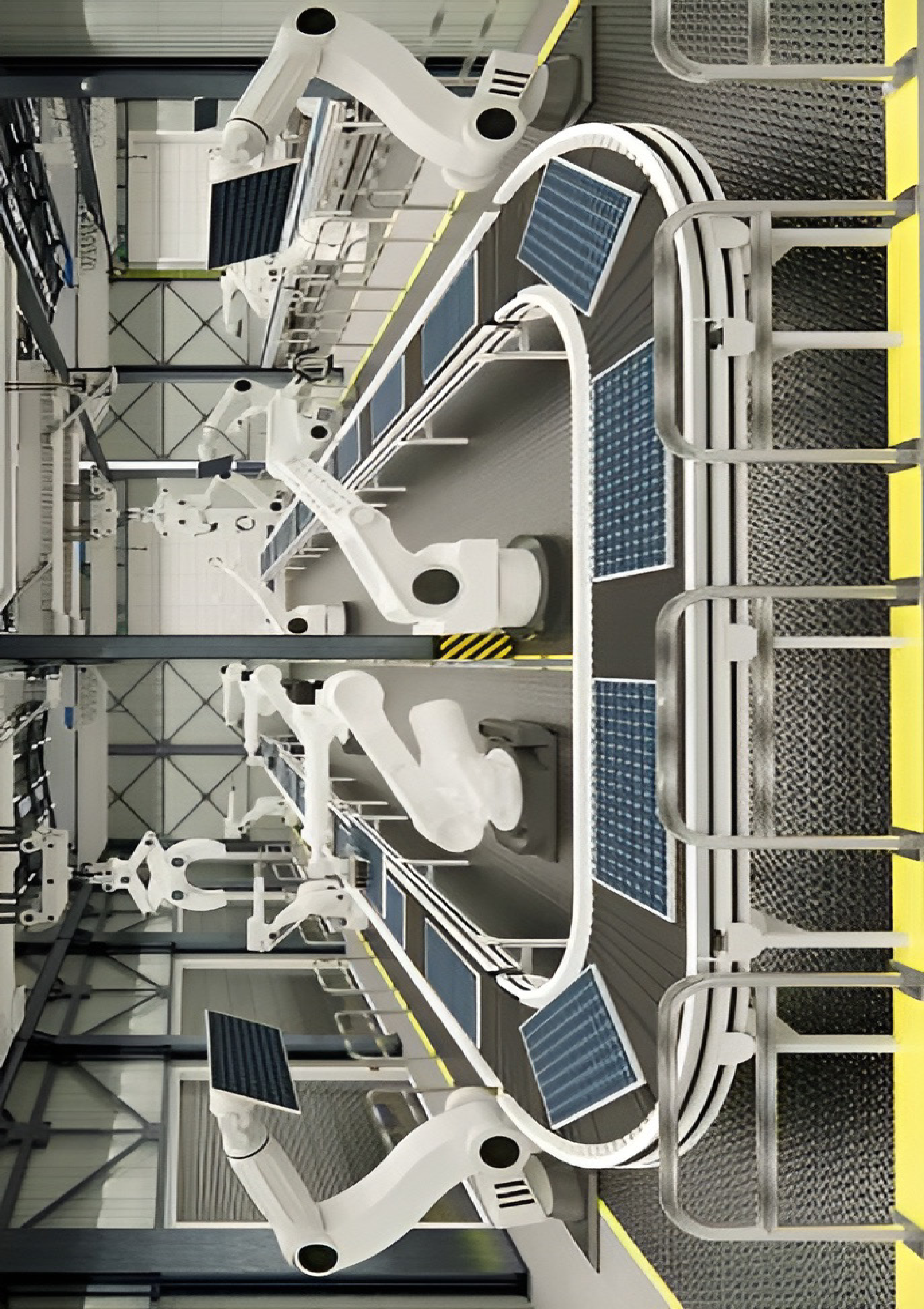

Electro Frontiers

Technical Magazine

2024-25

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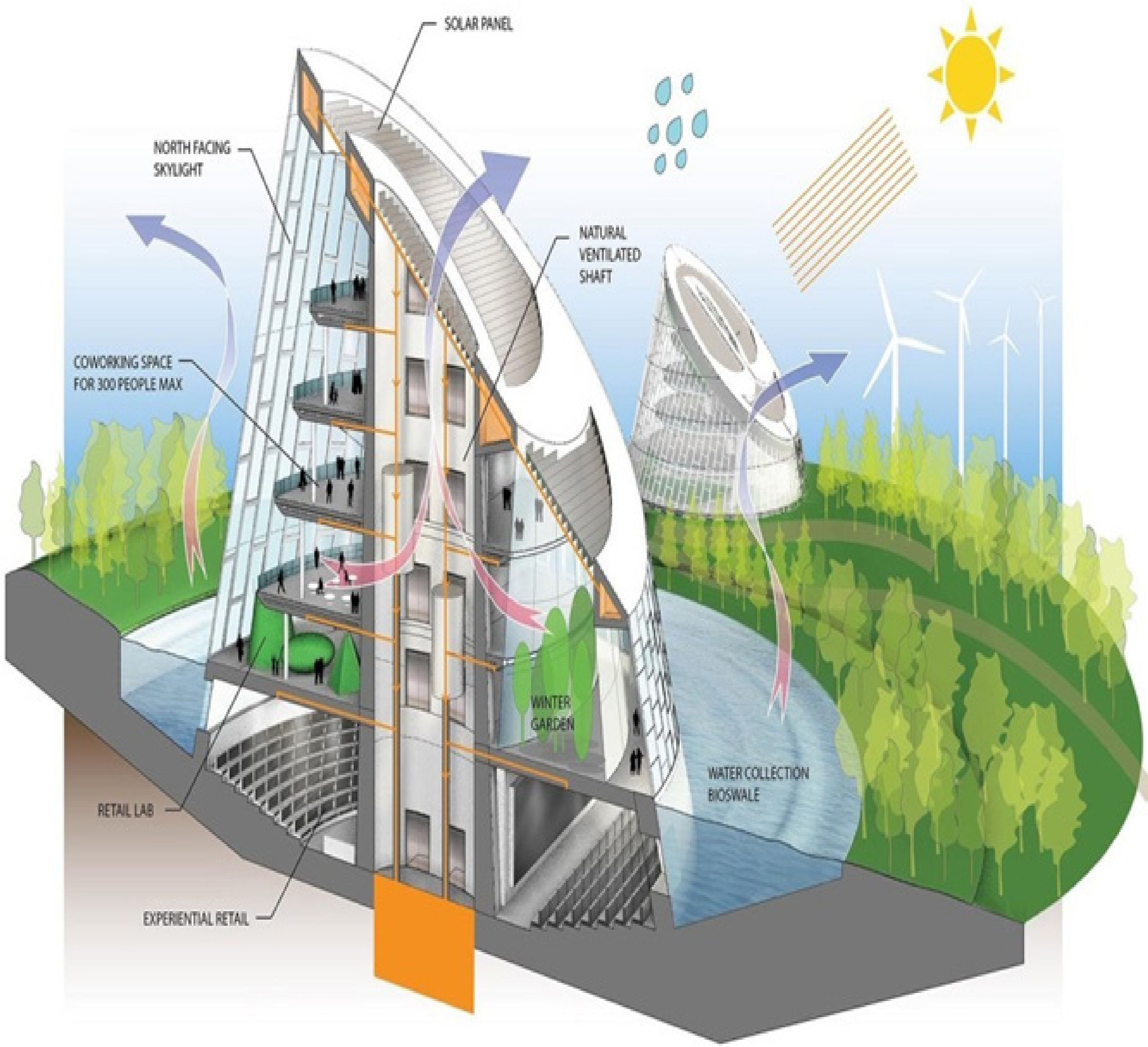
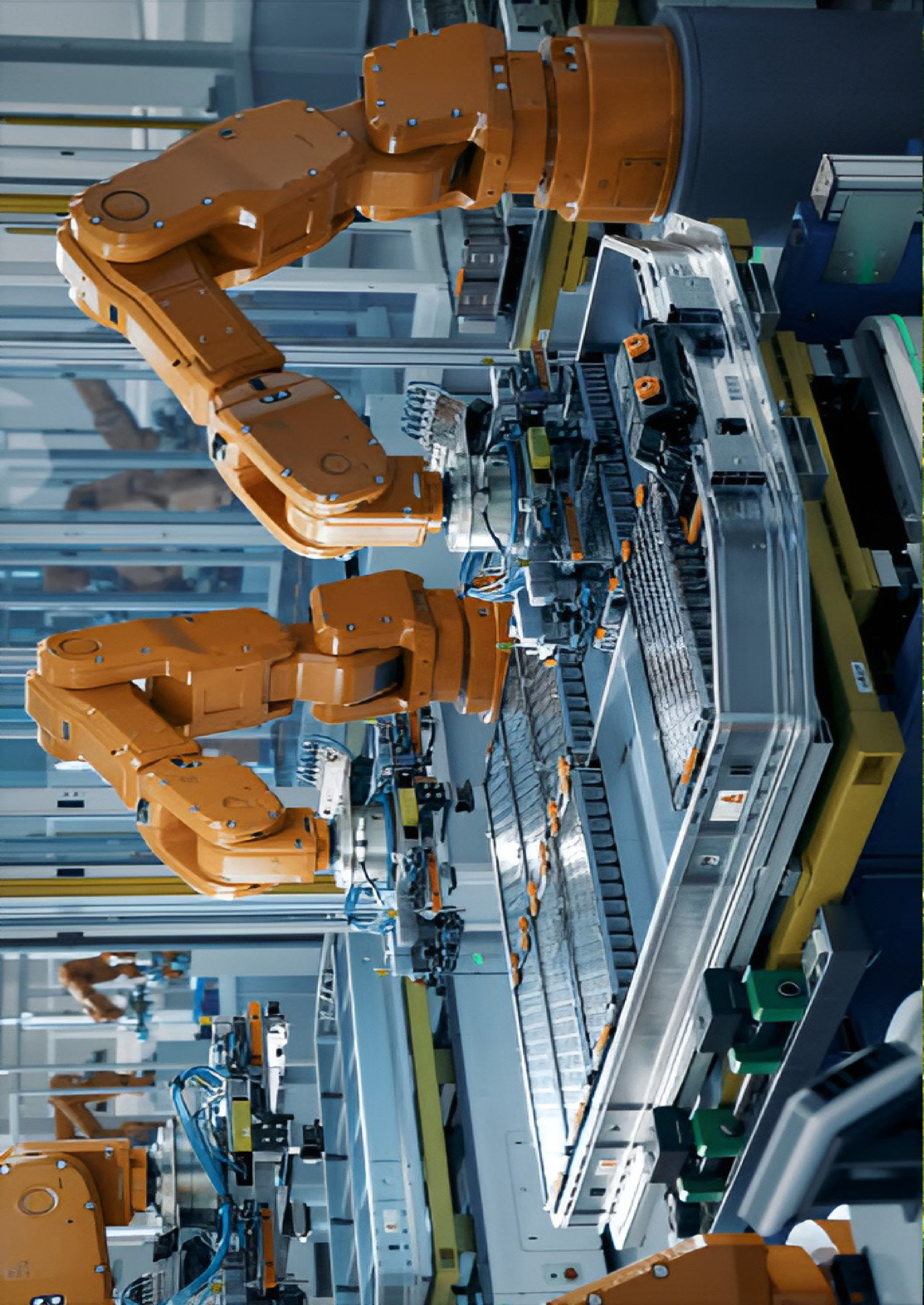
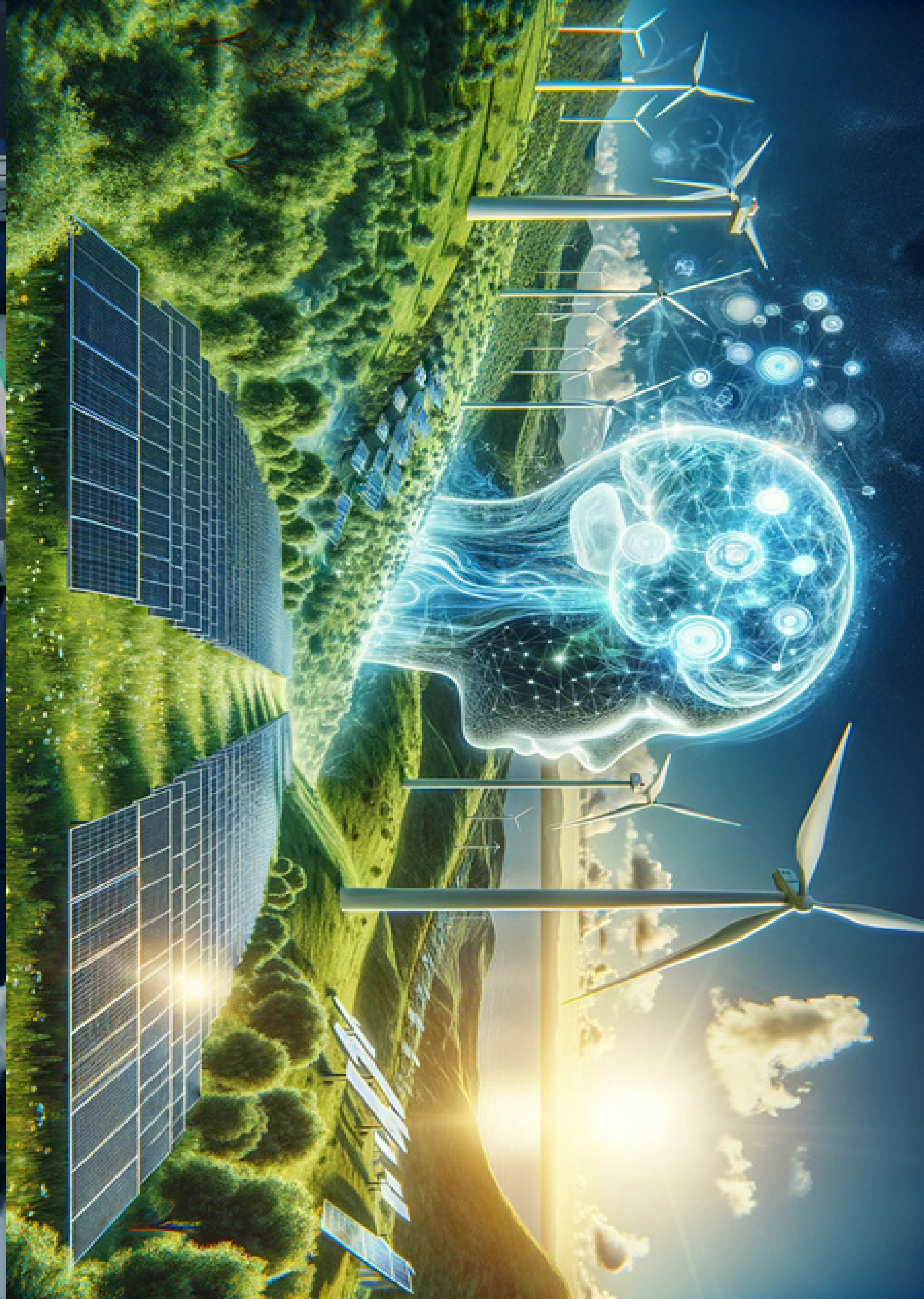


Department of
Electrical & Electronics Engineering
Velagapudi Ramakrishna Siddhartha School Of Engineering
SIDDHARTHA ACADEMY OF HIGHER EDUCATION
An Institution DEEMED TO BE UNIVERSITY
(Under Section 3 of UGC Act, 1956)
(Sponsored by Siddhartha Academy of General & Technical Education), Vijayawada-520007, A.P.

