ELECTRICAL ENGINEERING DEPARTMENT

FINAL YEAR DESIGN PROJECTS

BOOK OF ABSTRACTS

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UNIVERSITY OF ENGINEERING & TECHNOLOGY TAXILA

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Project Title:	**Enhancing Grid Reliability through Solar PV and BESS**
Students:	Taha Rafiq Ali Grewal (22-EE-85) Mohsan Ali (22-EE-137) Muhammad Saad (22-EE-149)
Supervisor:	Dr. Tahir Mehmood
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Abstract:	The increasing integration of renewable energy sources into modern power systems has introduced significant challenges in maintaining grid stability, power quality, and supply reliability. Solar photovoltaic (PV) systems are clean and sustainable energy sources; however, their intermittent nature causes fluctuations in voltage, frequency, and power output, which can adversely affect grid performance. To address these issues, this project presents a grid-connected Solar PV system integrated with a Battery Energy Storage System (BESS) to improve the reliability and operational stability of the electrical grid. The proposed system employs a Solar PV array as the primary renewable energy source, while the Battery Energy Storage System provides energy buffering by storing surplus solar energy and supplying power during periods of low solar generation or sudden load variations. A bidirectional DC-DC converter enables efficient charging and discharging of the battery, whereas a grid-connected voltage source inverter regulates active and reactive power exchange with the utility grid. Appropriate control strategies are implemented to ensure stable DC-link voltage, effective power management, and synchronized operation with the grid under varying operating conditions. The complete system is designed and simulated using MATLAB/Simulink to evaluate its dynamic performance under different scenarios, including variations in solar irradiance, changes in load demand, and transient disturbances. Simulation results demonstrate that the integrated Solar PV-BESS system effectively smooths power fluctuations, enhances voltage and frequency regulation, improves power quality, and ensures continuous power delivery during disturbances. The Battery Energy Storage System significantly reduces the impact of renewable energy intermittency by compensating for rapid power variations and maintaining system stability. The findings indicate that integrating Battery Energy Storage Systems with Solar PV generation substantially enhances grid reliability, increases renewable energy utilization, and supports stable operation of modern electrical networks. The proposed system contributes to sustainable energy development by reducing dependence on conventional fossil-fuel-based generation while improving the efficiency, resilience, and reliability of future smart grids. This work demonstrates that the coordinated operation of Solar PV and BESS provides a practical and effective solution for addressing the technical challenges associated with high renewable energy penetration in contemporary power systems

Project Title:	**Solar Wireless Electric Vehicle Charging System (SWEVCS)**
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Abstract:	Modern power distribution grids are evolving rapidly with the integration of renewable energy sources, electric vehicles, and distributed generation, creating an urgent need for high-resolution, real-time monitoring at the distribution level. Traditional Phasor Measurement Units (PMUs), deployed primarily at the transmission level, are prohibitively expensive ($10,000–$50,000 per unit) and are not economically viable for widespread deployment at the distribution feeder level. This thesis presents the design and implementation of a **low-cost Micro Phasor Measurement Unit (µPMU)** suitable for distribution grid monitoring at a fraction of the cost of conventional PMUs, using readily available hardware components including a microcontroller/DSP platform, voltage and current transducers (PT and CT), a GPS module for time synchronization, and a 16-bit ADC for high-rate sampling. The **Discrete Fourier Transform (DFT)** algorithm is implemented for real-time phasor estimation, achieving micro-phasor measurements compliant with the **IEEE C37.118.1-2011** standard, with the system sampling voltage and current waveforms at rates sufficient to meet reporting requirements of 30 to 60 frames per second

Project Title:	**Design and Implementation of BLDC Motor Controller for Electric Vehicles.**
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Abstract	This project presents the design and implementation of a Brushless DC (BLDC) motor controller for electric vehicles. Six-Step (Trapezoidal) Commutation technique using hall sensor feedback is used. Three hall sensors embedded within the BLDC motor continuously provide rotor position information to the microcontroller. Based on the hall sensor states, the microcontroller determines the appropriate switching sequence from the six-step commutation table and generates the required gate signals. A three-phase full-bridge inverter is made to energize the appropriate motor phases according to the commutation sequence. A high side low side gate driver circuit is employed between the microcontroller and the inverter for proper switching. Microcontroller adjusts the duty cycle of the PWM gate signals, enabling smooth speed variation. This controller provides efficient motor operation and variable speed regulation, making it suitable for electric vehicle applications.

Project Title:	**Battery Management System for Electric Vehicle.**
Students:	Suleman Abdullah (22-EE-54) Ali Imran Qazi (22-EE-90) Zahid Jamil (22-EE-99)
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Abstract:	Electrical energy plays a major role in innovation in the modern world and the behavior of battery management is a key concept in the safety and reliability of electric vehicle power systems. Battery Management Systems (BMS) are essential in the testing and analysis of performance of lithium-ion battery packs, including cell balancing, voltage monitoring, temperature sensing, and current protection. But most of the educational establishments could not afford to have full-scale EV battery testing setups, because of the complexity, cost, and resource requirements. This project seeks to design and build a small, safe, and practical Battery Management System for an Electric Vehicle that will be used for educational and demonstration purposes. The system will enable students and trainees to observe battery management phenomena such as cell balancing, overvoltage protection, and current sensing in a controlled and safe manner. The working BMS model will have key components including; a 182-cell lithium-ion battery pack (3.7V, 2200mAh per cell) in 13S14P configuration delivering 48V DC, a passive cell balancing circuit using MOSFET (75N75) with 4.7Ω (2W) resistors, voltage measurement using a 10KΩ potentiometer, temperature monitoring via a 10KΩ NTC thermistor, and current sensing through a 3.3Ω resistor at the MOSFET source terminal. NPN transistors (C1815/C945) and a voltage regulator are also incorporated for switching and stable supply control. This model is academically oriented and will allow narrowing the gap between theory and practice. Although the present prototype is built for basic BMS testing, there is the possibility to expand the design to handle more advanced EV battery management in future versions.

Project Title:	**Multi-Level STLF for New Energy Plan (CTBCM) with Integrated System Studies**
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Abstract:	Pakistan's power sector faces stress from rapid urbanization, Distributed Energy Resources (DERs), and the transition to the Competitive Trading Bilateral Contract Market (CTBCM). Existing forecasting is too coarse to capture the demand dynamics, while legacy planning tools fail to assess whether physical infrastructure can sustain predicted peak demands. This project develops a validated, multi-level Short-Term Load Forecasting (STLF) framework integrated with comprehensive system studies, addressing both the predictive and physical dimensions of distribution network planning. At the DT level, five deep learning architectures were evaluated. The proposed RNN-Bi-LSTM achieved a best MAPE of 9.476%, outperforming the prior best DT-level result by 58%. At the DISCO level, BO-LSTM, BO-XGBoost, and BO-TCN were evaluated across ablated feature configurations on four years of hourly LESCO data. The proposed BO-TCN achieved a MAPE of 3.29% and R^2 of 0.9813 reducing MAPE by 17.13% over raw inputs. System studies on the Amir Town 11 kV feeder using FDRANA and PSSE revealed summer peak losses of 5% at 300 A loading with annual energy losses of 963,669 kWh. PSSE load flow confirmed far-end voltage violations under peak loading, which were fully resolved by 450 KVAR capacitor bank placement, restoring all bus voltages within NEPRA's ±5% limit. Together, these contributions provide a physically validated, data-driven planning tool aligned with Pakistan's CTBCM requirements.

Project Title:	**Development of an intelligent super capacitor management system for hybrid energy system in electric vehicle**
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Abstract:	Electric vehicles rely on lithium-ion batteries that degrade rapidly under the high-current transients of acceleration and regenerative braking. This thesis designs, simulates, and validates an intelligent battery-supercapacitor hybrid energy storage system (HESS) intended to shift this transient current away from the battery. A single 1.5 V symmetric supercapacitor cell was fabricated from low-cost materials activated carbon on stainless steel mesh, an epoxy/carbon-black binder, a Whatman No. 1 separator, and 1 M Na_2SO_4 electrolyte and characterized via galvanostatic charge-discharge testing to obtain its specific capacitance, ESR, and energy/power density, which parameterized the simulation model. This parameterized a 48 V MATLAB/Simulink hybrid energy storage system, in which a voltage-aware power-split controller directed the supercapacitor to supply approximately 88% of peak acceleration current and the majority of regenerative braking energy, reducing peak battery current by approximately 70%, lowering pack temperature from 44°C to 38°C, and indicating a theoretical battery cycle-life improvement of 25–35%. The results show that a simple, transparent, voltage-dependent control strategy built around a low-cost, locally fabricated supercapacitor cell can deliver much of the battery-protection benefit reported for far more complex optimization-based strategies, offering a practical and economical route to extending EV battery life relevant to Pakistan's emerging EV sector. Keywords: Supercapacitor, Hybrid Energy Storage System, Electric Vehicle, Battery Degradation, Energy Management, MATLAB/Simulink, Activated Carbon, Voltage-Aware Power Split.

Project Title:	**Efficient IoT-Based Energy Management for Real-Time Automation**
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Abstract:	The importance of Smart Energy Management Systems (SEMS) is increasing due to the growing demand for electricity and the need for efficient energy usage. Energy management is divided into demand-side management and supply-side management. This project proposed a design for demand-side energy management using the Internet of Things (IoT). Our designed project is an IoT-Based Energy Management and Automation System using the ESP32 microcontroller for real-time data acquisition and control. Multiple electrical parameters such as voltage, current, power, energy consumption, power factor, and frequency are continuously recorded by integrated sensors with a sampling rate of 1Hz. A new data file is automatically generated every twenty-four hours for organized storage. This data is stored locally on an SD card and then transmitted to Node-RED Server via MQTT protocol for monitoring and data logging. Data is visualized through a Node-RED dashboard and a mobile IoT MQTT Panel application for remote monitoring and control of appliances. The system supports both manual and automatic control modes. In automatic mode, environment monitoring sensors are used to control relays, while in manual mode, the user can control the appliances either using physical switches or through remote interfaces. The system is implemented on a custom PCB designed in EasyEDA and then fabricated into real-world hardware that reduces overall size and improves reliability. Our system achieves real-time energy monitoring, accurate measurement of electrical parameters, and reliable appliance control. It successfully enables intelligent load analysis using NILM, reducing complex hardware requirements and improving efficiency. Overall, the system provides a cost-effective and scalable solution for smart energy management applications.

Project Title:	**Fault Detection and Localization in Distribution Feeders Using pmu/IoT Sensors**
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Abstract:	Electrical distribution feeders are an essential part of power systems, and faults occurring in these feeders can interrupt the power supply, reduce system reliability, and increase maintenance time. Conventional fault detection methods generally require manual inspection or expensive protection equipment, making fault localization difficult in distribution networks. To overcome these challenges, an IoT-based fault detection and localization system has been developed using current sensors, an ESP32 microcontroller, a 16×2 LCD with an I2C interface, and the Firebase Realtime Database. The current sensors continuously monitor the feeder current, while the ESP32 processes the measured values and detects abnormal operating conditions using predefined current thresholds. The developed prototype successfully detects Line-to-Line (L-L) faults and identifies their approximate locations at 2 km, 4 km, 6 km, and 8 km along the distribution feeder model. The detected fault information is displayed on the LCD and simultaneously transmitted to Firebase through the built-in Wi-Fi module, enabling real-time remote monitoring. The proposed system offers a low-cost, reliable, and efficient solution for improving fault monitoring and reducing fault detection time in electrical distribution feeders. Keywords: Electrical Distribution Feeders, Fault Detection, Fault Localization, Internet of Things (IoT), ESP32, Current Sensor, Firebase, Real-Time Monitoring.

