. Proficiency in data science is important for handling large datasets, conducting predictive modeling, **detecting anomalies**, and enhancing system efficiency. Additionally, skills in instrumentation and control engineering enable the design of automation systems and feedback loops necessary for integrating HESS with smart grids and energy management systems. The convergence of these disciplines is key to building intelligent, responsive, and efficient energy storage solutions that meet the evolving demands of modern Power Systems.

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None