EDITORIAL BOARD

Siddhartha Academy of Higher Education (Deemed-to-be University) Vijayawada

Velagapudi Ramakrishna Siddhartha Engineering College (VRSEC) was the first private engineering college in the united Andhra Pradesh, founded in 1977. In 2024, VRSEC achieved deemed university status, marking a new era for the institution. With nine undergraduate and postgraduate programs in engineering, including B.Tech., MTech., MBA, and MCA, VRSEC has consistently upheld quality standards, being the first private engineering institution in the state to receive NBA accreditation in five cycles since 1998 and to adopt Outcome-Based Education (OBE) in 2013. The institute was reaccredited by NAAC with an 'A+' grade in 2021 and ISO 21001:2018 certified. The institute was conferred autonomous status in 2006 again in 2012 later it was extended from the UGC for an additional 10 years, up to 2028, without a peer team visit. VRSEC is recognized among India's top engineering institutions by agencies like Outlook, Data Quest, and Careers 360. The college has consistently ranked within the top 200 in the NIRF rankings for the last seven years.

In 2024, VR Siddhartha Engineering College was declared as a deemed-to-be university under Section 3 of the UGC Act, 1956 by Ministry of Education, Government of India. With a legacy of educational excellence, the institution's UGC-granted autonomy, renewed through 2027-28, provides a strong foundation for its transformation. Guided by a detailed 15-year strategic vision and a 5-year rolling implementation plan, Siddhartha Academy of Higher Education focuses on key areas such as academics, faculty recruitment, student admissions, research, ICT infrastructure, and administration, with specific annual milestones and measurable outcomes.

SAGTE, as a responsive educational trust, aligns with the Government of India's target of achieving a 50% GER in higher education by 2035. Siddhartha Academy of Higher Education, Deemed-to-be University, offers diverse undergraduate and postgraduate programs through its specialized schools, including the School of Engineering (B.Tech., M.Tech.), School of Management (MBA), School of Law, School of Science (B.Sc., M.C.A.), and School of Arts & Commerce (B.Com.). Envisioned to support interdisciplinary and multidisciplinary education for students' holistic development, the university aligns with the aspirations and requirements of NEP 2020 to equip students with the skills and knowledge essential for future growth and societal contributions.

VISION AND MISSION

UNIVERSITY VISION

To be a centre of excellence in education, innovation and research with a global presence in arts, science, technology, medicine, management, legal studies, and social studies, enriching the frontier areas of national and international importance.

UNIVERSITY MISSION

- To create a transformative educational experience for students focused on problemsolving skills, communication abilities, interpersonal relations, and leadership.
- To cultivate a vibrant university community that attracts and retains diverse, worldclass talent, creating a collaborative environment open to the free exchange of ideas where research, creativity, innovation, and entrepreneurship can flourish, and ensuring individuals achieve their full potential.
- To impact society pragmatically-regionally, nationally, and globally-by engaging with industry, outstanding national and international universities, and research organizations.
- To be a global university that nurtures excellence in education and innovation, fostering a knowledgeable society

INSTITUTE VISION

To nurture excellence in various fields of engineering by imparting timeless core values to learners and to mould the institution into a centre of academic excellence and advanced research.

INSTITUTE MISSION

To impart high quality technical education in order to mould the learners into globally competitive technocrats who are professionally deft, intellectually adept and socially responsible. The institution strives to make the learners inculcate and imbibe pragmatic perception and proactive nature so as to enable them to acquire a vision for exploration and an insight for advanced enquiry.

Siddhartha Academy of Higher Education (Deemed-to-be University), Vijayawada – Administrative Block

ABOUT THE DEPARTMENT

DEPARTMENT VISION

To impart quality education and strive for centre of excellence in research**.**

DEPARTMENT MISSION

To prepare future technocrats for a global work place through excellence in teaching and research. The department endeavours to prepare the students professionally skilful, intellectually proficient and socially responsible

Velagapudi Ramakrishna Siddhartha Engineering College, established in the year 1977, is the first private Engineering College in the state of Andhra Pradesh. It is a self-financing institution which owes its foundation to the bold and inspired vision of Siddhartha Academy of General and Technical Education, Vijayawada. Established in the year 1977, the EEE department offers two programs, one undergraduate and one postgraduate. The undergraduate program is the B. Tech. Program in Electrical and Electronics Engineering (EEE) with an intake of 132. The department has twenty six qualified faculty supported by thirteen technical and administrative staff. The faculty composition is Two Professors, Four

Associate Professors, Two Senior Assistant professors and Fifteen Assistant Professors with 12 Ph.D and Eleven M.Tech. The faculty is also committed for research and publishing papers regularly in different areas. The research area comprises Optimal Control Systems, Power System Operation and Control, HVDC Transmission, Electric Drives, Power Quality, Distributed Generation, Gas Insulated Substations, Reduced order modelling, Optimal power flow, FACTS etc. The EEE department having ten laboratories which are well equipped with advance equipment.

The Department is equipped with High Voltage Engineering Lab, AC Network Analyzer and EHV 220kV Transmission Line Simulator in Power Systems Lab first of its kind in any private engineering college in A.P. Also, the department is actively engaged in consultancy work in electrical meter testing and third-party quality assurance for Vijayawada Municipal Corporation electrical works. The technical staff provides assistance to faculty for various laboratories and they provide electrical maintenance for the college campus.

Department produces well-disciplined students with high pass percentage and good campus placements. For the last forty-seven years, the department has produced highly professional and competitive engineers with greater quality and appropriate skills suitable for a rapidly changing industrial scenario. Our alumni are well established in India as well as abroad. **Under Graduate Program of our department is accredited by National Board of Accreditation (NBA) for a period of 3 years i.e., from 01-07-2022 to 30-06-2025.**

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

Program: B.Tech. Electrical and Electronics Engineering

PEO1: Excel in chosen professional career and/or higher education

PEO2: Demonstrate leadership, teamwork and managerial abilities with effective communication.

PEO3: Design innovative, economical Sustainable and socially responsible engineering solutions in multidisciplinary environment.

PEO4: Engage in lifelong learning and uphold ethical and professional values to adapt in emerging technologies and global challenges.

PROGRAMME OUTCOMES (POs)

PO1: **Engineering Knowledge:** Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.

PO2: **Problem Analysis:** Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4).

PO3: **Design/Development of Solutions**: Design/Development of Solutions: Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)

PO4: **Conduct Investigations of Complex Problems**: Conduct Investigations of Complex Problems: Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modeling, analysis & interpretation of data to provide valid conclusions. (WK8).

PO5: **Engineering Tool Usage:** Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modeling recognizing their limitations to solve complex engineering problems. (WK2 and WK6).

PO6: The Engineer and The World: Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).

PO7: Ethics: Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)

PO8: Individual and Collaborative Team work: Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.

PO9: Communication: Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.

PO10: Project Management and Finance: Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.

PO11: Life-Long Learning: Recognize the need for and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)

PROGRAMME SPECIFIC OUTCOMES (PSOs)

PSO1: Apply knowledge of electrical engineering to analyze, design and develop efficient systems for the generation, transmission, distribution and utilization of electric power using simulation tools and techniques.

PSO2: Develop expertise in control and power conversion technologies for effective energy management emphasizing applications in renewable energy systems and electric vehicles.

PSO3: Design and implement intelligent electronic systems using IoT, embedded, and VLSI technologies for efficient and smart automation solutions.

PSO4: Demonstrate proficiency in programming, simulation and system integration to innovate and optimize AI enabled smart, sustainable and intelligent electrical systems aligned with emerging industrial and societal needs.

HOD'S DESK

It gives me immense pleasure to present **Electro Frontiers**, the Technical Magazine of the Department of Electrical and Electronics Engineering for the academic year **2024–25**. This edition reflects our department's unwavering pursuit of academic excellence, technological innovation, and holistic professional development. It serves as a valuable platform to highlight the accomplishments, research contributions, technical activities, and creative endeavors of our students, faculty members, and staff.The Department of Electrical and Electronics Engineering continues to evolve by integrating advanced technologies, strengthening industry partnerships, and fostering a vibrant culture of research and innovation. This magazine captures the essence of our academic journey by showcasing significant achievements, cutting-edge projects, technical events, publications, and student successes that demonstrate our commitment to nurturing competent, socially responsible, and future-ready engineers.

Our dedicated faculty members remain the driving force behind the department's progress through their excellence in teaching, impactful research, consultancy, and industry engagement. Supported by state-of-the-art laboratories and a dynamic learning environment, we strive to equip our students with strong technical knowledge, practical skills, ethical values, and leadership qualities essential for addressing the challenges of the rapidly evolving engineering profession.I sincerely express my gratitude to the university management, leadership, editorial committee, faculty, students, and all contributors whose commitment and collective efforts have made this publication possible. I hope this edition of **Electro Frontiers** serves as a source of knowledge, inspiration, and motivation, encouraging every reader to pursue innovation, uphold excellence, and contribute meaningfully to the advancement of engineering and society.

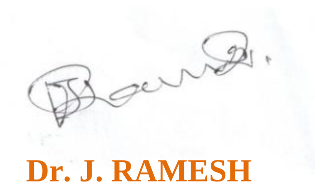
Yours

Dr. P.V.R.L. NARASIMHAM
Professor & Head

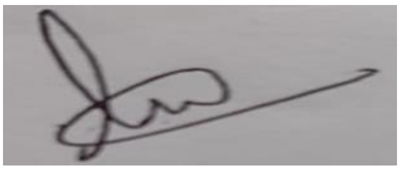
EDITORIAL MESSAGE

It is with immense pride and pleasure that we present the **2024–25 edition of *Electro Frontiers***, the Technical Magazine of the Department of Electrical and Electronics Engineering. This publication showcases the achievements, innovations, and academic excellence that continue to define our department and reflects the collective dedication of our students, faculty, and staff.The strength of any academic institution lies in the commitment, knowledge, and vision of its faculty and students. Our faculty members remain dedicated to mentoring young minds, promoting innovation, encouraging research, and equipping students with the technical competence, analytical abilities, and professional values required to succeed in the ever-evolving field of electrical and electronics engineering.

This magazine serves as a vibrant platform to highlight outstanding technical achievements, research contributions, innovative projects, industrial activities, and academic accomplishments that reflect the dynamic learning environment of our department. It also provides an avenue for students to express their creativity through literary, cultural, and extracurricular contributions, making it a comprehensive representation of our academic community.Electro Frontiers stands as a testament to the collaborative efforts of our students, faculty members, editorial team, and well-wishers. We sincerely thank the university management, Principal, Head of the Department, and everyone who contributed their time, effort, and expertise to make this publication a success.We hope this edition will inspire curiosity, encourage innovation, and motivate readers to strive for excellence while providing meaningful insights into the academic journey, achievements, and future aspirations of the Department of Electrical and Electronics Engineering.



Dr. J. RAMESH
ASSOC.PROFESSOR
CHIEF-EDITOR



Mr. P. VENKATESH
ASST. PROFESSOR
EDITOR

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1.Innovation in Action: How a Student Project Became a Startup

Chitti Motors Pvt. Ltd.

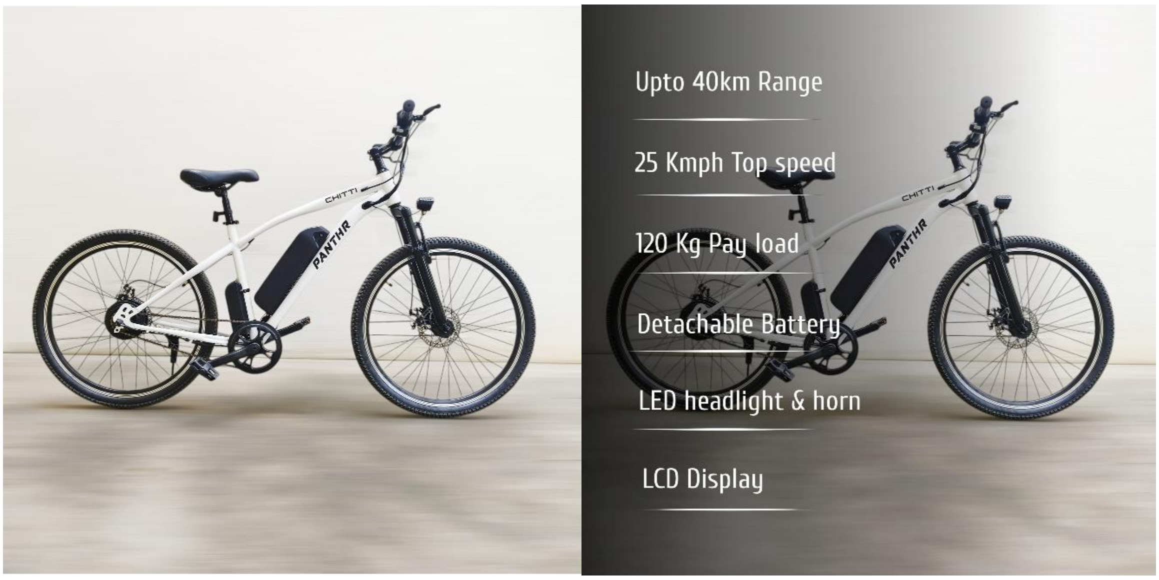
About Us

Chitti Motors Pvt. Ltd. was co-founded by Avinash Bavisetty and Mohan Murali Krishna Reddy Karri. The company is committed to delivering *innovative and high-quality products* to the electric vehicle market. Supported extensively by *Velagapudi Ramakrishna Siddhartha Engineering College*, Chitti Motors has been incubated under *VRS TBI*, providing a robust foundation for its operations and research initiatives.

Our Products

Panthr

Panthr, our first product, marks a significant step toward revolutionizing electric mobility. Designed with a focus on affordability and sustainability, it caters to the needs of modern urban commuters. For more details, visit our website: chittimotors.com.



Panthr Model with Specifications

Chitti Pi 15 (Under Development)

Chitti Pi 15 is a low-cost smart electric two-wheeler, specially designed for short-distance travel. Combining the best features of scooters and bicycles, it offers: Speed: 25 kmph,Range: 40 km/charge,No license or registration requiredSmart features like gesture-based controls, virtual display, Bluetooth connectivity, integrated maps, and a smart battery management system.The future plans include adding pedals for pedal-assist mode, removable carrier seats, and cost-reduction strategies to make it more accessible.

Chitti Pi 15 Design (Concept)

Our Vision

To transform short-distance commuting with innovative, eco-friendly, and affordable electric solutions.

