IARE
INSTITUTE OF
AERONAUTICAL ENGINEERING

HIGH IMPACT PRACTICES [HIPS]

CORNERSTONE PROJECTS:
ELECTRICAL MACHINES
INFORMATION PACKET
2025-2026

INSTITUTE OF AERONAUTICAL ENGINEERING
25 YEARS 2000 2025

Cornerstone Project (CoP) – Electrical Machines

Institute of Aeronautical Engineering (IARE)

We appreciate your interest in the **Cornerstone Project (CoP)** under the **Department of Electrical and Electronics Engineering**, focusing on **Electrical Machines** at the **Institute of Aeronautical Engineering**!

The **Cornerstone Project (CoP)** is strategically introduced in the early or middle stages of the undergraduate program to lay a strong foundation in **electrical engineering concepts**, with a special emphasis on **Electric Machines**. These projects are designed to help students transition from theoretical learning to real-world application by solving moderately complex, practical engineering problems.

Project Focus – Electrical Machines

These cornerstone projects aim to bridge the gap between classroom concepts and hands-on skills by applying fundamental principles of **DC machines, transformers, synchronous and induction machines, special machines**, and **control systems** in tangible ways. Students may engage in:

- Developing prototypes such as **automated speed control systems**, **loss minimization techniques**, or **load-sharing algorithms for parallel transformers**
- Analyzing real-time operational data from motors or generators for performance optimization
- Simulating faults in machines using MATLAB/Simulink and proposing detection and protection mechanisms
- Designing models for machine learning-based condition monitoring in rotating electrical machines

Project Objectives and Benefits

- **Simulate real-world industrial scenarios** – Students work on setups or simulations that mimic operational conditions in power systems, electric vehicles, renewable energy plants, etc.
- **Encourage interdisciplinary learning** – Projects can integrate concepts from power electronics, embedded systems, control theory, and energy management.
- **Promote responsible engineering** – Develop awareness about efficiency, safety, sustainability, and compliance with industrial standards in machine design and operation.
- **Support engineering decisions** – Enable students to propose data-supported modifications or innovations in machine design, fault tolerance, or energy use optimization.
- **Foster hands-on experience** – Engage in hardware-in-the-loop (HIL) testing, simulation-based validation, or prototype building in labs dedicated to electric machines and drives.
- **Build strong project portfolios** – Equip students with industry-ready documentation, working models, and exposure to advanced tools like **MATLAB/Simulink**, **LTspice**, and **dSPACE**.
- **Bridge theory with application** – Apply core topics like **magnetic circuits**, **loss analysis**, **torque-speed characteristics**, and **machine modeling** using actual test data.

Cornerstone Project Structure

- **Collaborative Learning**: Students work in teams of two or more, engaging in mutual learning and shared responsibilities to solve practical problems in electrical machine applications.
- **Mentorship and Infrastructure**: Faculty coordinators assign mentors based on specific machine-related domains (e.g., transformer health monitoring, motor control, etc.) and facilitate access to labs and resources.
- **Short-Term but Impactful**: Designed to be completed within a semester or assigned project duration, ensuring achievable goals while maintaining technical depth.
- **Socially and Industrially Relevant**: Students are encouraged to develop solutions that address societal challenges—such as efficient energy usage, rural electrification, and electric mobility—through machine-based systems.

  Through this program, students of Electrical and Electronics Engineering not only strengthen their conceptual grasp of electrical machines but also gain practical insight into their use in emerging technologies and sustainable development. The **CoP in Electrical Machines** serves as a launchpad for advanced capstone projects, internships, and industry collaboration.

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

IARE Sustainability Development Goals (SDGs) highlighted with Blue Colour Font	
SDG #1	End poverty in all its forms everywhere
SDG #2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
SDG #3	Ensure healthy lives and promote well-being for all at all ages
SDG #4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG #5	Achieve gender equality and empower all women and girls
SDG #6	Ensure availability and sustainable management of water and sanitation for all
SDG #7	Ensure access to affordable, reliable, sustainable and modern energy for all
SDG #8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG #9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
SDG #10	Reduce inequality within and among countries
SDG #11	Make cities and human settlements inclusive, safe, resilient and sustainable
SDG #12	Ensure sustainable consumption and production patterns

SDG #13	Take urgent action to combat climate change and its impacts
SDG #14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
SDG #15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG #16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
SDG #17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

High Impact Practices (HIPs) – Electrical Machines **Information Packet: 2025-26**

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

1**.** Armature Reaction and Compensation in DC Machines (SDG 7,9,13)

2.Magnetic Saturation and Hysteresis Effects in Core Materials (SDG 4,7,9)

3.Dynamic Modeling and Simulation of Synchronous Machines (SDG 9,11,12)

4.Design and Optimization of Special Electrical Machines (SDG 7,9,11)

5.Speed Control and Drives for AC and DC Machines (SDG 9,11,12)

6. Transients and Switching Surges in Transformers and Induction Motors (SDG 7,9,13)

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

Armature Reaction and Compensation in DC Machines

GOALS

The primary goal is to analyze, model, and mitigate the effects of armature reaction in DC machines using advanced compensation methods. Armature reaction distorts the main field flux, affecting commutation and machine efficiency, especially under varying loads. This study aims to design effective compensation strategies (interpoles, compensating windings, control algorithms) to ensure stable operation in high-demand scenarios such as railways, mining, and automated manufacturing.