Project Title:	**Intrusion Detection System for IoT in 5G Networks Using Machine Learning**
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Abstract:	IoT devices are getting widely used in various types of environments, but they are small and low-powered enough that running their own security software is not feasible. This makes it necessary to detect attacks at the network level using Intrusion Detection Systems (IDS). Another problem is that attack patterns evolve, and models trained on old data gradually loose accuracy, which is known as concept drift. This project implements and evaluates an adaptive, machine learning based IDS for 5G IoT networks in a three-phase approach. In Phase 1, we trained a Random Forest classifier using the CICIoT2023 dataset. Feature selection approach was used to reduce the input features from 47 to 28 without compromising the accuracy (99.1%) and FPR (0.8%). This also decreased the inference time from 11.8 ms to 7.0 ms per 10,000 flows, making the model faster and more suitable for deployment in MEC layers. During Phase 2, a 5G network model was simulated using OMNeT++ 6.3 with the Simu5G simulation framework having a base station, UPF (User Plane Function), MEC (Multi-Access Edge Computing) server, and ten IoT devices across twelve attack scenarios producing a total of approximately 12,000 flow records with labels. The trained model was tested on this simulation data without retraining. The F1 scores for the classes across the entire dataset were between 0.97 and 0.99, confirming that the features selected for use in this work perform well in both real and simulated environments. During Phase 3, an adaptive retraining mechanism was developed with an update cycle of 60 seconds and tested against the 5G network simulation for concept drift. The false-positive rate of the static model experienced a permanent increase to 8.7%. In contrast, the adaptive model recovered to approximately 2.0% within 3 to 4 cycles of retraining. This was confirmed through 5 independent test runs. A feature contribution analysis using SHapley Additive exPlanations (SHAP) determined that the two features which most contributed to detection errors during concept drift were the relative length of packets (r_Length) and the inter-arrival time (IAT).

Project Title:	**Power-Quality & Reliability Watch for Energy Communities**
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Abstract:	GridGuard is a data-driven power quality monitoring system developed to detect and classify power quality disturbances in community microgrids that include photovoltaic generation, battery storage, and electric vehicle charging. Such distributed energy resources can increase events such as voltage sag, swell, interruption, transients, harmonics, flicker, and notching, which may stress inverters, protection devices, and sensitive loads. The project used SEED-PQD-v1 as the main 17-class dataset and PQD-16c as an independent dataset for cross-testing. Raw voltage waveforms were normalized, resampled, harmonized through a unified label map, and converted into one-cycle windows for consistent comparison. Short-Time Fourier Transform spectrograms and Discrete Wavelet Transform features were extracted for classical models, while normalized raw waveform windows were used for one-dimensional convolutional neural networks. The implemented models included Support Vector Machine, Random Forest, XGBoost, 1D-CNN, and PatchTST. A Streamlit dashboard was also developed for operator visualization. The results show that the improved 1D-CNN v2 achieved the best single-dataset performance with a macro-F1 score of 0.9505 on the SEED 17-class task, exceeding the required 0.90 KPI. The noise-augmented CNN maintained a macro-F1 score of 0.9065 at 30 dB SNR. For real-time operation, XGBoost achieved 5.52 ms CPU latency including feature extraction, satisfying the 50 ms target. Overall, the project demonstrates a reproducible, lightweight, and software-based PQD monitoring pipeline for early risk detection in energy communities. Keywords: Cross-dataset analysis, energy communities, machine learning, one-dimensional convolutional neural network, power quality disturbance, Streamlit, supervised learning.

Project Title:	**Design and Implementation of Hybrid Inverter**
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Abstract:	A steady need for reliable and sustainable electricity generation, combined with grid instability and power failures has led to the need for sophisticated energy management systems. In this project, the design and the hardware implementation of an intelligent hybrid solar inverter is presented, a single platform combining solar PV generation, battery storage and utility grid power. The system employs voltage source inverter (H-bridge) of a single-phase with Sinusoidal Pulse Width Modulation (SPWM) using microcontroller. Battery charging and discharging is controlled by a bi-directional DC-DC converter and supervisory control logic ensures that the energy flows smoothly, using solar power whenever possible, battery power when the grid is away and the grid power when needed. Verification of system performance was conducted by simulation, implementing the system with hardware, analyzing the oscillation signals, and testing efficiency. Experimental results proved automatic switching in between solar, battery and grid without any interruption to the load supply. The generated 240 V AC output waveform by using the SPWM technique and optimized filtering stage was almost sine wave in shape and harmonic distortion was minimized. Measurements of efficiency under varying load conditions indicated a reduced loss in conversions, improved use of renewable energy and reduced reliance on the power grid. The developed inverter will be a practical, economical and environmentally friendly solution with the use of the locally available components for the residential purpose and Small Office. The proposed system also improves the reliability of energy supply in case of a power outage and promotes effective use of renewable energy. Flexible architecture makes it possible to implement future smart monitoring and energy management functions, promising future solutions for modern distributed power systems.

Project Title:	**Active Cell Balancing for Battery Storage Systems**
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Abstract:	The battery energy storage system (BESS) is an application today widely used in electric vehicles, renewable energy systems and many other modern systems. Differences in cell characteristics, cell aging and differences in operating conditions lead to voltage and State of Charge (SOC) imbalance which affects the battery capacity, efficiency and lifespan. Traditional passive balancing techniques dissipate surplus energy in the form of heat, which is not ideal for high performance battery systems. In this thesis, a design and implementation of Active Cell Balancing System Using a Single Inductor is presented. The proposed system utilizes an energy transfer mechanism that switching energy from high voltage cells to lower voltage cells by utilizing a microcontroller operated control algorithm and a single inductor and MOSFET switching network, combined with voltage sensing circuits. It has been designed and analyzed in MATLAB/Simulink and hardware implementation has been used to support the system. The results indicate that the proposed balancing technique is able to achieve a balance between the different voltages with minimum loss of energy. It can equalize the voltage at a higher efficiency than passive balancing, and can equalize the voltage at a higher speed; in addition, it has the characteristics of low heat generation and high battery utilization. Single inductor also is a solution to hardware complexity and low implementation cost. Thus, the proposed system is an efficient, compact and cost-effective system for BMS in electric vehicles and renewable energy storage applications.

Project Title:	**Design and Implementation of a Voice-Controlled Home Assistant Robot Using LiDAR-Based Navigation and Object Retrieval**
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Abstract:	An autonomous voice-controlled home assistant robot has been developed to support indoor tasks such as movement, object detection, location-based navigation, and basic object pickup. The robot includes a four-wheel mobile base, RPLIDAR A1, ROS 2, a camera-based object detection system, a web dashboard, and a six-degree-of-freedom robotic arm. A Raspberry Pi 5 is used as the main controller and runs Ubuntu 24.04 with ROS 2 Jazzy. An Arduino Mega controls the four encoder DC motors through two L298N motor driver modules, while an Arduino Nano controls the robotic arm and gripper. The web dashboard allows the user to view the camera feed, create maps, save locations, give text or voice commands, and check the robot's safety status. For autonomous navigation, the robot uses LiDAR-based mapping and Nav2 to move toward saved indoor locations without continuous manual control. In direct pickup mode, an Android phone sends a live MJPEG camera stream to the Raspberry Pi for object detection. When a bottle is detected repeatedly within a fixed and predefined area, the robotic arm performs recorded movements, including Home, pre-grasp, grasp, and carry positions. This enables the robot to pick up the bottle in a controlled stationary setup. The developed prototype demonstrates the integration of autonomous mobility, LiDAR mapping, object detection, voice control, web-based monitoring, and robotic arm operation in a single system. The final performance of the robot in terms of autonomous navigation accuracy, battery endurance, and unrestricted three-dimensional object grasping will be evaluated through final practical testing.

Project Title:	**Real-Time Fault Detection, Localization, and SMS Alerts for Transmission Networks**
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Abstract:	Transmission networks remain particularly susceptible to single line-to-ground, line-to-line, double line-to-ground, and three-phase faults, yet traditional detection still depends on slow field inspection that extends interruption duration and worsens reliability indicators such as SAIFI and SAIDI, particularly on rural feeders where installing SCADA infrastructure is not practical. This study presents the design and practical validation of a microcontroller-based fault detection, localization, and SMS notification system for a three-phase network at 380–400 V AC. Isolated ZMPT101B and ACS712 sensors send signals to an Arduino Mega microcontroller, which recognizes faults by evaluating RMS threshold limits, employs rule-based logic to categorize the fault type, and computes the probable fault distance through a single-ended impedance-based algorithm. The relay arrangement disconnects the faulted section, and a SIM800L GSM module sends an SMS containing the fault type, phase, location and time. The designed system is tested on a scaled urban–rural prototype with intentional fault application. The testing stage is intended to demonstrate detection within milliseconds, localization within ±5% of line length, and dependable alerts, considerably reducing fault-response time. The main contribution is a unified, hardware-tested, cost-effective platform that combines detection, categorization, localization, and alert generation within one medium-voltage system.

Project Title:	**Biometric Based Billing System for Mess and Cafe**
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Abstract:	This project focuses on introducing use of IoT in our daily life to make things simpler and efficient. As we are familiar with manual billing system which is used mostly in Pakistan, this traditional billing system takes much more time for both customers and the administration and moreover, there are more chances of over-billing. The main purpose of this project is to introduce biometric billing system in hostel mess and cafes. By introducing biometric billing system, we are aiming to increase the overall efficiency and streamline the whole process. Manual billing can cause errors in bill calculation which can lead to customers' dissatisfaction and moreover it can also cause revenue loss to the administration. Through this project we can overcome these problems and make a user-friendly interface for the customers through which they can easily check their due bill. The introduced idea consumes less time and is more efficient. Moreover, it can give us real-time monitoring and controlling of data.