Our Mission

To design and manufacture electric vehicles that redefine urban mobility, prioritizing quality and sustainability.

Acknowledgments

We extend our heartfelt gratitude to our project guide, **Dr. P. V. R. L. Narasimham**, Professor & Head, Velagapudi Ramakrishna Siddhartha Engineering College, for his unwavering support, and to **VRS TBI** for incubating us throughout our journey.

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CHITTI MOTORS

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RESEARCH ENGINEER

CHITTI MOTORS

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FOUNDER & CTO

CHITTI MOTORS

2. AI-Driven Green Hydrogen Marine Mobility

The global transportation sector is undergoing a remarkable transformation driven by the urgent need to reduce carbon emissions, improve energy efficiency, and develop sustainable mobility solutions. While significant progress has been achieved in electric road transportation, the maritime industry continues to rely predominantly on fossil-fuel-powered vessels that contribute substantially to greenhouse gas emissions, marine pollution, and operational costs. To address these challenges, researchers and engineers worldwide are exploring hydrogen-based propulsion systems capable of delivering clean, efficient, and intelligent transportation. The **Hydrogen Ocean Express** represents a futuristic high-speed marine transportation concept that integrates green hydrogen fuel cells, electric propulsion, artificial intelligence, renewable energy, and autonomous navigation technologies into a single zero-emission transportation platform. Designed for coastal cities, island connectivity, tourism, emergency response, and commercial transportation, this innovative vessel demonstrates how next-generation engineering can transform maritime mobility while preserving the marine ecosystem.

Green Hydrogen: The Fuel of the Future

Hydrogen is widely recognized as one of the cleanest energy carriers available for future transportation systems. Unlike conventional marine fuels such as diesel or heavy fuel oil, hydrogen produces no harmful emissions during energy conversion. Green hydrogen is generated by electrolyzing water using electricity obtained from renewable energy sources such as solar photovoltaic plants, offshore wind farms, or hydropower stations. During electrolysis, water molecules are separated into hydrogen and oxygen without producing carbon dioxide. The generated hydrogen is compressed and stored in high-pressure composite tanks onboard the vessel. This environmentally sustainable production process enables the entire transportation cycle to operate with minimal environmental impact while significantly reducing dependence on fossil fuels.

Hydrogen Fuel Cell Power Generation System

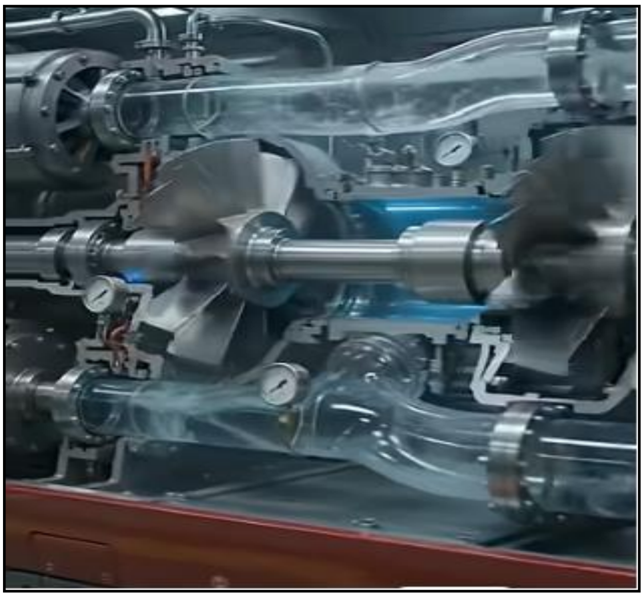
The primary power source of the Hydrogen Ocean Express is the Proton Exchange Membrane Fuel Cell (PEMFC), which converts chemical energy directly into electrical energy through an electrochemical reaction rather than combustion. Hydrogen supplied from storage tanks enters the anode side of the fuel cell, where it separates into protons and electrons. The electrons travel through an external electrical circuit to produce useful electrical power, while the protons migrate through the proton exchange membrane toward the cathode. Oxygen extracted from atmospheric air reacts with the electrons and protons to produce pure water and heat as the only by-products. This clean energy conversion process achieves higher efficiency than conventional diesel engines while eliminating carbon dioxide, sulfur oxides, nitrogen oxides, and particulate emissions. The electricity generated by the fuel cell powers high-efficiency electric propulsion motors and onboard auxiliary systems, making the vessel environmentally friendly and highly energy efficient.

Hybrid Energy Storage and Intelligent Power Management

Although hydrogen fuel cells provide continuous electrical power, marine transportation requires rapid power variations during acceleration, maneuvering, docking, and emergency operations. To satisfy these dynamic operating conditions, the Hydrogen Ocean Express incorporates a hybrid energy storage system consisting of lithium-ion batteries and high-power supercapacitors. The fuel cell supplies the average propulsion demand during normal cruising, while lithium-ion batteries provide additional energy during peak loading conditions.

Supercapacitors deliver instantaneous high-power output during rapid acceleration and absorb regenerative braking energy whenever propulsion loads decrease. An Artificial Intelligence-based Energy Management System continuously monitors vessel speed, battery state-of-charge, hydrogen consumption, propulsion requirements, sea conditions, and passenger load to determine the optimum power-sharing strategy. This intelligent coordination significantly improves overall system efficiency, extends fuel cell life, reduces hydrogen consumption, and enhances operational reliability.

Advanced Electric Water-Jet Propulsion Technology



Instead of conventional propeller-driven propulsion systems, the Hydrogen Ocean Express employs advanced electric water-jet propulsion technology. High-speed electric motors drive centrifugal pumps that accelerate large volumes of seawater through specially designed nozzles to generate forward thrust. Water-jet propulsion offers several engineering advantages, including reduced cavitation, improved maneuverability, enhanced passenger comfort, lower underwater acoustic noise, and increased operational safety due to the absence of exposed rotating propellers. Variable-speed permanent magnet synchronous motors controlled through advanced power electronic converters provide smooth acceleration, rapid speed control, and exceptional propulsion efficiency. This propulsion technology enables the vessel to operate at high cruising speeds while maintaining excellent hydrodynamic performance and reduced maintenance requirements.

Artificial Intelligence for Autonomous Marine Navigation

Artificial Intelligence serves as the central intelligence of the Hydrogen Ocean Express by enabling autonomous navigation, intelligent decision-making, and real-time operational optimization. Multiple sensors, including marine radar, LiDAR, GPS receivers, inertial navigation units, sonar systems, weather monitoring sensors, and high-resolution cameras, continuously collect environmental information. Advanced deep learning algorithms process this data to identify surrounding vessels, floating obstacles, coastal structures, navigation routes, and changing weather conditions. The AI navigation system predicts optimal sailing paths based on wave characteristics, tidal conditions, fuel consumption, and traffic density while automatically controlling steering, propulsion, and braking systems. During docking operations, computer vision and sensor fusion technologies provide centimeter-level positioning accuracy, allowing fully automated docking with minimal human intervention. Continuous learning algorithms further improve navigation performance by analyzing operational data collected throughout each voyage.

Internet of Things for Smart Vessel Monitoring

The Hydrogen Ocean Express functions as an intelligent cyber-physical system supported by thousands of interconnected Internet of Things (IoT) sensors distributed throughout the vessel. These sensors continuously monitor hydrogen pressure, fuel cell voltage, battery temperature, motor current, vibration levels, cooling system performance, structural stress, passenger occupancy, environmental conditions, and navigation status. The collected information is transmitted securely through high-speed communication networks to cloud-based monitoring centers where advanced analytics evaluate overall system health in real time. Operators can remotely supervise vessel performance, schedule preventive maintenance, optimize fuel consumption, and respond immediately to abnormal operating conditions. IoT-enabled monitoring significantly enhances operational efficiency while reducing maintenance costs and improving passenger safety.

Digital Twin Technology for Predictive Maintenance

One of the most advanced technologies integrated into the Hydrogen Ocean Express is Digital Twin technology. A Digital Twin is a dynamic virtual replica of the physical vessel that continuously updates itself using real-time operational data collected from onboard sensors. The digital model accurately simulates the behavior of the fuel cell stack, hydrogen storage tanks, electric motors, batteries, propulsion systems, structural components, and navigation equipment under various operating conditions.

Artificial Intelligence algorithms analyze these simulations to predict component degradation, estimate remaining useful life, detect abnormal operating behavior, and recommend maintenance activities before equipment failures occur. Predictive maintenance minimizes unexpected downtime, extends equipment lifespan, reduces maintenance expenditure, and significantly improves fleet availability and operational reliability.

Renewable Energy Integration and Smart Ports

The future Hydrogen Ocean Express is envisioned as an integral component of renewable-energy-powered smart ports. Solar photovoltaic systems installed at coastal terminals and offshore wind farms generate renewable electricity used for hydrogen production through water electrolysis. Smart hydrogen refueling stations equipped with automated robotic fueling systems enable rapid hydrogen replenishment while ensuring maximum operational safety. Intelligent energy management systems coordinate renewable energy generation, hydrogen storage, battery charging, and grid interaction to optimize overall energy utilization. Such integrated energy infrastructure supports carbon-neutral transportation and strengthens the transition toward sustainable smart coastal cities.

Advanced Safety and Cybersecurity Systems

Safety remains the highest priority in hydrogen-powered transportation. The Hydrogen Ocean Express incorporates multiple redundant safety mechanisms, including hydrogen leak detection sensors, explosion-proof electrical equipment, automatic emergency shutdown systems, fire suppression units, high-strength composite hydrogen storage cylinders, pressure relief valves, and advanced thermal management systems. Cybersecurity technologies protect navigation, communication, and energy management systems against unauthorized access and cyber threats through encrypted communication protocols, intrusion detection systems, secure cloud authentication, and AI-based anomaly detection. These integrated safety measures ensure reliable operation under both normal and emergency conditions while meeting stringent international maritime safety standards.

Future Scope of Hydrogen Marine Transportation

Rapid advancements in hydrogen technology, artificial intelligence, advanced materials, and autonomous systems are expected to revolutionize the maritime transportation industry during the coming decades. Future hydrogen vessels may incorporate solid-state hydrogen storage, superconducting electric propulsion motors, quantum computing-assisted navigation, 6G maritime communication, blockchain-enabled hydrogen trading, self-healing composite materials, autonomous drone-assisted inspection, robotic maintenance systems,and intelligent swarm coordination among multiple vessels. Integration with digital ports, smart logistics networks, and renewable energy microgrids will further enhance transportation efficiency while supporting global sustainability objectives. As hydrogen production costs continue to decrease and international hydrogen infrastructure expands, intelligent hydrogen-powered marine transportation is expected to become a cornerstone of next-generation coastal mobility.

The Road Ahead

The Hydrogen Ocean Express represents a transformative vision for sustainable maritime transportation by integrating green hydrogen fuel cells, hybrid energy storage systems, artificial intelligence, digital twins, IoT-enabled monitoring, renewable energy integration, and autonomous navigation into a unified transportation platform. By eliminating greenhouse gas emissions, improving propulsion efficiency, reducing operational costs, and enhancing passenger safety, this innovative concept

addresses many of the challenges faced by conventional marine transportation. Although still evolving, hydrogen-powered intelligent vessels have the potential to reshape global coastal transportation networks and play a vital role in achieving a cleaner, smarter, and more sustainable future for marine mobility.

Authored by

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Guided By

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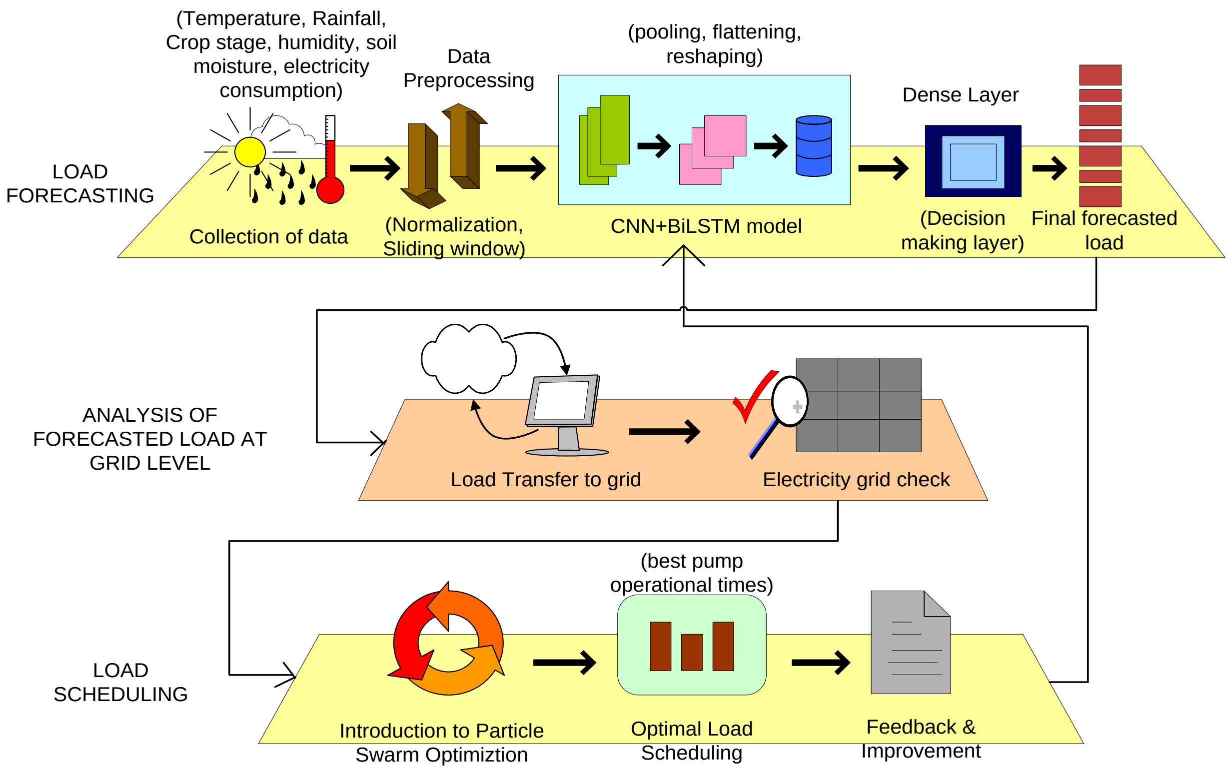
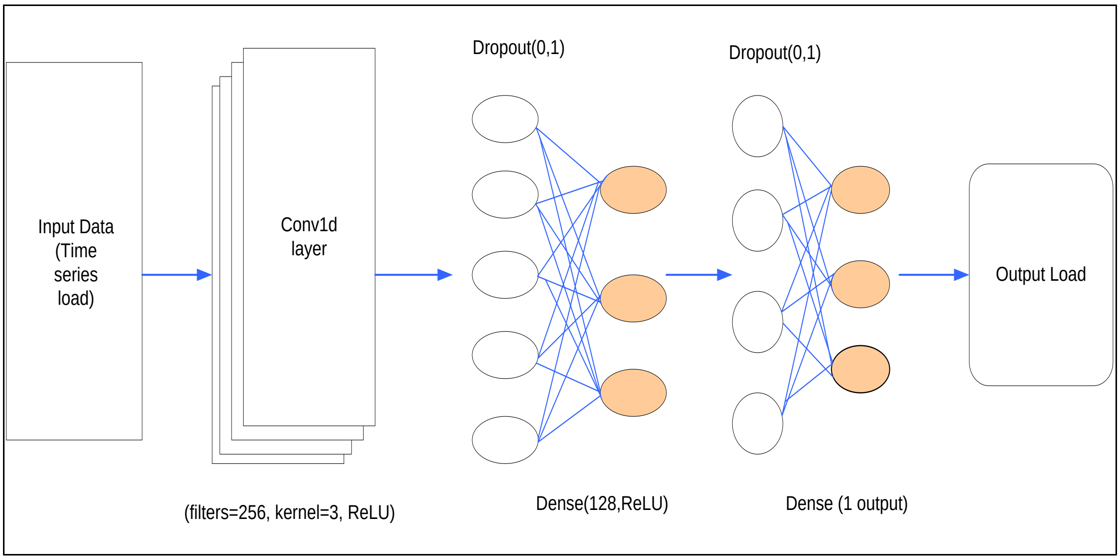
3. Smart Agricultural Energy Management Using Deep Learning

Agriculture is one of the largest consumers of electrical energy in India, particularly for irrigation pump operation. The increasing demand for electricity during irrigation seasons often creates peak load conditions that affect the stability of rural power distribution networks. Conventional irrigation practices operate pumps without considering real-time grid conditions, resulting in unnecessary energy consumption, voltage fluctuations, transformer overloading, and increased operating costs. Recent advancements in Artificial Intelligence (AI) and Deep Learning provide innovative solutions for accurately forecasting agricultural electricity demand and scheduling irrigation loads intelligently. By combining intelligent forecasting with optimal scheduling, modern smart agriculture can achieve efficient energy utilization, reliable power supply, and sustainable farming practices while reducing stress on the electrical grid.