Understand Armature Reaction Mechanisms: Study how armature current produces cross-magnetizing and demagnetizing effects that distort the flux distribution in the machine.

Quantify Flux Distortion: Use magnetic field analysis (analytical or FEM-based) to visualize field distortion under load.

Improve Commutation: Implement and test interpole (commutating pole) and compensating winding designs to reduce sparking and ensure smooth commutation.

Enhance Performance: Analyze how compensation improves torque stability, speed regulation, and machine lifespan.

Real-World Integration: Explore how modern industries compensate armature reaction in high-current applications (e.g., electric traction motors, heavy-duty DC drives).

Link Theory to Practice: Use simulation and prototyping to connect magnetic theory with physical machine behavior under various conditions.

Armature reaction is one of the fundamental electromagnetic phenomena affecting DC machine performance. Understanding and compensating it ensures stable, efficient, and reliable operation, especially in demanding environments like transportation and heavy industry**.**

METHODS & TECHNOLOGIES

Methods:

- **Theoretical Analysis:** Use vector diagrams and mmf models to analyze armature reaction components (cross vs demagnetizing).
- **Magnetic Field Simulation:** 2D/3D FEM tools (e.g., ANSYS Maxwell, COMSOL) for flux plotting and air-gap field analysis.
- **Experimental Measurement:** Use digital gaussmeters and oscilloscopes to study flux density and commutator performance.
- **Design & Implementation:**
  - Design **interpoles** aligned with the armature axis.
  - Add **compensating windings** in pole faces to neutralize cross-flux.
- **Performance Comparison:**Analyze speed-torque characteristics and commutation quality before and after compensation.
- **Case-Based Prototyping:** Build or simulate a low-voltage DC motor model with and without compensation systems.

Technologies & Tools:

- **Simulation Tools:** MATLAB/Simulink, ANSYS Maxwell, FEMM
- **Machine Design Software:** JMAG, Motor-CAD
- **Measurement Devices:**Gaussmeter, Oscilloscope, Tachometer
- **Hardware Platforms:** Custom DC motor rig, embedded controllers (Arduino, DSPs for control algorithms)
- **Experimental Setup:** Dynamometer for load testing and commutation analysis

MAJOR AREAS OF INTEREST

The following academic fields and engineering disciplines offer the foundation to understand and design systems that combat armature reaction in DC machines:

Electrical Engineering:

- Provides the core understanding of **electromechanical energy conversion**, **magnetic circuits**, **DC machine design**, and **commutation theory**.
- Topics such as **armature reaction analysis**, **field winding design**, and **machine efficiency** are directly relevant.

Electrical Machines Engineering:

- Offers system-level insight into how **DC machines are integrated** into larger systems like traction, mining, and grid-connected applications.
- Focuses on **reliability, performance under load, and fault conditions**.

Electromagnetic Field Theory:

- Critical for understanding how armature-generated flux **interacts with the main field** and distorts the air-gap field.
- Necessary for **finite element simulations** and magnetic flux optimization.

Mechatronics and Control Systems:

- Integrates motor compensation with **feedback control systems** that dynamically regulate current and flux to improve performance.
- Enables **real-time monitoring and adaptive compensation** using microcontrollers and DSPs.

Instrumentation and Measurement:

- Involves techniques for precise measurement of **magnetic fields**, **current**, **voltage**, and **rotor position**, essential for experimental validation.
- Enables accurate analysis of **commutation quality and flux distortion**.

Simulation and Modeling:

- Involves translating theoretical models into **digital simulations** using tools like MATLAB/Simulink or FEMM.

- Helps in validating the impact of compensation techniques before physical implementation.

EDUCATIONAL OUTCOMES & CROSS-DISCIPLINARY IMPACT

This topic encourages **constructivist, project-based learning**, where students model, simulate, and test real-world performance limitations in DC machines. It builds **interdisciplinary thinking**, linking:

- **Physics** (magnetic interactions),
- **Electrical Engineering** (machine behavior),
- **Software Tools** (simulation, measurement),
- **Control Engineering** (commutation enhancement),
- And **Mechanical Systems** (rotor/stator geometry).

It prepares students for roles in:

- **Electric vehicle design**,
- **Traction and locomotion systems**,
- **Industrial motor drives**,
- And **Power system engineering.**

MENTOR CONTACT INFORMATION

Dr.G.Seshadri
Email: dr.gseshadri@iare.ac.in

PARTNERS & SPONSORS

None

Magnetic Saturation and Hysteresis Effects in Core Materials

GOALS

The primary goal is to investigate how **magnetic saturation and hysteresis** in core materials affect the performance of electrical machines, transformers, and magnetic circuits. These non-linear magnetic phenomena directly influence **efficiency**, **energy loss**, **temperature rise**, and **signal distortion**, especially under high-load and dynamic operating conditions.