Project Title:	**Solar Wireless Electric Vehicle Charging System (SWEVCS)**
Students:	Khuzaifa Abdul Jabbar (22-EE-45) Muhammad Usman (22-EE-57)
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Abstract:	Increasing production of electric vehicles (EV) worldwide is creating higher demand for safe, convenient and sustainable charging systems. Traditional plug-in chargers use connectors that can wear out over time, become a safety concern if wet, and require an exclusively Electric grid-based power source. Such grid dependency can be limiting for countries like Pakistan where there are very few charging points and existing power supply is often unstable. This thesis documents the design, construction, and testing of a Solar Wireless Electric Vehicle Charging System (SWEVCS): A prototype static wireless EV charger utilizing solar photovoltaic (PV) power with inductive Wireless Power Transfer (WPT) and wireless smart control. A 20 W solar PV panel and conventional 220 V mains adapter serve as two input power sources connected to an automatically operated three position changeover switch so that only one source can be connected at a time. The active source is connected to a 12 V DC bus regulated by an LM2596 step-down (buck) converter before being converted to high-frequency alternating current (~15 kHz) by way of a power- electronic driver circuit. The high-frequency alternating current feeds a 12-turn copper transmitter coil, which transfers energy through a small air gap to an identical copper receiver coil fixed underneath a toy-car through electromagnetic induction. Rectified output of this receiver coil is used to charge a battery pack consisting of lithium- ion cells on board the car. The car chassis consists of an ESP32 microcontroller with an L298N motor driver and drove back-and-forth across the charging pad using a Wi- Fi/Bluetooth mobile app. The assembled prototype with all subsystems integrated was tested with solar and mains excitation. Driver stage validation was completed using Proteus followed by hardware implementation. Test results verify that contactless transfer of power over small coil separations was possible and that received power degraded as expected with increased air gap and coil misalignment. Link efficiency end-to-end for the assembled prototype fell within the range expected of small non-resonant loosely coupled air-core coils. The on-board battery was charged successfully from both sources. The presented work verifies that an indigenous low-cost solar-assisted wireless charging concept is possible for LEV applications. Further, resonant compensation, maximum power point tracking, and foreign-object detection were shown to be promising paths toward increased efficiency and real-world readiness.

Project Title:	**IOT Based Smart Home Energy Management System**
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Abstract:	The increasing demand for electrical energy, rising electricity costs, and the need for efficient energy utilization have created the need for intelligent residential energy management systems. Conventional home energy systems mainly depend on utility grid supply and often lack real-time monitoring, automatic source control, and proper renewable energy integration. To address these issues, this thesis presents the design and simulation of an IoT-Based Smart Home Energy Management System .The proposed system integrates utility/grid supply, solar energy, and battery backup. Arduino Mega is used as the main controller. ACS712 current sensors, ZMPT101 AC voltage sensors, and DC voltage sensors are used for monitoring current, voltage, power, energy consumption, and source availability. A relay-based switching system using ULN2003A is implemented for source selection and load control. Three 13 W AC bulb loads are classified as high-priority, medium-priority, and low-priority loads. HC-05 Bluetooth with Blynk mobile application is used for mobile monitoring, and a 4×16 LCD is used for local display.The system was designed and tested in Proteus under solar, utility, and peak-hour battery modes. During sufficient solar availability, all three loads operated with a total load of 39 W. During low solar condition, the system shifted to utility supply, isolated the inverter, disconnected the battery path, and operated high- and medium-priority loads with a total load of 26 W. During peak-hour mode, the system shifted to battery backup and supplied only the high-priority load of 13 W. The results confirm that the proposed system improves residential energy management through source switching, load prioritization, peak-hour control, inverter protection, and real-time monitoring. **Keywords:** Smart Home Energy Management System, IoT, Arduino Mega, Solar Energy, Battery Backup, Load Prioritization, Energy Monitoring, Source Switching

Project Title:	**Fault Detection for PV Module Using Machine Learning**
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Abstract:	PV systems are truly environmentally friendly. Installation of are becoming more and more affordable. Sometimes problems like open-circuit faults, short-circuit faults and partial shading can happen. The system can function more efficiently by generating less energy and can even cause harm because of these problems. So finding faults early and accurately is crucial to make sure photovoltaic systems work well and are reliable. This research introduces a machine learning-based approach to identify faults in PV modules using real environmental data from NASA. The data used was related to weather in Islamabad, which comprised of its sunshine and hotness. This data was then entered into a computer simulation of a PV system to observe its performance under normal conditions as well as the simulation of fault conditions. It was also possible to determine when the PV system was partially shaded (PSS) through the model by comparing the different levels of sun exposure. The model also enabled determining when the PV system was partially shaded (PSS), based on the different PV system sun exposure. The information about the environment and the PV systems performance, such as the amount of energy it produces and its temperature, was obtained and recorded to form a large dataset. The dataset was balanced and sensor noise was added to enhance the machine learning model. The data set was used to train a special machine learning model called Random Forest to distinguish four conditions: working well circuit, short circuit and partial shading. The model has proven to be effective at accurately detecting faults, as well as resolving the differentiation of these faults. Besides computer simulations a setup was built using a microcontroller, current and temperature sensors and light sensors to test the model in life. This approach shows that the combination of environmental data, simulated faults and machine learning can be used to develop a system capable of detecting faults in photovoltaic systems in a reliable and economically viable way. PV really is environmentally friendly. Are getting cheaper to install. PV systems can perform satisfactory. Be dependable in the event of a fault being detected early and detected correctly. The proposed methodology offers an economic solution, for intelligent PV fault detection systems.

Project Title:	**Design & Development of (Portable) Solar Based EV Charging System**
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Abstract:	This thesis presents the design and development of a portable solar based electric vehicle charging system concept for e-bikes and other light electric vehicles. The central aim is to make charging support more accessible in locations where grid electricity is weak, intermittent, expensive, or unavailable. A portable unit can be deployed at small shops, rural markets, farms, temporary work sites, university locations, emergency camps, and other places where a permanent charging station is not practical. The work therefore combines solar energy conversion, power-electronic voltage regulation, energy storage, basic monitoring, and a practical portability-oriented deployment concept. A low-voltage hardware model was constructed to demonstrate the electrical operating principle. The developed low-voltage model contains a solar panel, battery storage, Arduino-based sensing and PWM control, a custom buck-boost converter board, LCD monitoring, and a lamp load. The purpose of the developed model is to validate regulated energy flow and controllability before the architecture is extended into a field-deployable charger. The physical developed model is not presented as a substitute for a complete commercial e-bike charger; rather, it is an experimental platform that supports the proposed portable system design. The developed hardware was observed under no-load and bulb-load conditions through its LCD display. These observations confirm a change in the monitored battery-side voltage and current when the load was connected, demonstrating practical response of the storage, converter, control, and display path. The thesis also develops a realistic full-scale implementation route for a portable E-bike charger. In that route, a suitably rated PV array, MPPT stage, controlled the required lithium-ion charging voltage output, battery protection, weather-resistant packaging, and transport-friendly construction are required. The main contribution of the work is the connection between a functional developed model and a portable field-use concept. The portable design direction emphasizes modularity, safe handling, low-maintenance operation, easy transportation, and suitability for underserved areas of Pakistan. This distinction makes the work both technically honest and practically relevant: the developed model demonstrates the control concept, while the full-scale architecture defines how the same idea can support clean mobility outside conventional grid-dependent charging locations.

Project Title:	**Design & implementation of BLDC inverter fan**
Students:	M Huzaifa Munir (22-EE-30) Tehniyat Fatima (22-EE-04) M Abubakar Saeed (22-EE-06)
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Abstract:	This venture describes how we designed and built an strength-efficient BLDC inverter fan with an Arduino-primarily based manage system to update general AC induction motor fans. We created a hardware prototype using a 12V BLDC motor, a three-section MOSFET inverter, IR2101 gate drivers, and an Arduino Uno microcontroller that runs six-step trapezoidal commutation with PWM speed manipulate. Our assessments confirmed that the BLDC fan used simply 30W, even as a regular AC fan used 80W, resulting in a 60% discount in strength use. The machine reached about 85% efficiency, that is 25% better than conventional fanatics. The prototype also allowed for easy variable pace manipulate (100-320 RPM) and progressed safety by way of going for walks on low-voltage (12V DC) strength. those consequences display that an Arduino-based totally BLDC inverter fan may be a practical, low-cost, and scalable way to decrease household energy use and help electricity conservation and sustainability.

Project Title:	**Brain Tumor Detection Using Deep Learning**
Students:	Muhammad Omar (22-EE-126) Ali Hassan (22-EE-152)
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Abstract:	Brain tumors are among the most devastating neurological diseases a person can get, and early detection can make a big difference in how a patient responds to treatment. In Pakistan and similar developing countries, the availability of specialist radiologists who can reliably interpret MRI scans is not always the case, especially outside the major cities. The whole problem this project is addressing is that diagnostic gap. The present thesis proposes brain tumour detection and classification system using deep learning and Transfer Learning. The system takes a brain MRI scan as input and classifies it into four categories: Glioma, Meningioma, No Tumour, and Pituitary. The model was built on the VGG16 architecture, pre-trained on the ImageNet dataset of 1.2 million images, and fine-tuned for brain MRI classification with a two-phase training strategy. In the first phase, only the custom classification layers on top of VGG16 were trained while the base network was frozen. In the second phase, the upper convolutional block of VGG16 was selectively unfrozen and fine-tuned at a very low learning rate. This resulted in a test accuracy of 93.25 percent on 1,600 fully unseen MRI images with AUC scores above 0.96 in all four classes. We applied Gradient-weighted Class Activation Mapping to make the system interpretable and clinically trustworthy. This method places a heatmap over the original MRI scan, highlighting the area that had the biggest influence on the model prediction. The system was deployed as a web application that was permanently hosted on Streamlit Cloud using Streamlit. This allows any person with an internet connection to access the system from any device without needing to install any software. Keywords: Deep Learning, Transfer Learning, VGG16, Brain Tumor Detection, MRI Classification, Grad-CAM, Convolutional Neural Networks, Streamlit, Medical Imaging

Project Title:	**Converting a DC Motor into a Servo Motor Using Pulse Controller and Encoder Feedback**
Students:	Ahmad Yasin (22-EE-078) Muhammad Shoaib (22-EE-158) Shams u Din (22-EE-170)
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Abstract:	Conventional DC motors are widely used in industry owing to their low cost and simple construction, yet they fundamentally lack the closed-loop feedback required for precise position and speed control. Commercially available servo motors address this limitation but impose a significant cost penalty that restricts their adoption in academic laboratories, small industries, and developing-economy automation systems. This thesis presents the design, simulation, hardware implementation, and experimental validation of a system that converts a standard 12 V geared DC motor into a servo-like actuator using a quadrature rotary encoder, an Arduino UNO microcontroller, a PID-based pulse-width modulation (PWM) control algorithm, and an L298N dual H-bridge motor driver. The project is organized around two distinct experimental tasks. The first task addresses closed-loop speed control using an elevator analogy: a thread wound around the motor shaft carries a dead-weight load whose addition simulates increasing passenger mass in an elevator. The controller's ability to maintain constant shaft speed under the step-load disturbance is recorded and plotted in MATLAB, demonstrating integral-action wind-up elimination and settling-time performance. The second task demonstrates angular position control, wherein a 4×4 matrix keypad enables the user to enter a target angle in degrees; the microcontroller then drives the motor until the encoder-reported position matches the setpoint within a defined tolerance, displaying both target and actual angles on a 16×2 LCD module. A WiFi module (ESP8266 NodeMCU) extends this functionality to wireless mobile-phone commands, turning the prototype into a remotely operable actuator. Proteus-based circuit simulation precedes hardware construction, verifying controller logic before physical assembly. The assembled hardware prototype achieves a steady-state position error of less than 2°, a speed-regulation band of ±3 RPM under step-load changes, and a step-response settling time below 2 seconds. Total component cost is approximately 14,000–18,000 PKR, representing a cost reduction of 60–70% relative to equivalent commercial servo motors. The results confirm that encoder-based, PID-PWM closed-loop control transforms an ordinary DC motor into a precision actuator suitable for robotics, automation, educational demonstrations, CNC prototypes, and camera-gimbal systems. Keywords: DC Motor, Servo Motor, PID Control, Pulse-Width Modulation, Encoder Feedback, Closed-Loop Control, Arduino UNO, L298N Motor Driver, Position Control, Speed Control, Embedded Systems, MATLAB.