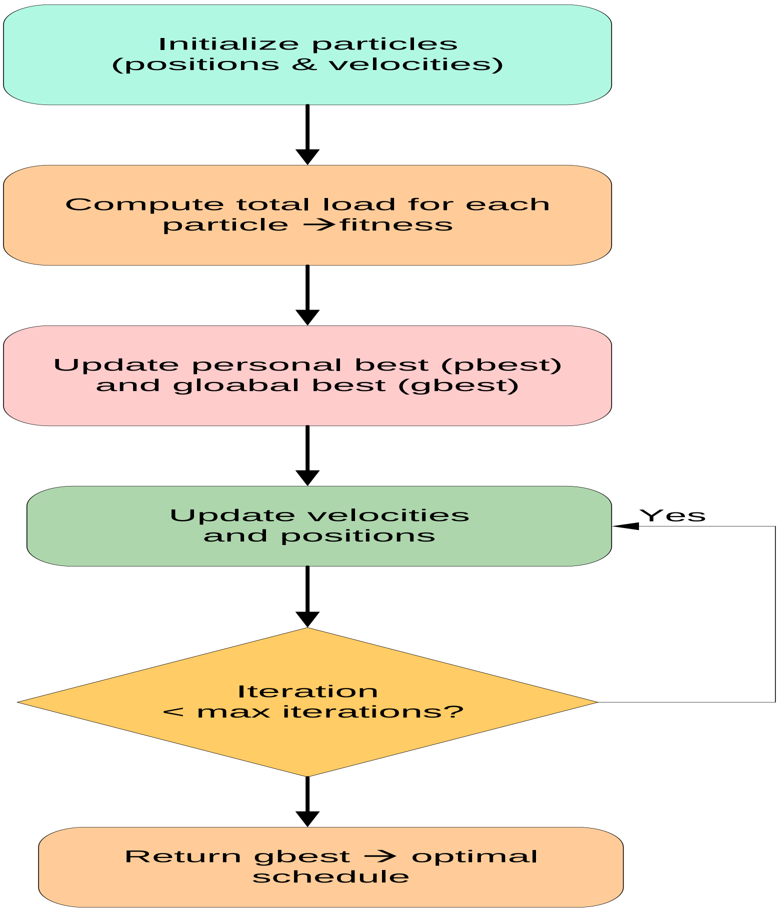
Deep Learning-Based Load Forecasting

Accurate prediction of future electricity demand is the foundation of intelligent energy management. The proposed system utilizes a hybrid Convolutional Neural Network (CNN) and Bidirectional Long Short-Term Memory (BiLSTM) architecture to forecast short-term agricultural load demand. Historical electricity consumption, weather parameters, soil moisture, crop growth stages, humidity, rainfall, and temperature are continuously analyzed to identify complex temporal and seasonal patterns. The CNN automatically extracts significant features from the input data, while the BiLSTM learns both past and future temporal relationships to generate highly accurate load predictions. These forecasted load values enable power utilities and farmers to anticipate future electricity requirements and prepare suitable irrigation schedules without overloading the distribution network.



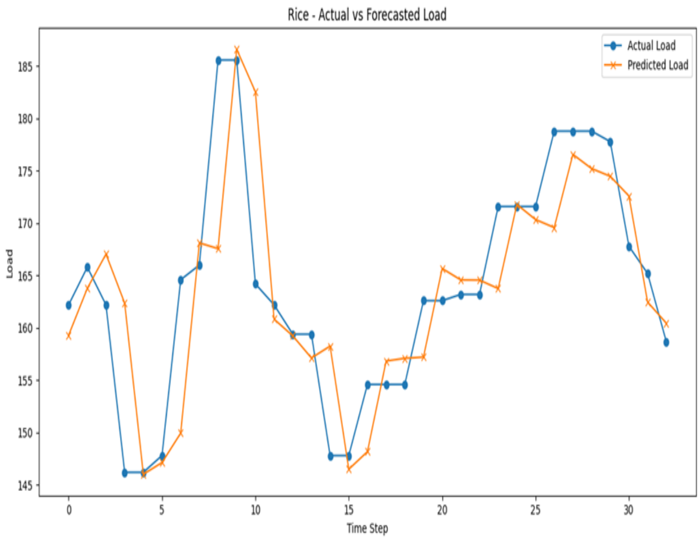
Smart Load Scheduling for Grid Stability

Once the future electrical demand is predicted, the forecasted load is evaluated against the available capacity of the electrical distribution network. Instead of operating all irrigation pumps simultaneously, the proposed system intelligently schedules pump operation during suitable time intervals using **Particle Swarm Optimization (PSO)**. The optimization algorithm allocates different irrigation loads to appropriate time slots while ensuring that the total demand remains within the permissible grid capacity. This intelligent scheduling minimizes peak demand, prevents transformer overloading, improves feeder reliability, and enables uninterrupted irrigation without affecting crop productivity. The coordinated operation between load forecasting and optimization significantly enhances overall energy efficiency and power system stability.



Future Smart Farming Technologies

The future of agricultural energy management extends beyond conventional automation through the integration of Artificial Intelligence, Internet of Things (IoT), Edge Computing, Smart Sensors, Digital Twin Technology, Geographic Information Systems (GIS), cloud computing, and renewable energy resources. Smart sensors installed in agricultural fields can continuously monitor soil moisture, weather conditions, crop health, and electricity consumption while transmitting real-time information to cloud-based control centres. Artificial Intelligence algorithms can automatically determine the optimal irrigation schedule based on crop requirements and electricity availability. Integration with solar



photovoltaic systems, battery energy storage, and microgrids can further reduce dependence on conventional grid electricity while promoting sustainable agriculture. Future digital farming platforms are expected to provide farmers with intelligent decision-support systems capable of predicting irrigation demand, minimizing energy costs, conserving water resources, and improving agricultural productivity.

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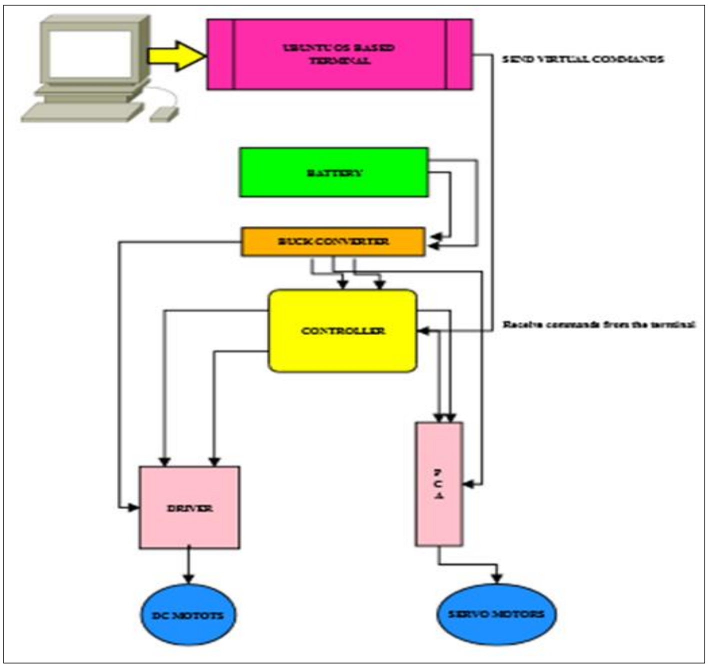
Guided by:

Mrs. V. Bindu

Assistant Professor

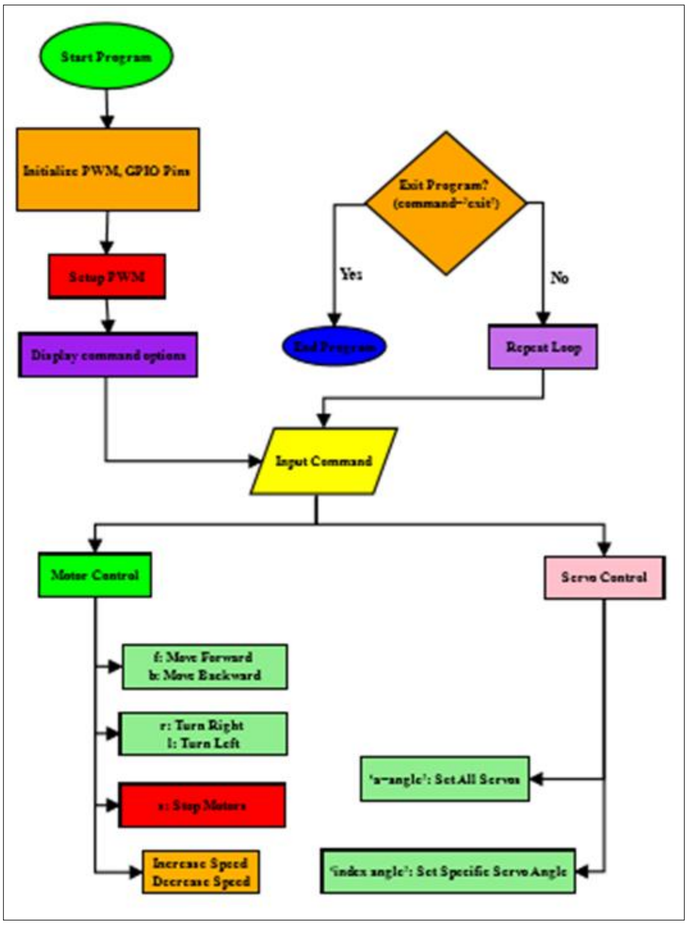
4. Enhancing Mobility In Autonomous Robotics Using A Four-Wheel And Four-Steering System

Autonomous mobile robots are rapidly transforming modern industries by performing complex tasks with greater accuracy, flexibility, and operational efficiency. These intelligent robotic systems are increasingly deployed in agriculture, industrial automation, warehouse logistics, defence, disaster response, surveillance, and smart transportation. Conventional mobile robots generally employ two-wheel or four-wheel drive systems with limited steering capability, restricting their manoeuvrability in confined spaces and complex terrains. To overcome these limitations, advanced robotic platforms incorporating **Four-Wheel Drive and Four-Wheel Steering (4W4D4S)** technology have emerged as an effective solution for achieving superior mobility, precise navigation, and multidirectional movement. Unlike conventional robots, every wheel in a 4W4D4S system can be independently driven and steered, enabling the robot to move forward, backward, sideways, diagonally, or rotate within a very small turning radius. Such advanced mobility significantly improves navigation efficiency while reducing mechanical stress and energy consumption. The proposed robotic platform utilizes the Ubuntu operating system, ARM Cortex-A processor, servo-based steering mechanism, and intelligent motor control to provide flexible remote operation and real-time navigation for future autonomous robotic applications.



System Architecture and Intelligent Motion Control

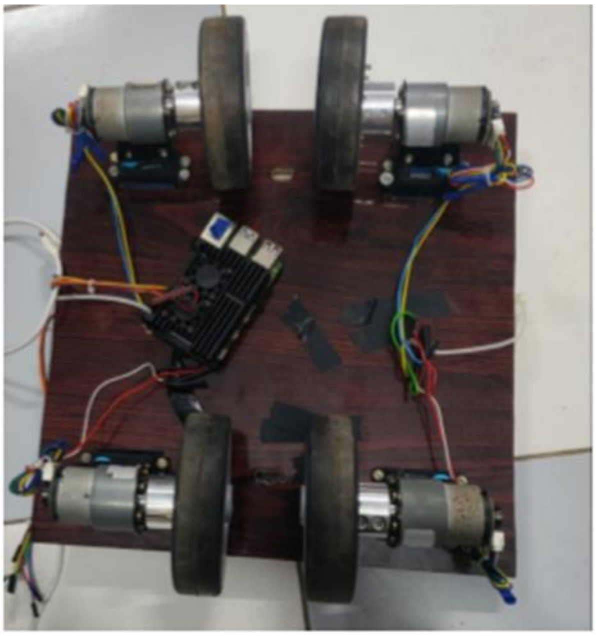
The proposed robotic system integrates mechanical, electrical, electronic, and software technologies into a compact autonomous platform capable of omnidirectional movement. The robot consists of a lightweight chassis carrying four independently driven DC motors and four servo motors that precisely control the steering angle of each wheel between **0° and 180°**. An



ARM Cortex-A processor acts as the central controller, communicating with motor drivers, servo controllers, sensors, and communication interfaces to coordinate all robot movements. The PCA9685 PWM controller generates high-resolution pulse-width modulation signals for accurate servo positioning, while high-current motor drivers regulate the DC motors responsible for propulsion. Powered by a rechargeable battery, the robot can execute multiple steering configurations such as straight motion, crab steering, diagonal movement, and zero-radius turning. The coordinated control of independent steering and driving allows the robot to navigate narrow passages and uneven terrain with exceptional stability and manoeuvrability, making it highly suitable for autonomous field operations.

Ubuntu-Based Remote Navigation and Smart Robotics

One of the most innovative features of the proposed robotic platform is its Ubuntu-based remote control architecture. Ubuntu provides a stable Linux environment capable of executing Robot Operating System (ROS 2) packages, Python programs, and intelligent navigation algorithms. Through secure communication protocols such as SSH and VNC, the robot can be remotely monitored and controlled from any location with network connectivity. Commands transmitted through the Ubuntu terminal are processed by the ARM Cortex-A controller, which generates real-time control signals for both steering and propulsion systems. The integration of ROS 2 enables seamless communication between software modules, allowing sensor data processing,



autonomous navigation, motion planning, and camera-based vision applications. This software-driven architecture provides excellent scalability for future autonomous systems while enabling rapid software development, real-time debugging, and remote maintenance. The combination of Linux, ROS 2, and embedded control technology forms a robust platform for intelligent robotic research and industrial automation.

Applications and Future Innovations

The Four-Wheel Drive and Four-Wheel Steering robotic platform demonstrates excellent potential for next-generation autonomous mobility systems. Its ability to independently steer all four wheels enables highly flexible navigation in environments where conventional robots cannot operate efficiently. Such robots can perform precision farming operations including crop monitoring, pesticide spraying, soil inspection, and autonomous harvesting. In industrial environments, they can transport materials through congested warehouses, perform inspection tasks in hazardous areas, and assist in automated manufacturing systems. Defence applications include reconnaissance, explosive detection, and surveillance in difficult terrains, while disaster management agencies can deploy these robots for search-and-rescue operations in collapsed structures or inaccessible locations.

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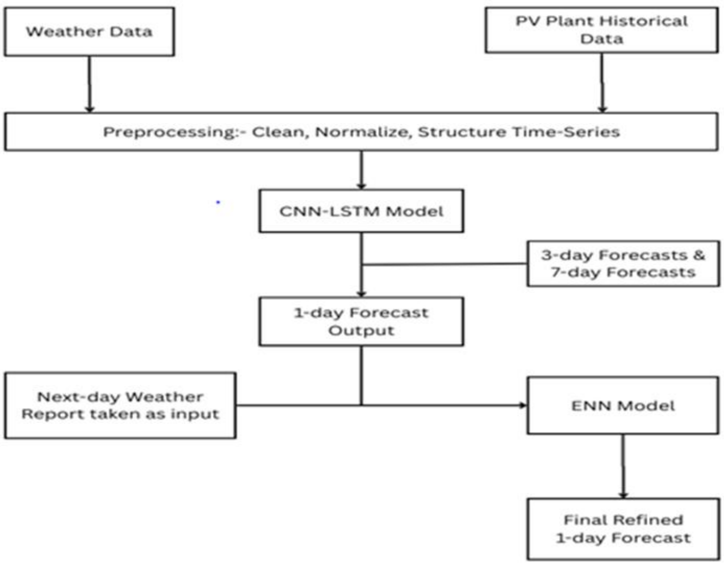
5. Smart Solar Power Forecasting Using Hybrid CNN–LSTM and Ensemble Neural Networks

The rapid expansion of solar photovoltaic (PV) power generation has become a key driver in the global transition toward clean and sustainable energy systems. However, the intermittent nature of solar energy, which is highly dependent on changing weather conditions such as solar irradiance, temperature, humidity, and wind speed, creates significant challenges for reliable grid operation and energy management. Inaccurate forecasting may lead to power imbalance, inefficient utilization of renewable resources, and increased operating costs. To address these challenges, Artificial Intelligence (AI) and Deep Learning have emerged as powerful tools for accurately predicting solar power generation. The proposed Hybrid CNN–LSTM and Ensemble Neural Network (ENN) Solar Power Forecasting System combines the spatial feature extraction capability of Convolutional Neural Networks (CNN), the temporal sequence learning ability of Long Short-Term Memory (LSTM) networks, and the robustness of Ensemble Neural Networks to provide highly accurate short-term and multi-day solar power forecasting. This intelligent forecasting framework enables solar plant operators, utility companies, and grid managers to make informed operational decisions while improving renewable energy integration into modern power systems.

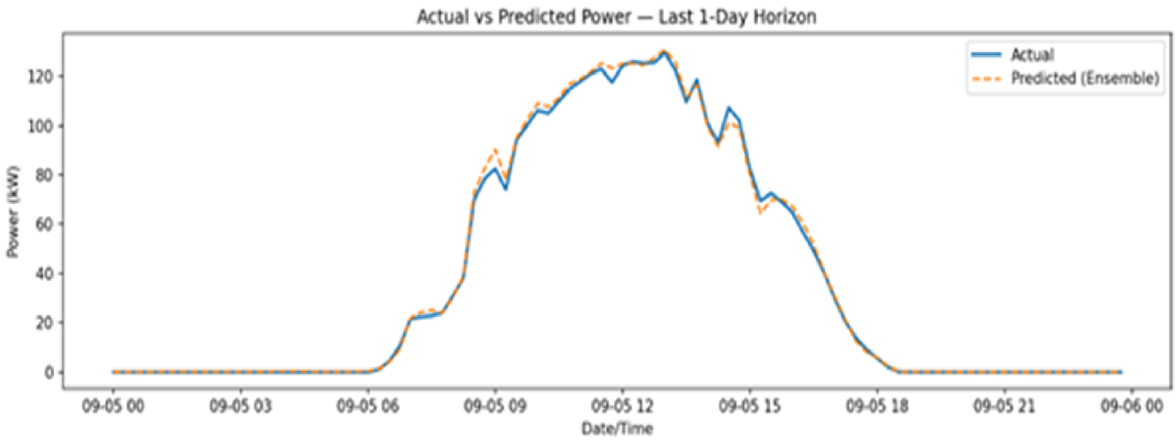


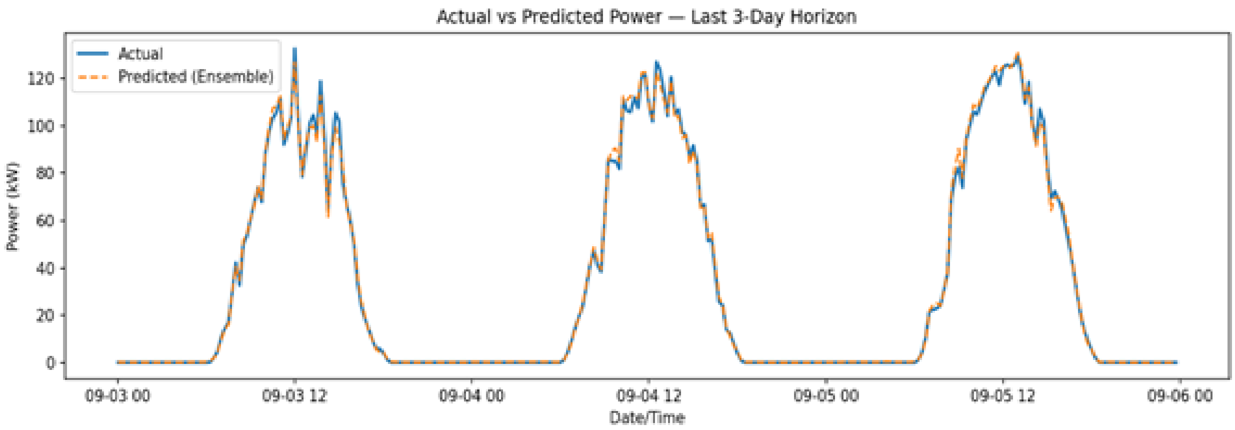
Hybrid Deep Learning Architecture for Intelligent Forecasting

The proposed forecasting system employs a hybrid deep learning architecture designed to exploit the strengths of multiple neural network models. Initially, historical photovoltaic generation data and meteorological parameters, including solar irradiance, ambient temperature, relative humidity, wind speed, and previous power output, undergo preprocessing, normalization, and feature engineering to remove inconsistencies and improve data quality. The CNN component automatically extracts meaningful spatial features and hidden relationships among weather variables, while the LSTM network captures long-term temporal dependencies present in sequential time-series data. For highly accurate day-ahead forecasting, the output generated by the CNN–LSTM model is further processed using an Ensemble Neural Network comprising multiple neural models trained with different configurations. This ensemble strategy minimizes prediction errors by combining the strengths of individual models, thereby producing more stable and reliable forecasts under varying weather conditions. The hybrid architecture enables accurate prediction for one-day, three-day, and seven-day forecasting horizons, making it highly suitable for renewable energy scheduling, smart grid operation, and energy trading applications.

Forecasting Performance and Practical Applications

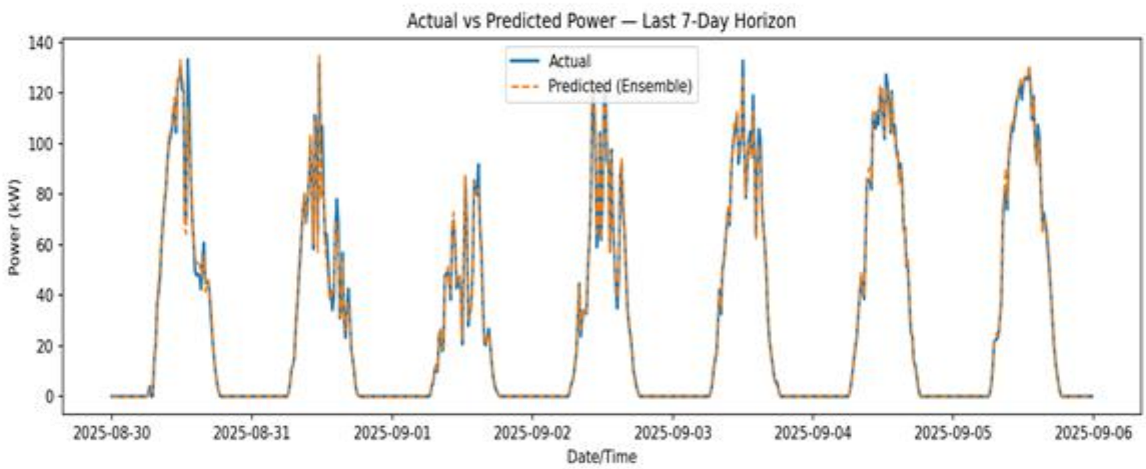
The effectiveness of the proposed hybrid forecasting system is demonstrated through extensive performance evaluation using real photovoltaic generation data collected from a **200 kW solar power plant**. Experimental results show excellent agreement between actual and predicted power generation across different forecasting horizons. The one-day prediction accurately follows daily power generation patterns with minimal deviation, while the three-day and seven-day forecasts successfully capture weather-dependent variations and long-term generation trends. Performance evaluation using Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Coefficient of Determination (R^2), and Capacity Factor Error confirms the superior accuracy of the hybrid CNN–LSTM framework compared with conventional forecasting models. Such accurate forecasting supports efficient power scheduling, battery energy management, renewable energy dispatch, load balancing, and electricity market participation, thereby enhancing the reliability and stability of future smart grids.





Future Scope of AI-Based Renewable Energy Forecasting

Artificial Intelligence is transforming renewable energy forecasting from conventional statistical estimation into intelligent predictive decision-making. Future solar forecasting systems can integrate Internet of Things (IoT)-enabled weather stations, satellite cloud imagery, Digital Twin technology, cloud computing, edge intelligence, and Explainable Artificial Intelligence (XAI) to further improve prediction accuracy and operational transparency. The integration of reinforcement learning, federated learning, and real-time adaptive neural networks will enable forecasting models to continuously learn from new environmental conditions without requiring complete retraining. Such intelligent forecasting systems can be seamlessly integrated with Battery Energy Storage Systems (BESS), electric vehicle charging infrastructure, virtual power plants, and smart microgrids for autonomous energy management. By supporting predictive maintenance, optimal power dispatch, demand response, and energy trading, hybrid AI-based forecasting technologies will become an essential component of future sustainable power systems and carbon-neutral energy infrastructure.



Final Thoughts

The Hybrid CNN–LSTM and Ensemble Neural Network forecasting framework represents an advanced Artificial Intelligence solution for accurate solar power prediction. By combining deep feature extraction, temporal sequence learning, and ensemble-based prediction, the proposed system successfully improves forecasting accuracy across multiple prediction horizons while reducing uncertainty caused by changing weather conditions. The framework supports efficient renewable energy integration, smart grid operation, battery management, and intelligent energy scheduling. As AI technologies continue to evolve, intelligent forecasting models will play a crucial role in enhancing the reliability, sustainability, and economic operation of next-generation renewable energy systems.

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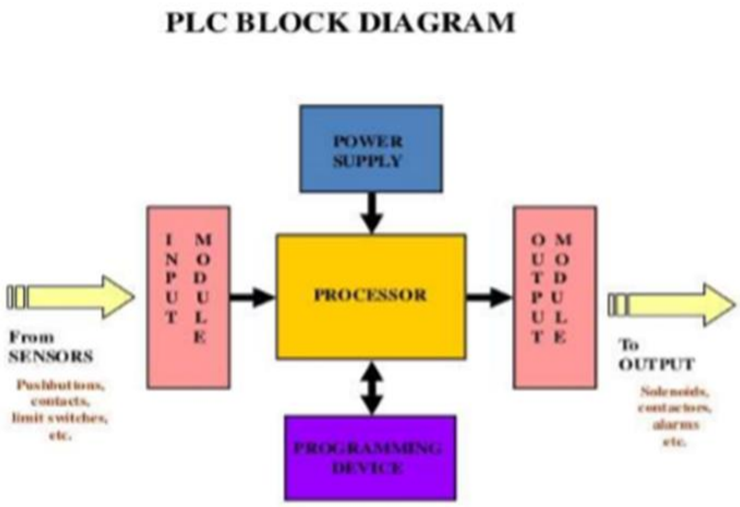
6. Smart PLC-Based Automation For PVC Window Manufacturing

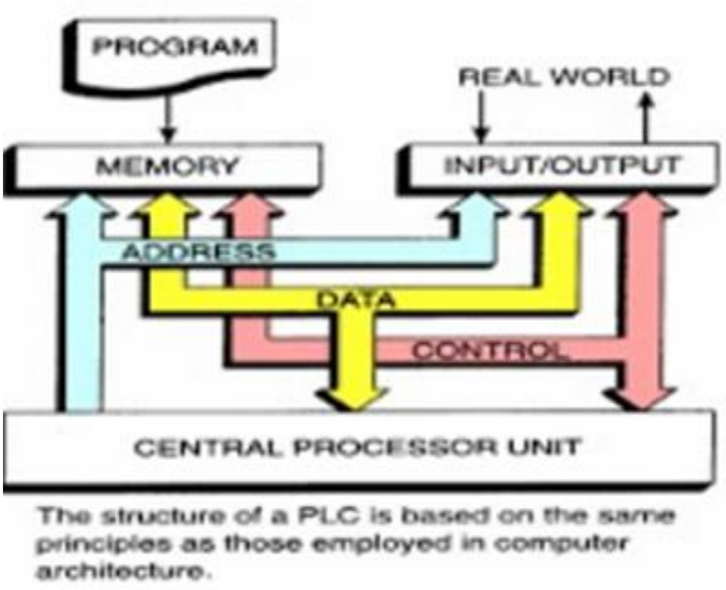
The manufacturing industry is rapidly embracing automation to improve productivity, product quality, and operational efficiency. Among various industrial products, PVC windows have gained widespread popularity due to their excellent thermal insulation, weather resistance, durability, low maintenance, and modern appearance. However, conventional PVC window manufacturing largely depends on manual operations such as profile cutting, reinforcement insertion, welding, hardware installation, and quality inspection. These manual processes often result in inconsistent product quality, higher labour costs, material wastage, and lower production rates. To overcome these limitations, industries are increasingly adopting **Programmable Logic Controller (PLC)-based automation** integrated with **Supervisory Control and Data Acquisition (SCADA)** systems. These intelligent automation technologies enable precise control of manufacturing operations, minimize human intervention, and improve overall production efficiency. The proposed PLC-based automation system provides an effective solution for developing a smart, reliable, and highly productive PVC window manufacturing process suitable for Industry 4.0 applications.