Project Title:	**AUTONOMOUS VACCUM CLEANING & AIR QUALITY MONITORING ROBOT**
Students:	Hamza Aslam(22-EE-140) Malik Khuram Sajjad(22-EE-164) Malik Fahad Ansar (22-EE-168)
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Abstract	The **Autonomous Vacuum Cleaning and Air Quality Monitoring Robot** is a smart robotic system designed to perform autonomous floor cleaning while continuously monitoring indoor environmental conditions. The project integrates vacuum cleaning with real-time sensing of dust concentration, temperature, and humidity to improve both cleanliness and indoor air quality. The robot uses ultrasonic sensors for obstacle detection and autonomous navigation, enabling it to move safely through indoor environments without human intervention. A vacuum cleaning mechanism removes dust from the floor, while a dust sensor and DHT11 sensor monitor environmental conditions. An ESP8266/ESP32-based IoT module transmits the collected data to a mobile application, allowing users to monitor air quality parameters and control the vacuum system remotely. The developed prototype successfully demonstrates autonomous navigation, efficient cleaning, reliable environmental monitoring, and wireless communication with the mobile application. By combining cleaning and air quality monitoring into a single intelligent platform, the system provides a practical, low-cost, and user-friendly solution for homes, offices, laboratories, and other indoor environments. The project also provides a strong foundation for future enhancements such as AI-based navigation, SLAM mapping, automatic charging, and smart home integration. **Keywords:** Autonomous Robot, Vacuum Cleaning, Air Quality Monitoring, IoT, ESP8266, Ultrasonic Sensor, DHT11, Dust Sensor, Mobile Application.

Project Title:	**Network Instruction Detection System Using ML/DL**
Students:	Farhan Khalid (22-EE-020) Obaid Ullah (22-EE-021) Saad Alvi (22-EE-029)
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Abstract:	Cyber threats targeting computer networks are growing in scale, sophistication, and frequency, rendering traditional signature-based intrusion detection systems increasingly inadequate against novel and evolving attack patterns. This project investigates whether machine learning and deep learning models, trained on real-world network flow data, can achieve reliable accuracy for multi-class intrusion detection while operating in real time through a deployable web-based interface. The system was built using the CICIDS2017 benchmark dataset comprising 2,830,743 network flows spanning 14 distinct attack categories including DoS, DDoS, PortScan, Brute Force, Botnet, and Web Attacks. A rigorous preprocessing pipeline encompassing data cleaning, ANOVA F-statistic based feature selection (50 features from 78), undersampling-based class balancing, and StandardScaler normalization was applied prior to training. Three models were developed: a Decision Tree classifier, a Random Forest ensemble, and a CNN+LSTM hybrid deep learning architecture. The findings demonstrate that all three models achieved outstanding detection performance. The Random Forest attained the highest accuracy of **99.7%** with a False Alarm Rate of **0.30%**. The CNN+LSTM hybrid achieved **99.6%** accuracy. The Decision Tree, while the most computationally efficient at under **0.1ms** per prediction, achieved **99.3%** accuracy. Across all models, rare attack classes including Heartbleed and SQL Injection were successfully detected following class rebalancing. End-to-end system validation across 88 automated tests confirmed a **97.7%** pass rate, with live packet capture, real-time classification, and WebSocket-driven dashboard updates functioning within acceptable latency thresholds. These results establish that hybrid ML-DL pipelines, when paired with principled preprocessing and a deployable interface, constitute a practical and high-accuracy solution for real-time network intrusion detection. **Keywords:** Network Intrusion Detection System, CICIDS2017, Random Forest, CNN+LSTM, Deep Learning, Feature Selection, Real-Time Detection, Cybersecurity, Machine Learning, Anomaly Detection.

Project Title:	**Sehat AI – A Healthcare Assistant for Every Pakistani**
Students:	Muhammad Abdul Rehman (22-EE-40) Abdul Qadir Abbasi (22-EE-44) Muhammad Tahawar Ali (22-EE-72)
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Abstract:	Pakistan's health care system is under a severe human resource crunch, as there are only about 4 doctors for every 6000 people in rural areas, which is causing people to seek assistance from unqualified individuals. To fill this critical gap, this research has created the "Sehat AI" Electronic Medical Record (EMR) and healthcare management system that is designed to be 100% off-line and privacy conscious, with an embedded medical Large Language Model (LLM). We used LoRA to fine-tune the foundational model, Qwen3-4B-Instruct, on the Medical-R1-Distill dataset, and added Chain-of-Thought reasoning to generate safe and evidence-based clinical decision support. The framework leveraged aggressive post-training quantization to 4-bit format for low-cost deployment without relying on the cloud in resource-poor clinics. The main findings of this work illustrate the clinical performance and applicability of edge-based clinical AI. The quantized MedQwen3-4B-Q4 model successfully passed the tough medical tests with an overall accuracy of 48.6% on them, including MedQA (60.6%) and MedMCQA (55.4%). Most importantly, the quantization process managed to reduce the model footprint to a mere 2.6 GB, 85.6% of the original (nearly seven times) smaller than the standard 8 billion parameter medical models while preserving the integrity of the clinical reasoning of the model. Moreover, system integration testing proved this lightweight architecture is fully functional locally without the need for an Internet connection, on standard computer hardware. The offline system was able to handle patient data that was FHIR R4 compliant, and provided real-time, context-aware differential diagnosis and treatment offers. These findings demonstrate a viable and scalable solution to enhance diagnostic precision and alleviate burden with high-performing, privacy-conscious AI, in the absence of centralized infrastructure.

Project Title:	**Drone Detection using UAV Aerial Datasets**
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Abstract:	Unmanned Aerial Vehicles (UAVs) have proliferated rapidly, raising new challenges for airspace security and motivating the development of Counter-UAV (C-UAS) systems. This thesis addresses the problem of detecting small, fast-moving drones in real-world daytime aerial scenarios. The work was initially framed as a tracking-by-detection pipeline, but preliminary experiments showed that the upstream detection of low-salience targets against dynamic background clutter is the dominant bottleneck. The study was therefore reorganized as a controlled benchmark of state- of-the-art deep learning object detectors. Representative single-stage (YOLO26-L, YOLOv12-L), two-stage (Faster R-CNN, Mask R-CNN), and Transformer-based (RT-DETR-L, RF-DETR-Base) architectures are evaluated. All models were trained and tested on the recently released VisioDECT dataset under a single Controlled Variable Set (CVS) to keep the cross-paradigm comparison fair. The results show that detection transformers achieve higher strict-IoU accuracy than the convolutional baselines on small objects. RT-DETR-L obtained the best overall localization accuracy (0.6484 mAP@50–95) and the best robustness across illumination scenarios (Δ = 0.0124), while RF-DETR-Base defined the accuracy–speed Pareto knee, reaching 67.0 FPS at near-equal accuracy. The two-stage anchor based detectors, particularly Faster R-CNN, degraded most under low-contrast evening conditions. The study concludes that global-context modelling through self-attention provides the localization precision and scenario robustness needed for real-time drone detection, and that the resulting frame budget leaves room for a future spatio-temporal tracking stage. **Keywords:** Unmanned Aerial Vehicles, Object Detection, Vision Transformers, Deep Learning, YOLO, VisioDECT

Project Title:	**Obstacle Avoidance in Perspective of Unmanned Ground Vehicles (UGVs)**
Students:	Muhammad Naqeeb Ahmed (22-EE-009) Abdullah Ibrahim (22-EE-073) Shamsa Batool (22-EE-096)
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Abstract:	Unmanned Ground Vehicles (UGVs) are increasingly deployed across industrial, logistics, and disaster management sectors due to their ability to operate autonomously in hazardous and unstructured terrains. Navigating these environments reliably requires an obstacle avoidance system capable of real-time perception and decision-making under varying conditions. This thesis presents a modular autonomous navigation and Obstacle Detection and Avoidance (ODA) framework for Unmanned Ground Vehicles using ROS 2 Humble and the Nav2 stack. The core contribution is an automated multi-controller benchmarking pipeline that evaluates three local control plugins, the Dynamic Window Approach Base (DWB), Regulated Pure Pursuit (RPP), and the Rotation Shim controller wrapping DWB, under identical global paths, identical maps, and identical environmental layouts. Validation is performed through software-in-the-loop Gazebo simulations on a custom indoor environment, with the global occupancy grid generated through LiDAR-based SLAM. The evaluation is organized into three categories: direct observations recorded during the runs, computed metrics derived from offline log analysis, and graphical evidence presented through trajectory, velocity, and distance figures. All three controllers reached the goal pose within the configured tolerance across every run, with no collisions recorded, confirming that each is a viable choice for the navigation task. Beyond goal completion, the three controllers exhibited distinct behavioral signatures. The proposed framework supports a meaningful side-by-side comparison of local controllers within a single ROS 2 pipeline, and provides a validated open-source baseline for autonomous navigation studies in industrial and logistical contexts. **Keywords:** Autonomous Navigation, UGVs, ROS 2, Nav2, Obstacle Avoidance, DWB, Regulated Pure Pursuit, Rotation Shim, Cross Track Error, Gazebo Simulation.

Project Title:	**Urdu Audio Spoof Detection**
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Abstract:	The human voice itself is a biometric identifier that is now utilized in banking, forensics, and government services where a system is required to transcribe what is said, attribute it to a speaker, and determine if it is the real voice. These tasks are usually addressed independently and the focus is on, English is the main language studied and research is sparse on the low-resource languages, particularly Urdu, which is spoken by more than 230 million people with frequent code switching, no public datasets and little benchmarks. This thesis presents an integrated bilingual voice biometric system for Urdu and English that combines transcription, speaker recognition, and spoof detection. All experiments use VeriVoice-V1, a bilingual corpus of 80 speakers in which each bona fide recording is paired with Seed-VC voice-conversion spoofs and with adversarial variants generated by the Malafide and Malacopula attacks. Whisper Large is used for transcription, ECAPA-TDNN for speaker recognition, and three baselines, an MFCC-based SVM, a spectrogram-based EfficientNetV2 model, and the end-to-end RawNet2, are compared for spoof detection under identical conditions. ECAPA-TDNN proved strong and largely language-independent, reaching 96.38% accuracy on Urdu and 98.18% on English in the monolingual setting and 94.27% in the cross-lingual setting. For verification, EfficientNetV2 was the most reliable detector across both languages, achieving up to 99.80% accuracy with an equal error rate of 0.0017, while the MFCC baseline was competitive only on simpler attacks and RawNet2 was the weakest, degrading sharply on Urdu adversarial samples. The overall observation on the study is that the pattern of representation of the features is more important than the pattern of representation of the classifiers and that all the classifiers perform poorer on the Urdu corpus as compared to English, due to the spectral and phonetic diversity of Urdu language and its limited training data. These findings reveal the constraints of pipelines based on English and the challenge of generalization for unseen attacks. Future research on speaker recognition and anti-spoofing in low resource, code-switched environments can benefit from the resource and benchmark provided by VeriVoice-V1 and the proposed framework.