PLC-Controlled Intelligent Manufacturing Process

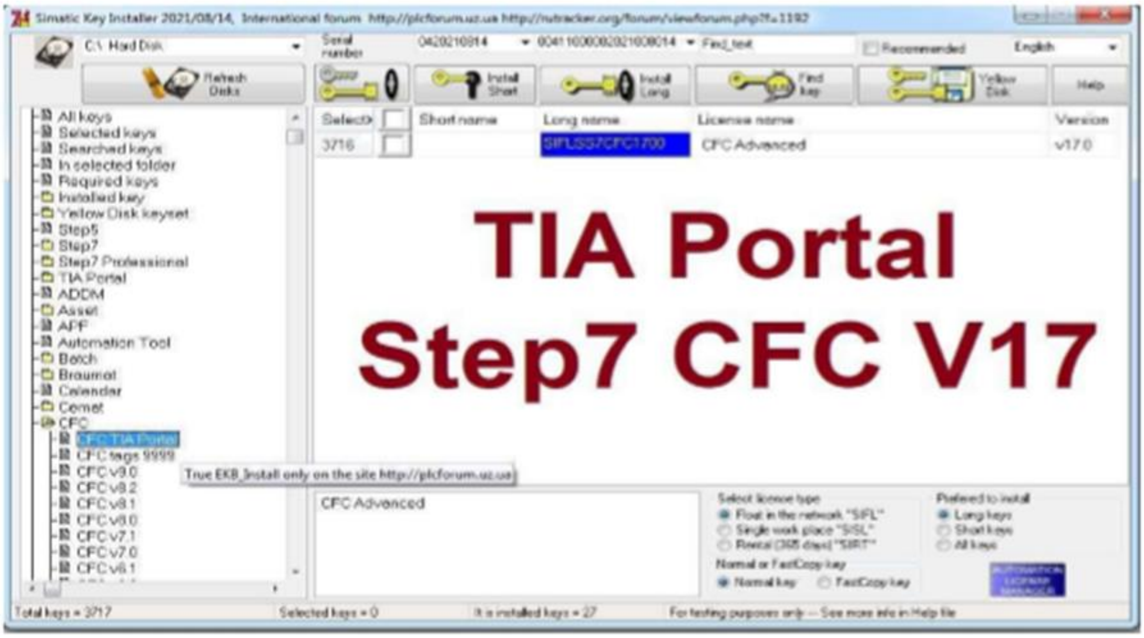
The proposed automation system employs a Siemens PLC as the central controller to coordinate every stage of PVC window production. Various industrial sensors continuously monitor the position of PVC profiles, machine status, and production sequence, while actuators, pneumatic cylinders, and motors perform automated cutting, reinforcement insertion, drilling, welding, and frame assembly operations. The PLC executes ladder logic programs that process input signals in real time and generate appropriate output commands for precise machine control.

Unlike conventional relay-based systems, PLC programming offers high flexibility, allowing production parameters to be easily modified without rewiring the control circuit. This intelligent control strategy ensures accurate synchronization between different manufacturing stations, minimizes production errors, and significantly improves process repeatability. By replacing manual operations with automated control, the system achieves higher manufacturing precision, reduced material wastage, shorter production cycles, and improved workplace safety, making it highly suitable for modern industrial manufacturing environments.



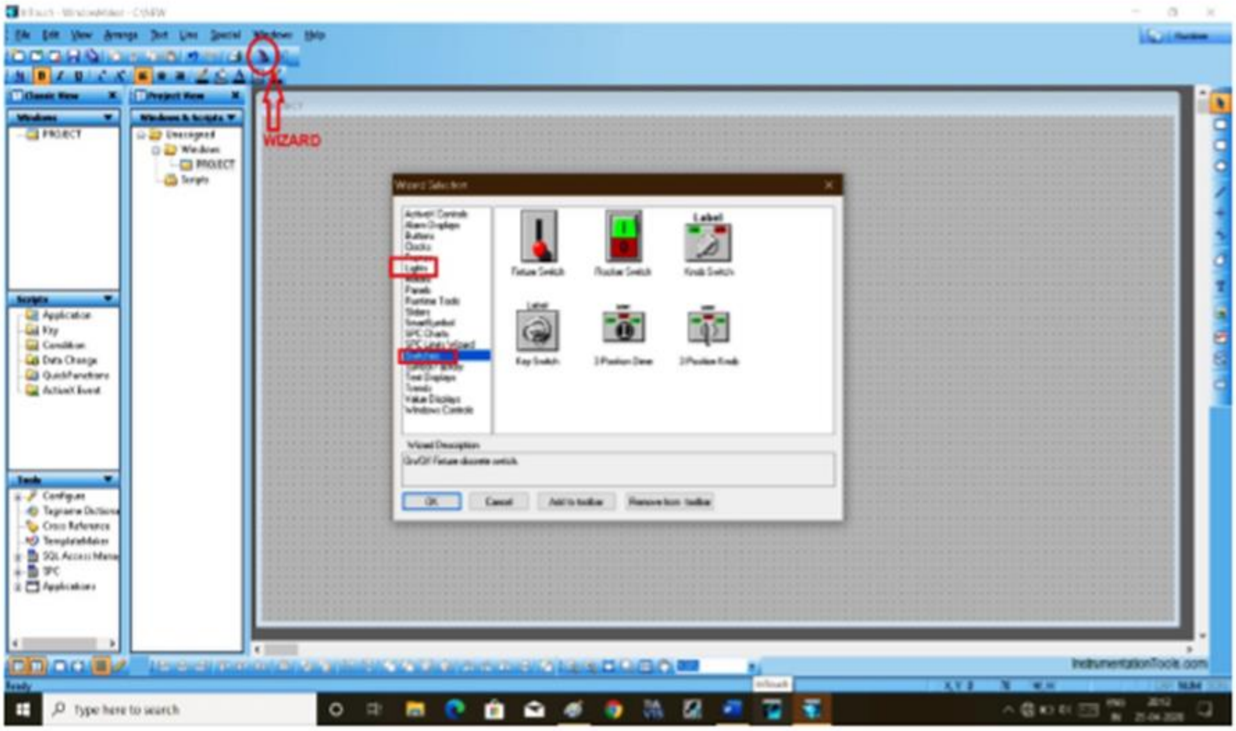
SCADA-Based Real-Time Monitoring and Industrial Control

An important feature of the proposed system is the integration of **SCADA (Supervisory Control and Data Acquisition)** technology, which enables real-time monitoring and centralized supervision of the entire manufacturing process. SCADA continuously acquires operational data from the PLC, displays machine status through graphical Human Machine Interface (HMI) screens, records production parameters, generates alarms, and assists operators in identifying faults immediately. Operators can monitor every stage of production, including cutting, welding, assembly, and hardware installation, from a single control station without directly interacting with the machinery. Historical data logging and trend analysis further support preventive maintenance, quality assurance, and production optimization. The seamless communication between PLC and SCADA enhances operational transparency, reduces machine downtime, and ensures continuous production with improved reliability and efficiency. Such intelligent monitoring systems are becoming indispensable components of modern smart factories and digital manufacturing environments.



Future Scope and Industry 4.0 Applications

Industrial automation is rapidly evolving towards fully digital and interconnected manufacturing systems under the framework of **Industry 4.0**. Future PVC window manufacturing plants can integrate Artificial Intelligence (AI), Industrial Internet of Things (IIoT), Digital Twin technology, cloud computing, machine vision, collaborative robots, predictive maintenance, and data analytics with PLC-based control systems to develop intelligent self-optimizing production facilities. Vision systems can automatically inspect product dimensions and surface quality, while AI algorithms can optimize production schedules, detect machine faults, and reduce energy consumption. Cloud-based monitoring platforms will enable remote supervision of manufacturing plants from anywhere in the world, and Digital Twin technology will allow engineers to simulate and optimize production before implementation. Such smart manufacturing ecosystems will significantly improve production flexibility, resource utilization, product quality, and overall competitiveness while supporting sustainable industrial development. The proposed PLC-based automation system represents an important step toward achieving intelligent, energy-efficient, and highly automated manufacturing facilities capable of meeting future industrial demands.



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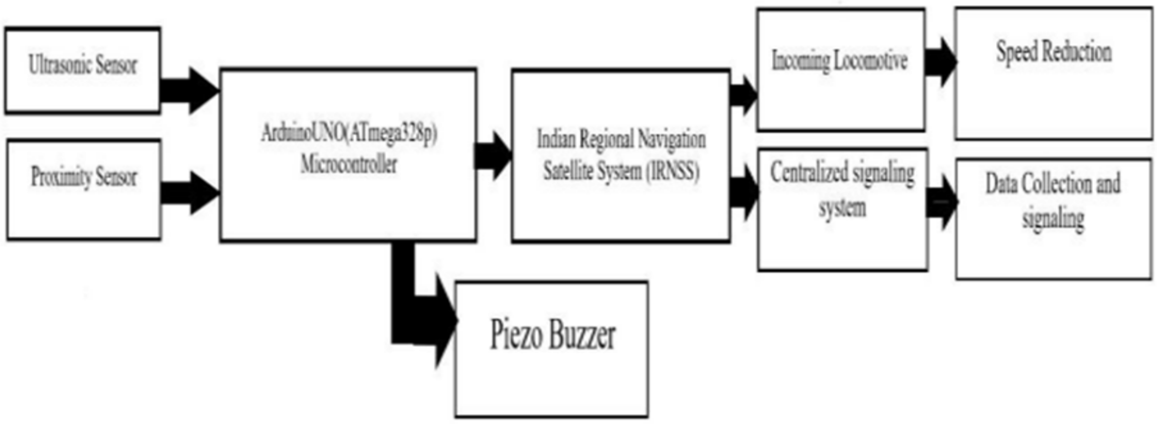
7. Smart Railway Line Tracking System For Reducing Animal Accidents

Railway transportation plays a vital role in connecting different regions of India by transporting millions of passengers and large quantities of freight every day. However, several railway routes pass through forests and wildlife habitats, where collisions between trains and wild animals have become a serious environmental concern. Large animals such as elephants are particularly vulnerable because of their slow movement and limited ability to escape from fast-moving trains. These accidents not only result in the loss of valuable wildlife but also cause damage to railway infrastructure and pose risks to passenger safety. The proposed Railway Line Tracking System for Reducing Animal Accidents introduces an intelligent sensing mechanism that continuously monitors

railway tracks and detects the presence of animals before a train reaches the affected location. By combining embedded systems, ultrasonic sensing, proximity detection, NAVIC (IRNSS) communication, and warning mechanisms, the system provides an effective solution for improving railway safety while supporting wildlife conservation.

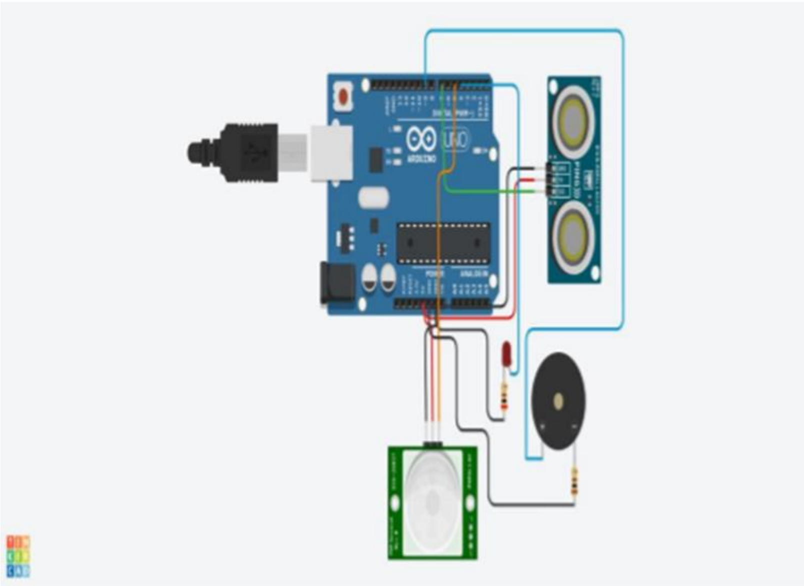
Intelligent Railway Monitoring Using Embedded Sensors

The proposed system employs an **Arduino Uno (ATmega328P)** microcontroller as the central processing unit for monitoring railway track conditions. Ultrasonic sensors continuously measure the distance between objects and the railway track, while proximity sensors detect the presence of nearby animals without physical contact. When an animal enters the danger zone, the sensor signals are processed by the Arduino controller, which immediately activates a piezo buzzer to generate sound that encourages the animal to move away from the track. Simultaneously, the system transmits the detected location to the centralized railway signalling system and the approaching locomotive using the **Navigation Indian Constellation (NAVIC/IRNSS)** communication network. Since NAVIC provides accurate regional positioning within India, the warning message can be delivered reliably even in remote forest regions. The sensing units remain in low-power mode and become active only when a train approaches within approximately 5 km of the protected zone, thereby reducing unnecessary power consumption while improving operational efficiency. The entire monitoring unit is powered using batteries supported by solar panels, making the system suitable for continuous deployment in isolated railway corridors.



Smart Alert Generation and Wildlife Protection

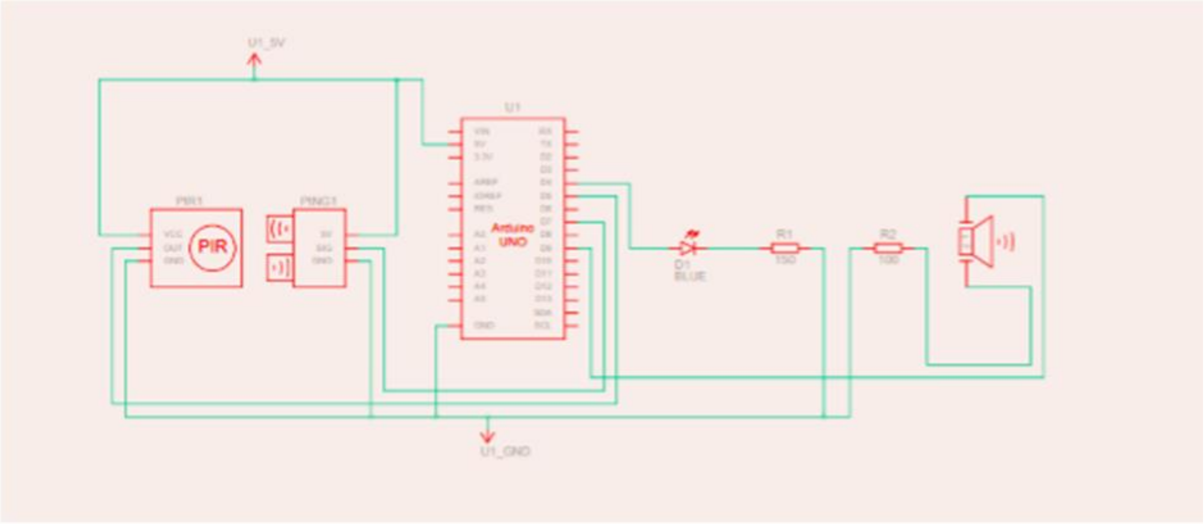
The effectiveness of the proposed system depends on rapid detection and immediate warning generation. The ultrasonic sensor continuously estimates the distance between the object and the railway track, whereas the proximity sensor confirms the presence of an animal near the sensing zone. Once both sensing conditions indicate a potential collision risk, the Arduino controller activates a high-frequency piezo buzzer that produces audible warning signals to discourage animals from remaining on the railway track. At the same time, location information is transmitted through the NAVIC communication module to the centralized railway signalling centre and the approaching train.



Based on the received warning, the loco pilot can reduce the train speed until the track is confirmed to be clear. The monitoring data collected over long periods can also be analysed to identify frequently used wildlife corridors, enabling railway authorities and forest departments to construct underpasses, overpasses, or protective fencing at critical locations. This combination of intelligent sensing and data-driven planning significantly improves railway safety while preserving biodiversity.

Future Scope and Sustainable Railway Safety

The proposed railway line tracking system provides a strong foundation for developing intelligent railway safety infrastructure. Future systems can integrate Artificial Intelligence (AI), Computer Vision, Thermal Imaging Cameras, Internet of Things (IoT), Wireless Sensor Networks, Edge Computing, Drone Surveillance, and Cloud-Based Monitoring to improve detection accuracy under all environmental conditions. Machine learning algorithms can analyse historical wildlife movement data to predict animal crossings and automatically issue early warnings before animals reach the railway track. Integration with modern railway signalling systems and automatic train protection technologies could enable temporary speed restrictions or autonomous braking in high-risk wildlife zones. Such intelligent solutions would contribute to sustainable transportation by protecting endangered species while maintaining safe and efficient railway operations. The adoption of advanced digital technologies will help establish environmentally responsible railway networks that support both infrastructure development and wildlife conservation.



Impact on Society

The Railway Line Tracking System for Reducing Animal Accidents demonstrates an effective application of embedded systems and intelligent sensing for wildlife conservation. By integrating ultrasonic sensors, proximity sensors, Arduino-based control, NAVIC communication, and audible warning mechanisms, the system enables early detection of animals near railway tracks and provides timely alerts to railway authorities and train operators. The proposed approach enhances passenger safety, minimizes wildlife mortality, and supports sustainable railway development. With future integration of Artificial Intelligence and smart railway technologies, such systems can become an essential component of India's next-generation intelligent transportation infrastructure.

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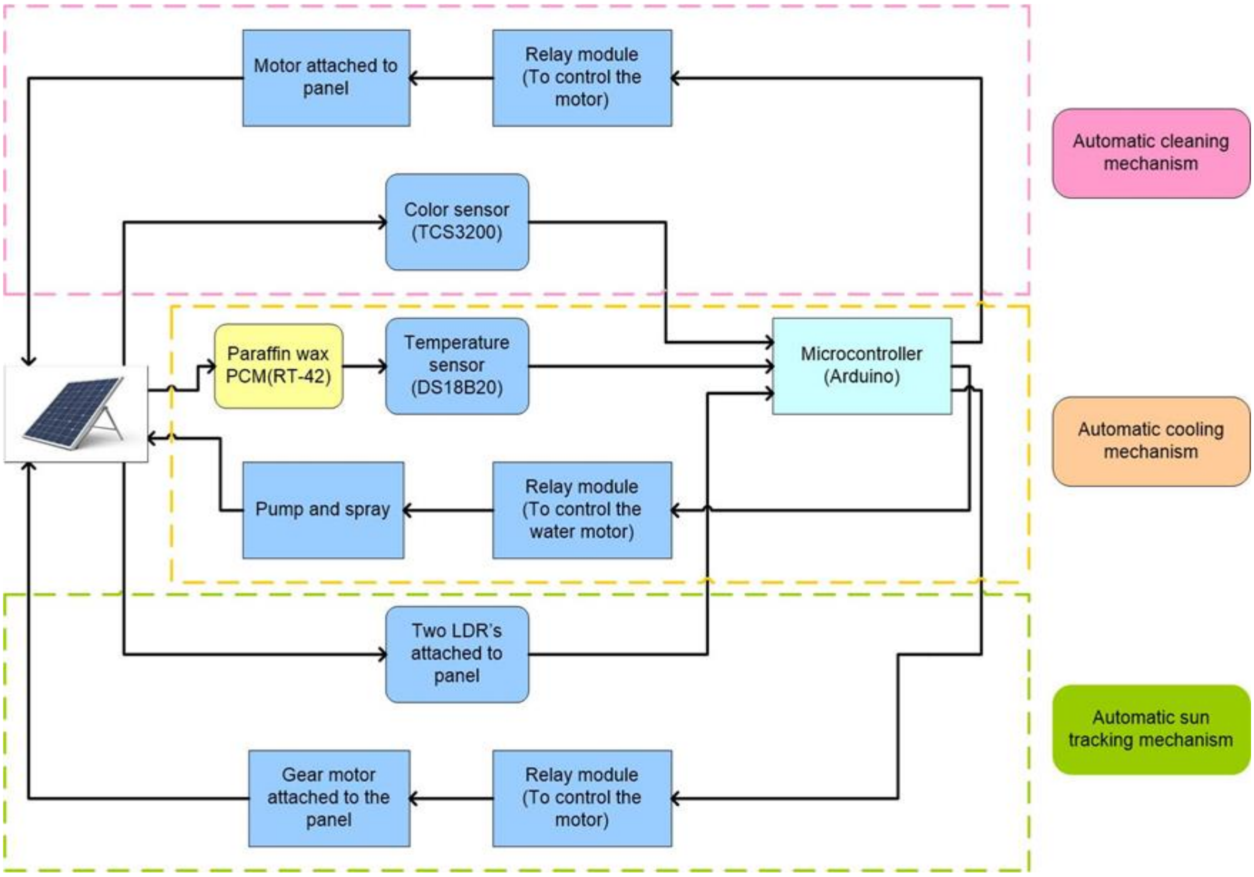
8. Smart Hybrid Cooling And Cleaning System For Solar Photovoltaic Modules

Solar photovoltaic (PV) technology has become one of the most promising renewable energy solutions for meeting the growing global demand for clean electricity. However, the actual performance of solar panels is often lower than their rated capacity due to environmental factors such as excessive temperature, dust accumulation, and improper orientation toward the sun. High operating temperatures reduce the open-circuit voltage and conversion efficiency of photovoltaic cells, while dust deposited on the panel surface blocks incident solar radiation, decreasing energy generation. Fixed-tilt solar panels also fail to capture maximum solar irradiance throughout the day because the sun continuously changes its position. To overcome these challenges, intelligent automation technologies are increasingly being integrated into photovoltaic systems. A **Smart Hybrid Cooling and Cleaning System** combines automatic sun tracking, hybrid thermal management, and intelligent cleaning into a single integrated platform, enabling the solar panel to continuously operate under optimum environmental conditions while improving energy output, reliability, and operational life.

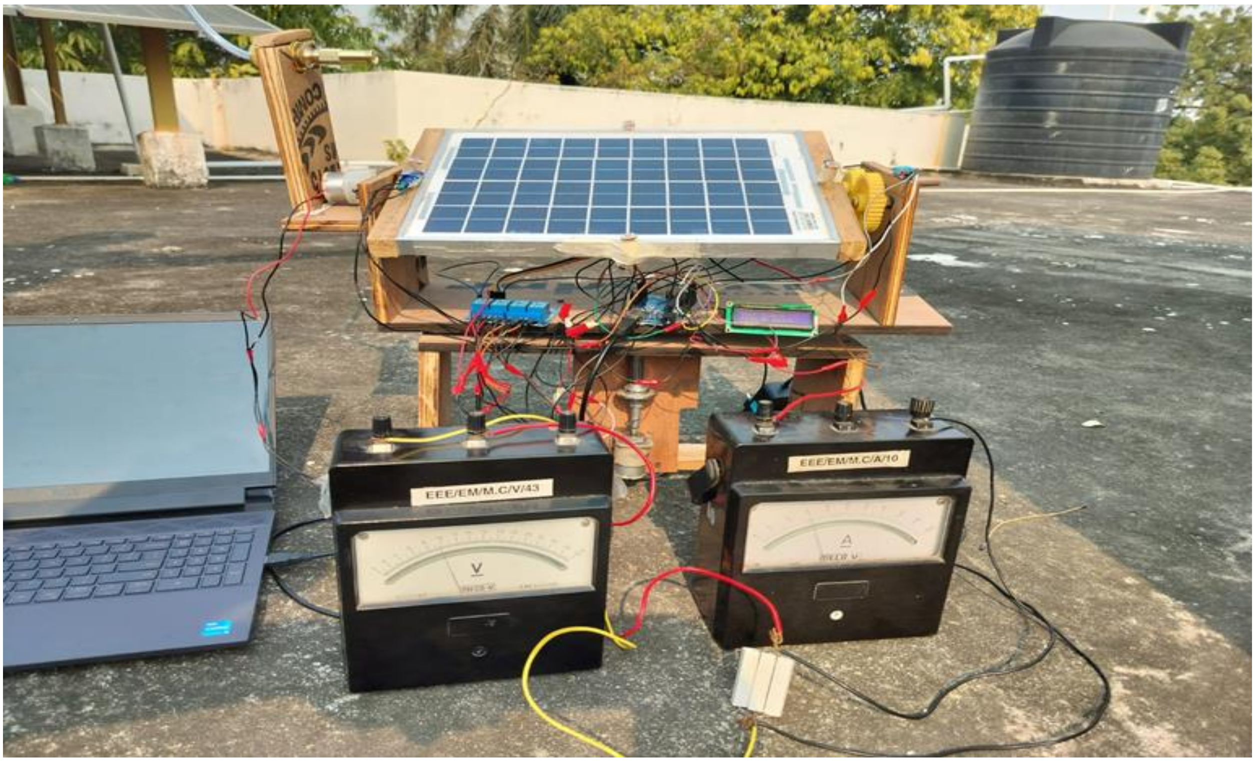
Intelligent Hybrid Cooling and Automatic Sun Tracking

The proposed system employs a **single-axis solar tracking mechanism** to maximize solar energy capture throughout the day. Two Light Dependent Resistors (LDRs) continuously detect the direction of maximum sunlight and provide feedback to an Arduino-based controller. Whenever unequal light intensity is detected, the controller drives a geared motor that rotates the photovoltaic panel until both sensors receive equal illumination, thereby maintaining the panel perpendicular to the sun's rays. Simultaneously, a hybrid cooling mechanism combines **passive cooling using Paraffin Wax Phase Change Material (PCM RT-42)** with **active water-spray cooling**. The PCM absorbs excess thermal energy during high irradiance periods by storing latent heat, while a temperature sensor continuously monitors the panel temperature. Whenever the temperature exceeds a predefined limit, the controller automatically activates a fine water-spray system to rapidly reduce the panel temperature through evaporative cooling. This integrated cooling strategy significantly minimizes thermal losses while maintaining stable electrical performance under varying weather conditions.



Automatic Cleaning and Smart Control System

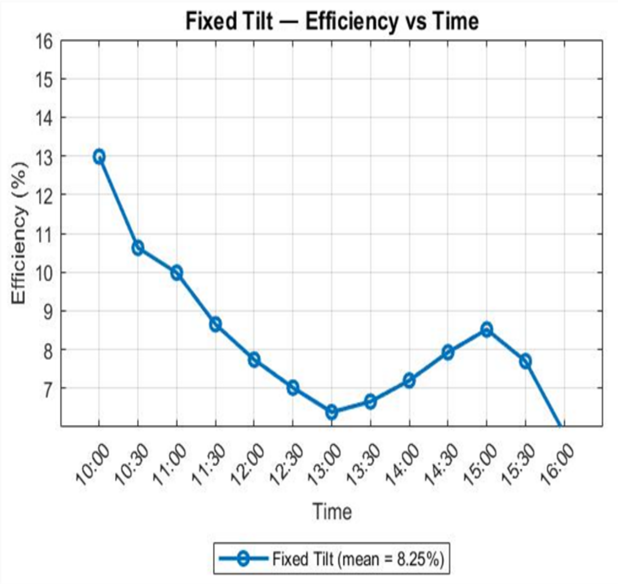
Dust accumulation is another major factor responsible for reducing photovoltaic efficiency, particularly in dry and dusty environments. To address this issue, the proposed system incorporates automatic dust detection and cleaning mechanism. A TCS3200 colour sensor continuously monitors the panel surface by analysing reflected light intensity. When dust accumulation exceeds a predetermined threshold, the Arduino controller automatically activates a motor-driven brush that moves across the panel surface to remove accumulated dust. After completing the cleaning cycle, the brush automatically returns to its initial position, ensuring continuous maintenance without manual intervention. The Arduino microcontroller serves as the central processing unit of the entire system by continuously acquiring data from LDR sensors, temperature sensors, and dust sensors, and intelligently coordinating the solar tracking, cooling, and cleaning operations. This integrated control strategy minimizes maintenance requirements while maximizing electrical energy generation under real operating conditions.

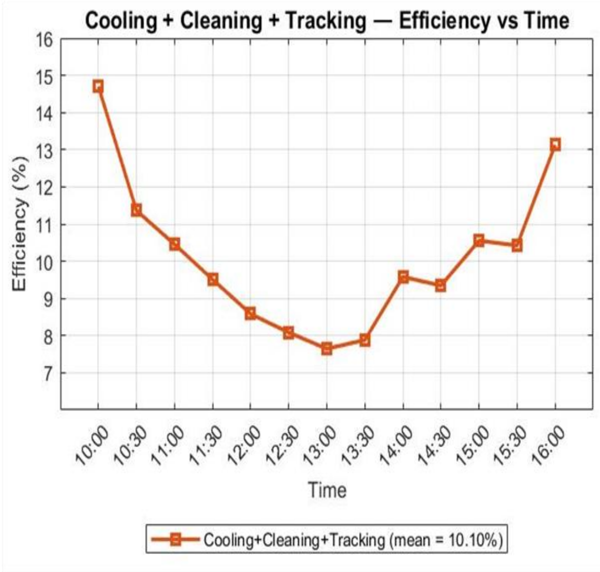


Performance Benefits and Future Scope

Experimental evaluation demonstrated that the integrated hybrid system significantly outperformed the conventional fixed-tilt photovoltaic panel. The hybrid cooling mechanism successfully reduced panel temperature from approximately **67°C to nearly 45°C**, thereby reducing thermal losses and improving voltage stability. The single-axis tracking mechanism continuously aligned the panel with the sun, increasing solar irradiance capture, while automatic cleaning minimized optical losses caused by dust deposition. The combined implementation of cooling, cleaning, and solar tracking resulted in a **maximum conversion efficiency of approximately 14.7%**, representing a considerable improvement over the conventional system. Looking ahead, future photovoltaic systems can further integrate **Artificial Intelligence (AI), Internet of Things (IoT), Digital Twin technology, cloud-based monitoring, predictive**

maintenance, weather forecasting, and machine learning algorithms to develop fully autonomous smart solar power plants capable of self-monitoring, self-optimization, and remote energy management.