Project Title:	**AI-Enhanced Coastal Monitoring: GIS and Remote Sensing for Automated Detection of Shoreline Retreat and Erosion Risks**
Students:	Khansa Zainab (22-EE-01) Fatima Ansar (22-EE-60)
Supervisor:	Dr. Muhammad Laiq ur Rehman
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Abstract:	Coastal shorelines are highly dynamic and continuously change due to waves, storms, sediment transport, and sea-level rise. Monitoring these changes is essential for managing erosion risks and protecting coastal infrastructure. This study investigates shoreline change at Narrabeen-Collaroy Beach, Sydney, Australia, a well-documented site with long-term survey records that enables validation of satellite-derived shorelines. An automated workflow was developed using Landsat and Sentinel-2 imagery from 1990 to 2024. Shorelines were extracted using three methods: CoastSat, Random Forest, and U-Net deep learning. After tidal correction, shoreline changes were analyzed along five transects using Digital Shoreline Analysis System (DSAS) metrics, including Net Shoreline Movement, End-Point Rate, and Linear Regression Rate. The results showed that all three methods successfully captured long-term shoreline trends, although their performance varied. The Random Forest and U-Net models achieved high classification accuracies, while CoastSat provided a reliable and well-validated shoreline time series. The analysis indicated an overall accretionary trend across the embayment, with significant local variations consistent with the known rotational behavior of Narrabeen Beach. The findings demonstrate that integrating traditional remote sensing techniques with machine-learning approaches improves the reliability of shoreline monitoring and provides a practical framework for coastal erosion assessment and management.

Project Title:	**Image Processing and Deep Learning Framework for Monitoring and Predicting Glacial Lake Dynamics**
Students:	Saad Anwar (22-EE-02) M. Shahmir Hassan (22-EE-34)
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Abstract:	Glacial lakes in the high-mountain regions of the Karakoram–Shyok corridor, Gilgit-Baltistan, Pakistan, are rapidly changing indicators of climate variability and represent a significant natural hazard through glacial lake outburst floods (GLOFs). This thesis presents an integrated two-stage framework that combines machine learning (ML) based temporal monitoring with deep learning (DL) based spatial segmentation for comprehensive glacial lake analysis. In the first stage, multi-decadal Landsat imagery (1990–2025) was processed using Google Earth Engine (GEE) with a Normalized Difference Water Index (NDWI) based workflow to generate a 35-year glacial lake inventory for the Karakoram–Shyok region. ERA5-Land climate reanalysis data were integrated with lake area records, and three forecasting models — Random Forest regression, Linear Regression, and ARIMA — were trained and evaluated. Random Forest achieved the highest predictive accuracy with an R^2 of 0.85, MAE of 630.2 m^2, and RMSE of 1183.7 m^2, projecting total glacial lake area to reach 221.7–394.9 km^2 by 2030 under a +2°C warming scenario. A total of 462 qualified glacial lakes were identified, with three high-risk proglacial lakes (KS-72, KS-144, KS-341) exhibiting sustained and rapid areal expansion. In the second stage, a U-Net deep learning segmentation model with a ResNet34 encoder pretrained on ImageNet was developed and trained on glacial lake image patches. The model achieved a Final Mean Dice coefficient of 0.9601 and a Mean Intersection over Union (IoU) of 0.9277 on the validation set, demonstrating high-precision pixel-level lake boundary delineation across diverse lake morphologies and complex spectral backgrounds. Combined, the two stages form ascalable, reproducible monitoring and prediction framework suitable for deployment across other cryospheric environments in the Hindu Kush–Himalaya–Karakoram (HKH) region.

Project Title:	**Deep Learning Models for Flood Prediction and Monitoring Using Satellite Imagery**
Students:	Muhammad Sohaib Farooq (22-EE-031) Saqib Shahzad (22-EE-053) Ahmad Hassan Rao (22-EE-138)
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Abstract:	The 2022 Pakistan floods showed a serious lack of ready-to-use Synthetic Aperture Radar (SAR) datasets for South Asia, and clearly revealed the urgent need for flood mapping tools that do not rely on locally labelled training data, especially in regions where ground survey data is difficult or impossible to collect quickly during an active disaster. This thesis studies how well deep learning SAR flood segmentation models, trained on a global benchmark, can work in a new disaster region they have never seen before. A new Pakistan SAR dataset of 1,721 image chips covering northern Sindh was built using Sentinel-1 satellite imagery processed in Google Earth Engine, with flood masks created through an automatic five-stage process that needs no manual labelling. Two segmentation models, U-Net and DeepLabV3+, were built on the same EfficientNet-B4 backbone and trained with identical settings on the 356-chip hand-labelled part of the Sen1Floods11 benchmark, then tested, without extra training, on the separate Pakistan dataset. DeepLabV3+ reached an Intersection over Union (IoU) score of 0.2759 and an F1 score of 0.4002, beating U-Net (IoU 0.2409, F1 0.3562) on four of five measures, a 14.5% relative gain in IoU, thanks to the multi-scale context gathered by its Atrous Spatial Pyramid Pooling module. U-Net still had a slightly higher recall, though it produced more false positives. These results show that useful flood detection across regions is possible even without any training data from the target region, supporting the use of pretrained SAR segmentation models as portable, near-real-time tools for first responders in data-sparse disaster regions. The Pakistan SAR dataset, the automatic masking process, and the repeatable experimental setup built in this work offer a lasting contribution to deep learning-based SAR disaster monitoring, and a solid foundation for future research on cross-domain flood mapping in other under-resourced parts of the world **Keywords:** Synthetic Aperture Radar, flood mapping, deep learning, semantic segmentation, U-Net, DeepLabV3+, cross-domain generalisation, Sentinel-1, Google Earth Engine

Project Title:	**Design and Implementation of a Smart Battery Management System for Electric Vehicles**
Students:	Saif Ali (22-EE-027) Sana Ullah Nadeem (22-EE-043) Muneeb Ul Hassan (22R/19-EE-191)
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Abstract:	This thesis presents the design and implementation of a smart battery management system (BMS) for a three-cell series-connected lithium-ion battery pack. The proposed BMS monitors individual cell voltages, estimates state of charge (SOC) using Coulomb counting, supervises temperature through an NTC-based input, and selects a hybrid cell-balancing mode. The balancing strategy uses an active energy-transfer path when the cell-voltage difference is 100 mV or greater and a passive resistor path for fine correction when the difference is between 30 mV and 100 mV. No balancing action is applied when the difference is below 30 mV. The system was investigated through MATLAB/Simulink operating cases, Proteus circuit verification, and a laboratory hardware prototype. The charging simulation brought initially unequal SOC values to the selected upper target in approximately 420 s. The active and passive balancing cases demonstrated convergence under large and small mismatch conditions, respectively, while the discharge case reached the selected lower limit in approximately 900 s. Hardware observations showed the LCD progressing from unequal readings of V1 = 3.89 V and V2 = 3.88 V to equal displayed values of V1 = 3.91 V and V2 = 3.91 V, followed by a completion message. The results demonstrate the functional feasibility of the hybrid control concept for a low-voltage, laboratory-scale 3S prototype; they do not constitute validation for a production electric-vehicle battery pack.

Project Title:	**Dynamic Wireless Charging System For Electric Vehicles**
Students:	Muhammad Umer Faisal (22-EE-70) Hareem Shakil (22-EE-65) Umar Farooq (21R/22-EE-94)
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Abstract:	This thesis covers the design, simulation, and hardware implementation of a small-scale Dynamic Wireless Charging System built for electric vehicles. The project tackles the well-known drawbacks of conventional plug-in charging — the delay, the range anxiety, and the reliance on fixed charging stations. The prototype works on inductive power transfer: a transmitter coil on the track generates an alternating magnetic field, and a receiver coil fitted on the vehicle picks up energy from that field with no physical contact involved. That received power is rectified and fed to the vehicle load or motor. Before any hardware was built, the design was modelled and verified in Proteus, covering the inverter, driver, switching, rectifier, and PCB layout stages. The hardware that followed used transmitter coils, a receiver coil, power electronics, relay-based switching, wiring, and a small vehicle model. Testing confirmed that power was transferred wirelessly whenever the receiver coil sat close to and in line with an energized transmitter coil, and the PCB layout came together without issue, with the hardware demonstration backing up the expected relationship between alignment, air gap, and output. While the prototype is far from capable of charging a full-size vehicle, it does demonstrate the underlying concept of dynamic wireless charging and lays groundwork for future refinements such as better coils, sensor-driven coil activation, compensation networks, and battery charging control.

Project Title:	**Hardware-Integrated NILM System for Real Time Load Monitoring**
Students:	Hajra Shafique (22-EE-13) Sahar Hameed Lone (22-EE-05) Muhammad Hasnain Javed (22-EE-177)
Supervisor:	Dr. Malik Intisar Ali Sajjad
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Abstract:	Non-Intrusive Load Monitoring (NILM) is cost-effective technique for disaggregating appliance-level energy consumption from a single measurement point, eliminating the need for appliance sensors. With the growing need for demand-side management, NILM offers a non-invasive solution for real-time energy monitoring in residential and commercial settings. Despite its potential, most existing systems are software-based and lack real-world hardware integration. This thesis presents the design, implementation, and evaluation of a hardware-integrated, event-based NILM framework for appliance switching event detection and identification in both offline as well as real-time environments. The framework is developed and tested across three progressive stages. On the UK-DALE dataset, preprocessing, event detection, and a seven-feature extraction pipeline is combined with a Random Forest classifier, achieving a training accuracy of 99.68%, testing accuracy of 96.23% with high F1-scores confirming the robustness and generalizability ability of the approach. Then on a local office dataset, an adaptive thresholding algorithm is applied using both aggregate current ad power separately. It achieves perfect recall, detecting all ground truth switching events without a single miss in both cases. Using aggregate real power, a Precision of 0.937 and an F1-score of 0.967 are obtained, outperforming the current-based approach due to real power's greater immunity to noise and the nature of loads. Finally, the edge detection algorithm is deployed in an ESP32 microcontroller system PZEM-004T sensor on mains. The system successfully detects ON and OFF switching events for 65W laptop charger and incandescent 100 W bulb with millisecond latency, with results displayed on an LCD and transmitted via serial monitor. Overall, the results confirm that the proposed NILM framework is accurate, computationally efficient and suitable for real-time deployment. It establishes a viable solution for demand-side energy management and smart grid applications. Keywords: Demand Side Management, Edge Detection, Non-Intrusive Load Monitoring, , Random Forest.

Project Title:	**Design of Distribution Transformer Health Monitoring System Using IoT.**
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Abstract:	Distribution transformers are important components of electrical power distribution networks. Their reliable operation is necessary to provide an uninterrupted electricity supply to residential, commercial and industrial consumers. Conventional transformer inspection methods rely on periodic manual monitoring, which is time consuming and may fail to detect faults at an early stage. This can lead to transformer failures, power outages, increased maintenance costs and reduced system reliability. To overcome these problems, this thesis presents the design and implementation of an Internet of Things (IoT)-based Distribution Transformer Health Monitoring System for real-time monitoring and fault detection. The proposed system continuously measures transformer parameters, including voltage, load current, temperature and oil level using sensors connected to an ESP32 microcontroller. The sensor data are processed in real time, displayed on a LCD and sent to an IoT platform for monitoring. When any parameter exceeds its safe limit, the system immediately sends alerts to the operator, helping to reduce the risk of transformer damage. A hardware prototype was developed and tested under different operating conditions, including normal operation, overload, high temperature and low oil level. The results showed that the system accurately monitored transformer parameters, detected abnormal conditions and provided reliable real-time monitoring. The prototype also demonstrated low cost, fast response and stable operation. The proposed system improves transformer stability, reliability by supporting predictive maintenance, reducing unexpected failures maintenance costs and improving operational safety. It also provides a practical and low-cost solution for modern smart power distribution networks.

Project Title:	**Comprehensive Indoor Building Services Including Electrical, HVAC, Fire Fighting and CCTV Design for a Public High-Rise Building**
Students:	Abdullah Ameen (22-EE-025) Abdullah Shahzad (22-EE-089) Muhammad Arsalan (22-EE-129)
Supervisor:	Dr. Sh. Saqib Haroon
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Abstract:	This Final Year Project presents the planning, analysis, and integration of electrical building services for a large public facility. The project focuses on developing a coordinated electrical infrastructure by combining power distribution, lighting, heating, ventilation and air conditioning (HVAC), fire protection, and closed-circuit television (CCTV) systems into a unified design framework. The existing high-voltage and low-voltage distribution network was studied, traced, and documented to understand its configuration and operation, serving as the basis for the design of the internal electrical services. A comprehensive load assessment was carried out to determine the electrical demand of various building systems. Based on the calculated loads, suitable electrical equipment, including transformers, generators, distribution panels, protective devices, and cables, was selected to ensure reliable and efficient operation. A complete illumination design of the main prayer hall was performed to achieve the required lighting levels while maintaining visual comfort and energy efficiency. The project also includes the electrical planning of the HVAC system, CCTV network, and fire fighting services, ensuring proper integration with the overall power distribution system. In addition, standby power arrangements, renewable energy integration, and power factor improvement were considered to enhance system reliability and reduce energy consumption. The project combines theoretical knowledge with practical engineering practices through electrical drafting, load calculations, equipment selection, and system coordination. The proposed design emphasizes operational reliability, electrical safety, maintainability, energy efficiency, and provision for future expansion. The outcome demonstrates a comprehensive approach to integrating multiple building services into a dependable electrical infrastructure suitable for large public and institutional facilities.

Project Title:	**Design and Implementation of Electric Thermal Energy Storage System using Molten Salt**
Students:	Huzaifa Shahzad (22-EE-124) Ali Murtajiz (22-EE-120) Talha Mustafa (22-EE-144)
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Abstract:	The increasing demand for efficient energy storage systems has created a strong need for low-cost and reliable storage technologies. Conventional electrical energy storage methods, especially batteries, are useful but may become expensive for large-scale thermal or industrial applications. Thermal energy storage provides an alternative method in which electrical energy can be converted into heat and stored in a suitable medium for later use. This thesis presents the design and implementation of an Electric Thermal Energy Storage system using molten salt as the heat storage medium. In this project, a molten salt mixture based on sodium nitrate and potassium nitrate is used because of its high heat capacity, good thermal stability and suitability for high-temperature heat storage applications. Electrical energy is converted into thermal energy using an electric heating element. The temperature of the molten salt is monitored using a K-type thermocouple and MAX6675 thermocouple interface module. An Arduino UNO microcontroller is used to process the temperature signal and control the heater through a relay. A 16×2 LCD is used to display the measured temperature and heater status. Ceramic wool insulation and a suitable storage container are used to reduce heat losses and improve thermal retention. The designed prototype demonstrates the basic working principle of an Electric Thermal Energy Storage system. For a 5 kg molten salt storage medium heated from 30°C to 300°C, the estimated stored thermal energy is approximately 2815 kJ, equal to about 0.782 kWh. Considering practical heat losses, a heater rating of approximately 1000 W to 1200 W is suitable for prototype-level heating. The control system successfully turns the heater ON below the lower temperature limit and OFF above the upper temperature limit, providing stable temperature monitoring and automatic control. The project supports clean energy storage, renewable energy utilization and future integration with solar and wind energy systems.

Project Title:	**Hybrid cell balancing method**
Students:	Muhammad Zaid Amjad (22-EE-155) Ahmed Ali (22-EE-91) Muhammad Hamza Ahmad (22-EE-178)
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Abstract:	The methods used for cell balancing are Active Cell Balancing and Passive cell balancing. Active Cell Balancing is done by different methods i.e through inductor, capacitor etc. Active Cell Balancing involves complexity, efficiency and is used on large scale i.e electric vehicles but because of cost it is not used for small scale .On the otherhand, Passive Cell Balancing has simple circuit with resistors but all the energy in voltage balancing had been dissipated and wasted, although it is cost effective but still not efficient. Distributive Cell Balancing is the combined approach of Active Cell Balancing and Passive Cell Balancing. In Distributive Cell Balancing, the circuit is not as much complex and also more efficient than the Cell Balancing discussed and used conventionally. In this thesis, we discussed how we have implemented this approach on MATLAB and PROTEUS. This research presents a hybrid cell balancing method that combines the advantages of both active and passive balancing techniques to improve the performance, efficiency, and lifespan of lithium-ion battery packs. The proposed method uses active balancing to transfer energy from higher-charged cells to lower-charged cells through inductors and capacitors, while passive balancing with resistors is employed to dissipate any remaining excess energy. The hybrid approach reduces energy loss, lowers circuit complexity compared to fully active systems, and improves balancing speed compared to passive systems. The method is particularly suitable for electric vehicles and renewable energy storage systems where both efficiency and cost are critical factors. The system is modeled and simulated in MATLAB/Simulink and implemented in PROTEUS to validate its performance under different operating conditions. Simulation results show that the proposed hybrid method achieves faster balancing, higher efficiency, and better voltage uniformity across the battery cells. This work demonstrates that the hybrid cell balancing method is a practical and cost-effective solution for improving battery pack performance and ensuring safe and reliable operation.

Project Title:	**Optical Sensor Design System for Hydropower Plant & Flood Prediction**
Students:	Ahmed Yousaf (22-EE-37) Ramna Ajmal (22-EE-41) Noman Sajid (22-EE-125)
Supervisor:	Dr. Mamoona Khalid
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Abstract:	Analyzing the need to protect hydropower plants from flooding and give proper safety control, this project proposes an integrated fiber optic sensor-based flood monitoring and safety control system in MATLAB/Simulink. This system consists of a Water Level Sensor, a Turbidity Sensor, and a Fiber Bragg Grating (FBG) Strain Sensor that can collect the water level, water quality and structural strain data of the pond constantly, to detect the flood early. The data from the sensors is passed to a signal conditioning module, where it is processed and then passed to a Flood Risk Index calculation which sorts Plant States into a Normal, Warning and Critical state. The danger level that will be detected activates protective actions automatically, such as alarmation, operating gates of the spillways, warning indication and shutting down emergency generators, so that rapid response can be achieved with no human participation. Results obtained from the simulations illustrate the accuracy of the flood hazard classification, proper execution of safety action on the system, and speedy response of the system, indicating that the proposed system could be applied for monitoring, safety management, indication, and shutdown of the emergency generators for intelligent hydropower. Keywords: Fiber Bragg Grating (FBG), Fiber Optic Sensors, flood monitoring, safety controller, water level sensor, turbidity sensor, MATLAB/Simulink, Signal Conditioning, hydraulic power plant safety, Prediction Flood Risk.

Project Title:	**Optical Fiber Based Sensor Design for Fault Detection in Power Transmission Lines**
Students:	Syeda Laraib Akhtar (22-EE-55) Amna Naeem (22-EE-130)
Supervisor:	Dr. Mamoona Khalid
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Abstract:	Reliable fault detection is essential for ensuring the safe and efficient operation of power transmission systems. This thesis presents the design and simulation of an optical fiber-based sensor for fault detection in power transmission lines. The proposed system utilizes the advantages of optical fiber technology, including high sensitivity, immunity to electromagnetic interference, lightweight structure, and remote monitoring capability. A simulation model was developed to analyze the system under normal and fault conditions. Various fault scenarios were evaluated to assess detection performance and response characteristics. The results demonstrate that the designed sensor can accurately and rapidly detect faults, improving the reliability and protection of transmission networks. The study highlights the potential of optical fiber sensing technology as an effective solution for real-time monitoring and fault detection in power transmission lines.

Project Title:	**IOT BASED REMOTE PATIENT MONITORING SYSTEM WITH WIRELESS COMMUNICATION AND ALERTS**
Students:	Saleha Sarfraz (22-EE-36) Saad Ahmad (22-EE-67) Abdul Wahid (22-EE-83)
Supervisor:	Dr. Mamoona Khalid
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Abstract:	Bringing the Internet of Things (IoT) into the medical world has completely changed how we look after patients from a distance. However, there is still a massive problem: we do not have an accessible, non-stop way to monitor patients who live in far-off or rural areas. When patients live far away from hospitals or have just been sent home to recover, they rarely get the around-the-clock medical attention they need. Family members and caregivers have their own busy lives and cannot sit by a patient's bed every single second. This leaves vulnerable people completely alone and helpless if their health suddenly takes a turn for the worse. On top of that, everyday home dangers like extreme room temperatures, bad humidity, or sudden fire hazards can make a patient's situation even more dangerous, yet regular medical equipment completely ignores these environmental factors. Right now, if something goes wrong at home, there is no reliable system to instantly warn people in the next room and doctors far away at the exact same time. Existing setups are often too complicated to install, or they only track basic health stats while completely ignoring environmental safety. Most designs also lack a backup warning setup that can handle both local emergencies and remote digital notifications. This lack of technology severely hurts rural communities, elderly people living by themselves, and patients recovering from major surgeries who need close watching but simply cannot stay in a hospital bed forever. To fix this serious problem, this project presents the complete design and software simulation of an easy-to-use and reliable remote monitoring system. The simulated system models a smart wearable device that tracks essential body signals specifically heart rate and body temperature while simultaneously keeping an eye on room temperature, humidity, and the presence of fire. Using a simulated wireless microcontroller network, the setup models how data is safely uploaded to an online cloud platform where it can be viewed in real-time. Most importantly, an automatic, multi-way alert system is programmed into the simulation to send out immediate virtual warnings through local buzzers and phone notifications the exact moment any reading goes outside safe limits. Through comprehensive software testing and simulation environments, this project successfully proves that a smart, multi-dimensional safety system can be designed effectively, showing a clear path toward making continuous patient monitoring accessible for everyone, preventing dangerous accidents, and saving lives no matter where a patient lives.