Technology Outlook

The Smart Hybrid Cooling and Cleaning System demonstrates an effective engineering solution for enhancing the efficiency and reliability of photovoltaic power generation. By integrating intelligent sun tracking, hybrid thermal management, automated cleaning, and sensor-based control into a unified system, the proposed design successfully addresses the major environmental factors responsible for photovoltaic performance degradation. The combination of passive PCM cooling, active water-spray cooling, automatic dust removal, and real-time solar tracking enables higher energy generation, lower maintenance costs, improved system durability, and enhanced operational efficiency. As intelligent control technologies continue to evolve, such integrated photovoltaic systems are expected to become essential components of next-generation renewable energy infrastructure, supporting sustainable and efficient solar power generation.

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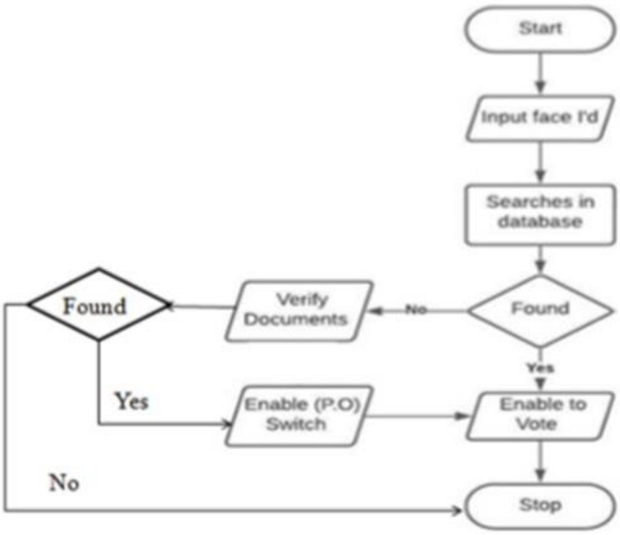
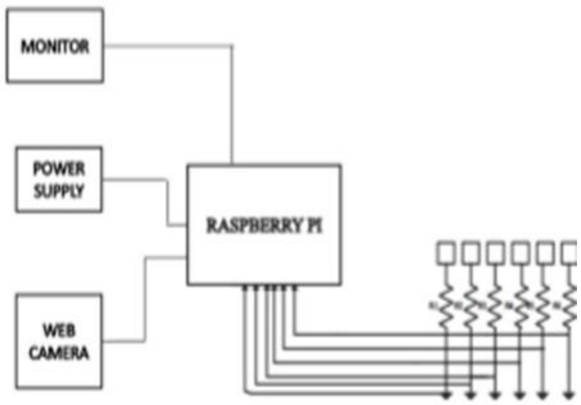
9. Next-Generation E-Voting System with Intelligent Face Authentication

Elections form the foundation of every democratic nation, and ensuring secure, transparent, and accessible voting is essential for good governance. Although Electronic Voting Machines (EVMs) and Voter-Verified Paper Audit Trail (VVPAT) systems have significantly improved the election process, challenges such as voter verification, migration of voters, low polling percentages, and election malpractices continue to exist. Many eligible voters are unable to cast their votes because they reside outside their registered constituencies for education, employment, or other reasons. To address these challenges, the proposed **Hybrid E-Voting System** integrates both offline and online voting into a single secure platform. The system combines Raspberry Pi-based Electronic Voting Machines, face recognition technology, cloud-based databases, and a secure web portal to provide authenticated voting while maintaining transparency and preventing duplicate voting. By enabling migrated voters to participate remotely through online voting, the proposed system aims to increase voter participation and improve the efficiency of future electoral processes.



Intelligent Face Recognition-Based Voting System



The proposed voting system employs a **Raspberry Pi 3 Model B+** as the central controller integrated with a webcam for voter authentication using face recognition. Facial images of registered voters are collected, trained using the **Haar Cascade Algorithm**, and securely stored in a database. During offline voting, the voter appears before the camera, and the captured facial image is compared with the stored database. If authentication is successful, the voter is permitted to cast the vote through the Electronic Voting Machine. If facial recognition fails due to image mismatch or poor capture quality, polling personnel manually verify the voter's identity and authorize voting through a dedicated manual switch. After successful voting, the voting status is immediately updated in a secure cloud-based Google Sheet, preventing duplicate voting attempts. This intelligent authentication mechanism significantly improves election security while reducing manual verification time and minimizing election malpractices.

Integrated Online Voting and Cloud-Based Election Management

To improve voter participation, the proposed system introduces a secure online voting platform for citizens who cannot physically reach their polling stations. Eligible voters register through the dedicated online voting portal by submitting details such as Aadhaar number, PAN number, email address, date of birth, and constituency information. After verification by election officials, login credentials are automatically sent to the registered email before the election. On the polling day, voters securely log into the portal, complete face verification using their webcam, and cast their vote electronically. Once voting is completed, both online and offline voting records are synchronized and securely stored in cloud databases and SQL servers, ensuring that each voter can vote only once. The integrated architecture eliminates duplicate voting, improves transparency, and simplifies vote management for election authorities.

Future Directions

Future electronic voting systems can be further strengthened through the integration of Artificial Intelligence, Blockchain technology, Multi-Factor Authentication (MFA), Digital Identity Verification, Quantum-Resistant Cryptography, Edge Computing, and Explainable AI. Blockchain can provide tamper-resistant vote storage with complete auditability, while AI-based fraud detection can identify abnormal voting patterns in real time. Biometric authentication combining facial recognition, fingerprint verification, and iris recognition can further improve voter authentication. Cloud-native election management systems integrated with national digital identity platforms can facilitate secure remote voting while maintaining voter privacy and election integrity. These emerging technologies have the potential to build highly secure, transparent, scalable, and trustworthy digital election ecosystems for future democratic societies.

Impact on Society

The proposed Hybrid E-Voting System successfully integrates offline Electronic Voting Machines with an online voting platform through secure face recognition and cloud-based data management. By combining Raspberry Pi, computer vision, web technologies, and centralized databases, the system enhances voter authentication, prevents duplicate voting, and enables remote participation for migrated citizens. The intelligent integration of online and offline voting improves election transparency, increases polling percentages, and provides a scalable foundation for next-generation digital electoral systems while preserving the security and integrity of the democratic process.

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10. Smart Fall Detection Using Yolo-Pose And Edge Artificial Intelligence

Falls are one of the leading causes of serious injuries among elderly and physically challenged individuals, often resulting in fractures, prolonged hospitalization, and reduced quality of life. Rapid detection and immediate medical assistance are essential to minimize complications and improve survival rates. Conventional fall detection systems mainly rely on wearable sensors such as accelerometers and gyroscopes or cloud-based vision systems. Although wearable devices can detect sudden body movements, they require continuous usage and are often inconvenient for elderly users. Similarly, cloud-based vision systems introduce communication delays, privacy concerns, and higher operational costs. To overcome these limitations, a **real-time intelligent fall detection system** based on **YOLO Pose Estimation** has been developed. The proposed framework performs real-time human pose estimation locally on an edge device, analyses body posture across multiple video frames, and instantly alerts caregivers through an Internet of Things (IoT)-based Telegram notification system. By combining Artificial Intelligence, Computer Vision, and Edge Computing, the proposed system provides an accurate, privacy-preserving, and cost-effective solution for continuous healthcare monitoring.

YOLO-Pose-Based Intelligent Fall Detection Framework

The proposed system employs the **YOLOv8 Pose Estimation** model to detect human body keypoints, including shoulders, hips, knees, and ankles, from live video captured through a USB camera. Unlike conventional image classification methods, YOLO simultaneously performs human detection and skeletal keypoint estimation in a single inference step, enabling high-speed operation suitable for real-time monitoring. The extracted skeletal coordinates are processed using posture analysis algorithms that calculate torso angle, torso aspect ratio, hip-to-ankle distance, and body orientation to distinguish normal activities such as standing, sitting, bending, and sleeping from actual falls. To eliminate false alarms, the system incorporates a **multi-frame debouncing mechanism**, which confirms a fall only when the abnormal posture persists for several consecutive frames with minimal body motion. Furthermore, two adaptive operating modes—**Seminar Mode** and **Bedroom Mode**—allow the system to automatically adjust detection thresholds according to the surrounding environment, preventing false alerts when a person is resting on a bed or other elevated surfaces. Since all computations are performed locally, the system ensures low latency, improved privacy, and reliable performance without continuous cloud connectivity.

Edge AI, IoT Alert Mechanism, and System Performance

A major advantage of the proposed framework is its ability to perform complete fall detection directly on an edge computing platform without transmitting video streams to external servers. After confirming a fall, the system immediately captures an image of the incident and transmits it securely to caregivers using the **Telegram Bot API**. The notification contains a real-time snapshot together with an alert message, enabling immediate visual verification and faster emergency response. The system employs confidence thresholds, motion analysis, posture verification, and cooldown timers to avoid repeated or false notifications. Experimental evaluation demonstrates that the framework accurately differentiates between standing, walking, sitting, bending, sleeping, and actual falls under different indoor environments. The adaptive posture analysis and environmental awareness significantly improve detection reliability while maintaining real-time operation suitable for smart healthcare applications.

Towards Smarter Solutions

The proposed vision-based healthcare monitoring system can be further enhanced by integrating **Explainable Artificial Intelligence (XAI)** for transparent decision-making, **Transformer-based Human Activity Recognition**, **Thermal Imaging Cameras** for low-light operation, **Millimeter-Wave Radar Sensors** for privacy-preserving monitoring, and **Federated Learning** to improve model accuracy without sharing personal data. Integration with **Electronic Health Records (EHRs)**, wearable medical sensors, smart hospitals, and IoT healthcare platforms will enable continuous patient monitoring and predictive healthcare analytics. The incorporation of Digital Twin technology, edge AI accelerators, and autonomous emergency response systems will further improve reliability, reduce response time, and support the development of next-generation intelligent healthcare systems capable of safeguarding elderly individuals living independently.

Final Thoughts

The proposed YOLO-Pose-based Intelligent Fall Detection System successfully combines Artificial Intelligence, Edge Computing, Computer Vision, and IoT technologies to provide a reliable, real-time, and privacy-preserving healthcare monitoring solution. By integrating posture analysis, motion tracking, multi-frame confirmation, adaptive environmental modes, and instant Telegram notifications, the system effectively minimizes false alarms while ensuring rapid emergency response. Its lightweight architecture, low computational requirements, and ease of deployment make it suitable for smart homes, hospitals, elderly care centres, and assisted living environments, contributing to safer and more independent living for vulnerable individuals.

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FACULTY PUBLICATIONS

International Journals

SCI/SCIE: 19, SCOPUS: 4, ESCI: 9

Q1: 5 Q2: 18 Q3: 6 Q4: 1 UG: 1

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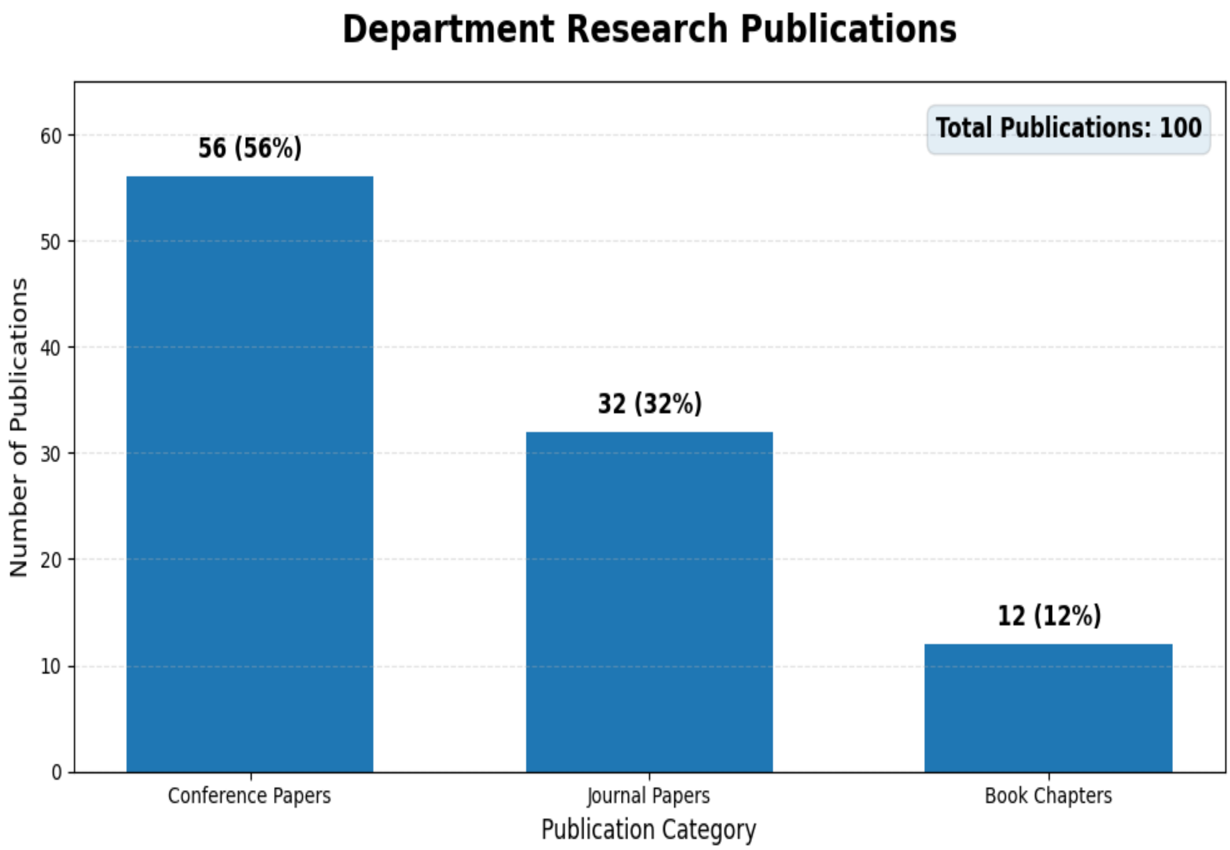

Fig. 1. Category-wise distribution of research publications during the academic year 2024–25.

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