Project Title:	**Modeling, Analysis and Power Enhancement of IEEE-50 Bus system using PSSE**
Students:	Mishal Zahra (22-EE-166) Ghulam Ayesha (22-EE-03)
Supervisor:	Dr. Aamir Rashid
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Abstract:	Modern power systems are confronted with increasing challenges related to voltage instability, power losses, reactive power deficiency, and dynamic disturbances arising from growing load demands and network complexities. This project presents a comprehensive modeling, analysis, and power enhancement study of the IEEE 50-bus test system, aimed at improving the overall performance, stability, and reliability of the power network. The study begins with the development of an accurate model of the IEEE 50-bus system, followed by **Load Flow Analysis (LFA)** using established numerical methods to determine the steady-state operating conditions, including bus voltages, phase angles, and active and reactive power flows across the network. Subsequently, **Stability Constrained Analysis (SCA)** is performed to identify critical buses and weak areas of the system susceptible to voltage collapse and instability under varying load conditions. To address reactive power deficiencies identified during the analysis, **Reactive Power Compensation (RPC)** techniques are implemented at optimal locations within the network to enhance voltage profiles and minimize real power losses. Furthermore, **AC Current Carrying Capacity (ACCC)** analysis is conducted to evaluate thermal loading limits of transmission lines and identify overloaded branches under contingency scenarios, ensuring the system operates within safe thermal boundaries. Finally, **Dynamic Stability Analysis** is carried out to assess the transient and small-signal behavior of the system under fault conditions and sudden load perturbations. The dynamic response of the system, including rotor angle stability and voltage recovery characteristics, is evaluated before and after the application of enhancement measures. Results demonstrate significant improvements in voltage profiles, reduction in active power losses, enhanced load ability margins, and improved dynamic stability of the IEEE 50-bus system following the proposed power enhancement strategies. The findings of this project provide valuable insights into the planning and operation of large-scale interconnected power systems.

Project Title:	**Seamless wireless electric vehicle charging for fleet operators**
Students:	Saniyah Taj (22-EE-069) Abdul Hanan Buttt (22-EE-075) Muhammad Zohaib Khan(22-EE-093)
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Abstract:	This project aims to propose an integrated wireless electric vehicle (EV) charging system for fleet operation. It allows for automatic and cable-free charging, minimizing downtime and improves convenience but may reduce efficiency due to transmission losses. Based on electromagnetic induction, the system transfers power from a charging pad on the ground to a receiver under the vehicle, providing a safer and more convenient alternative to wired charging. The microcontroller is used to control various parameters like the battery state of charge, temperature, and charging efficiency, ensuring safe and reliable operation while preventing overcharging. This solution enables charging of vehicles without driver participation, while working and lowering maintenance costs. The experimental results showed that the wireless power transfer (WPT) system can achieve stable power transfer, high efficiency, and reduce maintenance work, which has great potential for application in future smart and sustainable transportation systems. The keywords for this post are Wireless EV Charging, Wireless Power Transfer, Smart Charging, Electric Vehicles, Wireless, Energy Efficiency, Fleet Operators and Sustainable Transportation.

Project Title:	**AI based intrusion detection system for SCADA networks**
Students:	Talal Maqsood Bajwa (22-EE-016) Muhammad Ahsan Siddique (22-EE-088) Muhammad Munaas Ali Khan (22-EE-128)
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Abstract:	Supervisory Control and Data Acquisition (SCADA) systems operate many services that cannot afford silent failure, including power networks, water plants, oil and gas processes, and industrial automation. As these systems become connected with IIoT devices, remote monitoring, and enterprise networks, conventional rule-based intrusion detection becomes less effective against stealthy or previously unseen attacks. This thesis develops a Hybrid AI-Based Intrusion Detection System for SCADA and Industrial Control Networks using the WUSTL-IIoT-2018 and WUSTL-IIoT-2021 datasets. The system combines a Residual Autoencoder for reconstruction-error-based anomaly detection with an XGBoost classifier for attack classification, and supports the model output through preprocessing, feature handling, logging, alert generation, and a secure web dashboard. The Residual Autoencoder learns the normal behavior of industrial traffic and highlights suspicious deviations, while XGBoost strengthens the final decision by providing supervised classification of normal and malicious records. The implemented framework also connects model inference with operator-level monitoring, so that detection results are not limited to offline numerical outputs. Keywords: SCADA, Industrial Control Systems, Intrusion Detection System, Residual Autoencoder, XGBoost, WUSTL-IIoT, Anomaly Detection, CybersecurityKeywords: SCADA, Industrial Control Systems, Intrusion Detection System, Residual Autoencoder, XGBoost, WUSTL-IIoT, Anomaly Detection, Cybersecurity

Project Title:	**Network Slicing in 5G/6G Using Deep Reinforcement Learning (DRL)**
Students:	Sohail Ilyas (22-EE-24) Mazeen Ahamed (22-EE-64) Khadija Kousar (22-EE-84)
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Abstract:	With the evolution of wireless communication technologies and smart applications there has been a need for more efficient, reliable and intelligent mobile networks. Fifth Generation (5G) and Beyond Fifth Generation (5G/6G) networks will provide a vast number of connected devices with a wide range of Quality of Service (QoS) requirements, such as ultra-low latency, high data rates, reliability and efficient resource utilization. Static resource allocation methods cannot cope with the dynamic and heterogeneous nature of modern wireless networks. Intelligent network management techniques are thus needed to increase the efficiency of the use of the resources and network performance. This research introduces a framework which leverages the Proximal Policy Optimization (PPO) algorithm of Deep Reinforcement Learning (DRL) for intelligent network slicing in 5G/6G networks. The proposed system dynamically assigns multiple network slices to the network based on different traffic demands and network quality of service (QoS) requirements. The performance of the proposed framework was evaluated through a simulation environment developed in Python, under different network conditions. The implemented PPO-based model continuously learns from the environment of the network, and optimizes resource allocation decisions to maximize throughput, latency reduction, and slice utilization. The simulation was carried out to analyze the different parameters such as throughput, delay, reward convergence, and QoS satisfaction. From the results obtained, one can conclude that the proposed slicing mechanism based on PPO shows improved management of resources and network efficiency as compared to the conventional slicing methods. The model also demonstrates stable convergence behavior and adaptability in the presence of dynamic traffic conditions. The proposed framework is an intelligent and scalable solution for the future wireless communication system of 5G/6G. The research makes a significant effort towards the development of autonomous and adaptive network slicing techniques that can be used to serve next-generation mobile communication services and applications.

Project Title:	**Coreless Axial Flux BLDC Motor**
Students:	M Abdurrehman (22-EE-100) Fatima Mudassar (22-EE-19) Amna Seemab (22-EE-118)
Supervisor:	Engr. Hammad Shaukat
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Abstract:	With the rise in demands for small, light, and power-efficient electric propulsion systems, the need for efficient motor topologies capable of offering better performance at lower losses is becoming increasingly important. Generally, the conventional radial flux motors face difficulties in terms of achieving a high torque density, weight, and efficiency, which makes them not suitable for various applications including UAVs, robotics, and electric vehicles. This study introduces an innovative three-phase Coreless Single Stator Double Rotor (SSDR) Axial Flux BLDC Motor equipped with a segmented Halbach magnetization scheme aiming at improving electromagnetic performances while decreasing the cogging torque and magnetic flux leakage. The proposed motor is analyzed analytically by employing electromagnetic design equations and designed using ANSYS Maxwell 3D software package. Finite Element Analysis is utilized in order to analyze the magnetic flux distribution, air-gap flux density, Back Electromotive Force (Back-EMF), electromagnetic torque, torque ripple, and motor performance. This study will demonstrate that the proposed motor is expected to have better torque density, better utilization of magnetic field, decreased cogging torque, and higher efficiency compared to conventional axial flux motor designs. With its compact design and low weight, this motor has considerable promise in UAVs, robotics, EVs, and other applications where high-performance electric drive motors are needed.

Project Title:	**Electrostatic Water Precipitator for Atmospheric Fog Harvesting.**
Students:	Muhammad Haris (22-EE-49) Noor Ali(22-EE-76) Ghadeer Raza (22-EE-109)
Supervisor:	Engr. Hammad Shaukat
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Abstract:	Water scarcity is a critical challenge in arid and semi-arid regions where conventional freshwater sources are depleted or inaccessible. Atmospheric fog offers an abundant yet underutilized alternative, but traditional passive collectors are fundamentally limited — droplets smaller than 10 μm follow air streamlines and bypass the collector surface, yielding efficiencies of only 1–5%. This thesis presents the design, development, and experimental validation of an Electrostatic Water Precipitator (EWP) that overcomes this constraint through space charge injection. The system uses a Zero Voltage Switching (ZVS) flyback driver to generate a 20 kV DC output applied to a corona needle electrode inside a controlled fog chamber. The resulting discharge ionizes ambient air and charges incoming fog droplets, subjecting them to a Coulombic force that drives them toward a grounded curved collection mesh regardless of aerodynamic trajectory. The prototype integrates a 3D-printed high-voltage enclosure, a ZVS circuit, an ultrasonic humidifier for fog generation, a PVC conveyance duct, and an acrylic precipitation chamber housing the ionizing wire and collection plates. Experimental results show the active system achieves collection efficiency exceeding 90%, against 1–5% under passive conditions. Performance scaled consistently with applied voltage across the 5–20 kV range, and overall energy consumption was approximately 2 kWh/m³ — substantially below the 3–5 kWh/m³ typical of reverse osmosis desalination. These findings confirm that electrostatic precipitation is a viable, energy-efficient, and scalable approach to fog harvesting, with applications in water-scarce communities, agricultural irrigation, and industrial demisting.

Project Title:	**EC FlecCast Forecasting and Scheduling for Community Flexibility**
Students:	Usman Nasir (22-EE-14) Syed Muhammad Hamood (22-EE-59)
Supervisor:	Dr. Mansoor Ashraf
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Abstract:	The rapid integration of solar photovoltaics (PV), battery storage, and electric vehicles (EVs) into modern energy communities is creating highly volatile and unpredictable electricity demand. Traditional rule-based scheduling and classical statistical forecasting models struggle to capture the non-linear fluctuations introduced by these distributed resources. Such forecasting limitations can be paralyzing for countries like Pakistan, where the existing centralized power infrastructure is already prone to instability and frequent load-shedding. This thesis documents the design, implementation, and evaluation of EC FlexCast: an artificial intelligence-driven forecasting and scheduling prototype designed to optimize community energy flexibility. The system simultaneously predicts next-day electrical load, solar PV generation, and battery state-of-charge (SoC), translating these forecasts into actionable 24-hour flexibility windows for shifting controllable loads such as EV charging and HVAC systems. The framework utilizes real-world grid data sourced from Pakistan's Independent System and Market Operator (ISMO), augmented with exogenous weather variables and historical smart-meter profiles. Data preprocessing pipelines standardized the inputs into 15-minute intervals, handling missing values and extracting time-lagged features. The predictive engine was evaluated across a diverse suite of models—including SARIMA, LSTM, and gradient boosting architectures—using walk-forward validation. Test results verify that the LightGBM model achieved the highest predictive accuracy, minimizing Mean Absolute Percentage Error (MAPE) to 5.1% while maintaining exceptional computational efficiency. The forecasted outputs feed into an integrated scheduling optimizer deployed via an interactive Streamlit dashboard, successfully demonstrating peak-to-average ratio (PAR) reduction and maximized renewable self-consumption. The presented work verifies that an accessible, AI-assisted energy management tool can effectively stabilize community microgrids. Furthermore, integration with peer-to-peer (P2P) energy trading and reinforcement-learning-based autonomous scheduling are shown to be promising paths toward fully decentralized smart communities.

Project Title:	**Design and Optimization of Solar Wind Hybrid System for off-grid rural Communities**
Students:	Qalb e Abbas (22-EE-039) Sadaf Hussain Shah (22-EE-146) Muhammad Ali (22-EE-066)
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Abstract:	Rural communities in developing regions face persistent energy poverty due to unreliable grid infrastructure and the high costs of fossil fuel-based alternatives. This project addresses these challenges by designing and implementing an optimized Solar-Wind Hybrid Energy System (HRES) that combines renewable energy sources with intelligent power management to deliver sustainable, cost-effective electricity for off-grid applications. The system integrates photovoltaic solar panels and a small-scale wind turbine with battery storage to mitigate the intermittency of individual renewable sources. A microcontroller-based energy management system dynamically prioritizes power sources based on availability and demand, ensuring stable electricity supply while maximizing renewable energy utilization. The design incorporates real-time performance monitoring to optimize efficiency and provide operational insights. Through modeling (Proteus software) and physical prototyping, the system's technical and economic viability is evaluated. Key performance metrics include energy reliability, system efficiency, and cost savings compared to conventional diesel generators or standalone solar/wind systems. The results demonstrate that the hybrid configuration significantly improves power continuity while reducing both operational expenses and carbon emissions. This project contributes to sustainable rural development by offering a scalable model for decentralized electrification. The optimized HRES aligns with multiple UN Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), by displacing fossil fuel dependence with renewable alternatives. The modular design allows for future expansion, including integration with microgrids or smart energy management algorithms. By combining technical innovation with practical implementation, this work provides a blueprint for renewable energy adoption in underserved regions, demonstrating how hybrid systems can overcome the limitations of single-source renewable solutions while remaining economically viable for rural communities. Keywords: Hybrid renewable energy, rural electrification, off-grid power systems, energy management, sustainable development.

Project Title:	**Analyzing the Impact of Household Distributed Solar PV on a Domestic Feeder**
Students:	Hafiiz Suleman bin Zafar (20-EE-156)
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Abstract:	Application of distributed solar photovoltaic (PV) systems at the household level is disrupting the normal distribution systems presenting operational and technical opportunities and challenges. The proposed project investigates the impact of the residential PV integration on an ordinary domestic low-voltage feeder having some crucial parameters such as the voltage drop and losses. The simulation model of a suburban feeder has been developed using SynerGi Electric and Arc GIS using real residential load profile and solar irradiance data. They were experimented with different loading and generation conditions in order to establish their effects on the various PV penetration conditions. The mid-range of PV integration, as practiced in the project, can enhance profile of voltage and reduce losses of energy across the feeder. However, further on, the issues of voltage rise and high reverse power currents are now observable where the health of the protection coordination and transformers is now dangerous. The observations are in line with the prior research that recorded the duality of the distributed PV at low-voltage networks. Also, the findings help to point out the significance of voltage control system together with the on-load tap changers (OLTCs), intelligent inverters and energy storage systems to minimize the adverse effects at higher rates of penetrations. In this paper, the author will contribute to the research on distributed PV implications on domestic feeders and provide recommendations to grid operators and planners that want to make sure that the quality of power and the stability of the system are preserved in increasingly decentralized energy systems.

Project Title:	**State of health estimation via incremental capacitive analysis (ICA)**
Students:	Muhammad Sami (22-EE-97) Abdul Rehman Abid(22-EE-17) Syed Muhammad Ahmad (22-EE-123)
Supervisor:	Dr. Ahsan Ali
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Abstract:	Lithium-ion batteries are widely used in electric vehicles, portable electronics, and renewable energy storage systems, making accurate State of Health (SOH) estimation essential for ensuring their safe, reliable, and efficient operation. Conventional SOH estimation methods often require complex algorithms, expensive equipment, or large datasets, limiting their practical implementation. This project proposes a simple and reliable SOH estimation approach based on Incremental Capacity Analysis (ICA), which identifies battery degradation by analyzing changes in the voltage–capacity (dQ/dV) characteristics during charging. The proposed methodology involves collecting battery voltage and current data under controlled charging and discharging conditions, generating ICA curves, and extracting key degradation features such as peak position, peak height, and peak area. These features are then correlated with battery capacity fade to estimate the State of Health accurately. MATLAB/Python tools are used for data processing, smoothing, ICA curve generation, and feature extraction to ensure reliable and interpretable results. The developed ICA-based SOH estimation method is expected to provide a low-cost, non-destructive, and accurate solution for battery health monitoring. The proposed system can support Battery Management Systems (BMS) used in electric vehicles, renewable energy storage, and backup power applications by enabling predictive maintenance, improving battery safety, extending battery life, and reducing maintenance costs. The proposed framework offers an interpretable and scalable approach for battery health diagnosis by linking electrochemical degradation mechanisms with measurable ICA features. Unlike conventional black-box methods, ICA provides clear insights into battery aging through observable changes in the dQ/dV curve, making the estimation process more transparent and reliable. The outcomes of this project can contribute to the development of intelligent battery monitoring systems, supporting safer energy storage technologies and improving the overall performance and longevity of lithium-ion batteries in real-world applications.

Project Title:	**Axial Flux Brushless DC Generator**
Students:	Shoaib Nazir (22-EE-153) Syeda Hijab Batool Hamdani (22-EE-157) Muzammil Mushtaq (22-EE-161)
Supervisor:	Engr Hafiz Mehboob Riaz
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Abstract:	Axial Flux Permanent Magnet (AFPM) generators have emerged as a dominant technology for localized, low-speed renewable energy harvesting installations, such as small-scale wind and micro-hydro networks, due to their distinct disc-type geometry and superior torque-to-weight ratios. However, conventional slotted iron-core axial machines suffer from a critical electromechanical limitation: cogging torque. This structural sticking friction establishes high initial mechanical starting thresholds, preventing power generation entirely during weak, low-velocity fluid stream states. This research directly resolves this bottleneck by implementing, modeling, and verifying a dual-rotor single-stator coreless AFPM generator layout. By completely eliminating the heavy ferromagnetic stator core and substituting it with an advanced non-magnetic epoxy resin matrix, the structural cogging torque is entirely nullified, drastically lowering the mechanical cut-in speed and minimizing high-frequency stator core losses. The physical baseline configuration was initially modeled using analytical multi-variable sizing algorithms, and numerical validation was performed utilizing 3D Finite Element Analysis (FEA) to map air-gap magnetic flux density distribution and track spatial field boundaries. The physical prototype integrates alternating high-grade NdFeB (Neodymium N42) permanent magnet sectors facing three-phase, trapezoidal copper wire windings encased in a structurally stable polymer composite. Experimental validation of the physically fabricated coreless prototype confirms the total absence of cogging torque, allowing smooth, friction-free mechanical startup at near-zero input velocities. Open-circuit benchmarking demonstrates a perfectly linear relationship between the rotor's rotational velocity and the induced voltage parameters at a rated operating speed of 1400 RPM, yielding a measured phase-to-phase output voltage of 39 V and a corresponding phase-to-neutral voltage of 24 V. The generated output waveform displays an exceptionally clean sinusoidal profile with a measured Total Harmonic Distortion (THD) of less than 1.8%, validating the optimization of the trapezoidal coil geometries and eliminating the need for complex filter networks. Under load testing at rated capacity, the generator successfully achieves its targeted steady-state output power with an overall electromechanical conversion efficiency exceeding 90%. Due to the complete absence of core hysteresis and localized eddy-current loss pathways within the stator substrate, the machine exhibits an exceptionally flat efficiency curve across variable high-frequency states and operates at a highly stable thermal equilibrium, with a maximum recorded winding temperature rise of only 24°C above ambient under full-load operation. These empirical discoveries prove that the coreless axial flux configuration provides a highly efficient, thermally stable, and lightweight solution that successfully optimizes power conversion efficiency for off-grid distributed renewable energy clusters.

Project Title:	**Design and Implementation of a Voice-Controlled Home Assistant Robot Using LiDAR-Based Navigation and Object Retrieval**
Students:	Hamza Hussain (22-EE-94) Taha Haroon (22-EE-132) Ameer Hamza (22-EE-150)
Supervisor:	Engr. Hafiz Mehboob Riaz
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Abstract:	An autonomous voice-controlled home assistant robot has been developed to support indoor tasks such as movement, object detection, location-based navigation, and basic object pickup. The robot includes a four-wheel mobile base, RPLIDAR A1, ROS 2, a camera-based object detection system, a web dashboard, and a six-degree-of-freedom robotic arm. A Raspberry Pi 5 is used as the main controller and runs Ubuntu 24.04 with ROS 2 Jazzy. An Arduino Mega controls the four encoder DC motors through two L298N motor driver modules, while an Arduino Nano controls the robotic arm and gripper. The web dashboard allows the user to view the camera feed, create maps, save locations, give text or voice commands, and check the robot's safety status. For autonomous navigation, the robot uses LiDAR-based mapping and Nav2 to move toward saved indoor locations without continuous manual control. In direct pickup mode, an Android phone sends a live MJPEG camera stream to the Raspberry Pi for object detection. When a bottle is detected repeatedly within a fixed and predefined area, the robotic arm performs recorded movements, including Home, pre-grasp, grasp, and carry positions. This enables the robot to pick up the bottle in a controlled stationary setup. The developed prototype demonstrates the integration of autonomous mobility, LiDAR mapping, object detection, voice control, web-based monitoring, and robotic arm operation in a single system. The final performance of the robot in terms of autonomous navigation accuracy, battery endurance, and unrestricted three-dimensional object grasping will be evaluated through final practical testing.

Project Title:	**Industrial Automation with Auto-Phase Selection and Advanced Protection**
Students:	Mohammad Kaleem Kashif (22-EE-98) Muhammad Zakriya (22-EE-179) Naseem Hassan (22-EE-165)
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Abstract:	This project focuses on the development of an industrial automation system that incorporates auto-phase selection and advanced protection mechanisms for a three-phase electrical system. This automated phase selection capability enhances the overall system stability and reduces energy consumption, resulting in improved operational efficiency. In this project, we are using three phase power, or R, Y, and B phases, which are used to continuously put some load. When any one of the three phases goes out, the other two are ready to supply a single phase load, and an LCD is ready to show which phase is operating. We will use different advanced protection tools for the safety of the automated system. In addition to auto-phase selection, the proposed system integrates advanced protection mechanisms to ensure the reliable and safe operation of the three-phase system. Intelligent fault detection algorithms are employed to identify potential electrical faults, including overvoltage, undervoltage, phase imbalance, and short circuits. Once a fault is detected, the system promptly initiates protective measures, such as isolating the faulty phase, activating backup power sources, and issuing real-time notifications to operators. Our aim is to design an advanced system in which there will be the technique to properly automate the industry using automated system and different advanced protection tools that will be helpful in the safety of the equipment.