- **Understand Magnetic Saturation**: Analyze how increasing magnetic field intensity leads to non-linear B-H characteristics and flux limiting in core materials.
- **Characterize Hysteresis Behavior**: Explore the lag between magnetization and magnetic field variation, leading to hysteresis loss and core heating.
- **Quantify Energy Loss**: Use empirical B-H loop data and analytical models to estimate hysteresis and eddy current losses in various materials (e.g., silicon steel, ferrites).
- **Improve Material Selection**: Evaluate different core materials for specific applications (e.g., high-frequency ferrites in SMPS, silicon steel in transformers).
- **Model Performance Impact**: Link hysteresis and saturation to distorted waveforms, reduced efficiency, and overheating in machines.
- **Real-World Integration**: Examine case studies in transformers, motors, and inductors where core material behavior directly influences industrial performance.

Understanding magnetic saturation and hysteresis is essential for optimizing the **design, material selection**, and **performance prediction** of modern electrical machines and power components.

METHODS & TECHNOLOGIES

Methods:

- **Theoretical Analysis**:
  - Study magnetic hysteresis using Preisach or Jiles-Atherton models.
  - Analyze saturation using B-H curves and core reluctance models.
- **Material Characterization**:
  - Use Epstein Frame or Ring Tester setups to obtain B-H loops experimentally.
  - Measure loss components using wattmeters and temperature sensors.
- **Simulation and Modeling**:
  - Develop models using tools like MATLAB/Simulink, FEMM, or ANSYS Maxwell to simulate core behavior under dynamic flux conditions.
- **Loss Estimation**:
  - Use Steinmetz equation to estimate hysteresis and eddy current losses in transformers and rotating machines.
- **Design Optimization**:
  - Select materials and geometries to minimize saturation and hysteresis effects for target applications.

Technologies & Tools:

- **Simulation Tools**: ANSYS Maxwell, FEMM, COMSOL Multiphysics, JMAG
- **Modeling Platforms**: MATLAB/Simulink, Python (SciPy/Magnetodynamics)
- **Measurement Devices**: B-H loop tracers, Digital power analyzers, Infrared thermometers
- **Material Testing Setups**: Epstein Frame, Single Sheet Testers, Hysteresisgraph systems
- **Hardware Testbeds**: Transformer prototypes, Induction motor rigs with adjustable loads.

MAJOR AREAS OF INTEREST

This topic is relevant to multiple disciplines within electrical and materials engineering:

Electrical Engineering

- Studies the interaction of core behavior with overall circuit/machine performance.
- Includes transformer design, inductor behavior, and magnetic material application.

Materials Science and Metallurgy

- Focuses on magnetic properties of materials, domain theory, and thermal effects.
- Explores alloying, heat treatment, and microstructural effects on hysteresis/saturation.

Power Electronics

- Concerned with the effect of core losses in converters, filters, and high-frequency magnetic components.
- Designs magnetic elements that can operate efficiently under high switching frequencies.

Electromagnetic Field Theory

- Supports accurate modeling of non-linear magnetic behavior in complex field geometries.
- Essential for solving Maxwell's equations with non-linear materials.

Thermal and Mechanical Engineering

- Core losses translate into heat—interdisciplinary insight is needed for thermal management and cooling systems.

Simulation and Design Automation

- Enables accurate modeling of core behavior in simulation environments to aid design decisions and prototyping.

EDUCATIONAL OUTCOMES & CROSS-DISCIPLINARY IMPACT

This topic promotes deep, hands-on learning by combining physics, materials science, and electrical design. Students will:

- Learn to **visualize and analyze B-H loops**, saturation effects, and loss characteristics.

- Simulate **core behavior in real applications**, enhancing analytical and practical skills.
- Develop knowledge of **material selection and testing**, preparing for work in R&D, power engineering, and component design.

Cross-Disciplinary Learning Includes:

- **Physics**: Magnetic properties and domain theory
- **Electrical Engineering**: Transformer/motor efficiency and waveform analysis
- **Thermal Engineering**: Core heating due to hysteresis and eddy currents
- **Software Tools**: Finite Element Simulation and modeling platforms
- **Materials Engineering**: Microstructure-property-performance relationships

Career-Relevant Applications:

- Design of **transformers, motors, inductors, chokes**
- R&D in **magnetic material development**
- Simulation and optimization in **power system modeling**
- Application in **electric vehicles**, **aerospace converters**, and **energy-efficient devices.**

MENTOR CONTACT INFORMATION

Dr.V.C.J.Mohan

Email: dr.vcjmohan@iare.ac.in

PARTNERS & SPONSORS

None

Dynamic Modeling and Simulation of Synchronous Machines

GOALS

The primary goal is to build accurate **dynamic models** of synchronous machines that capture their electrical and mechanical behavior under **transient**, **steady-state**, and **fault conditions**. These models support control system development, performance analysis, and integration into Electrical Machines and microgrids.

- **Understand Machine Dynamics**: Derive and analyze the differential equations governing synchronous machine behavior using d-q axis (Park's) transformation.
- **Model Electrical and Mechanical Systems**: Represent both stator and rotor dynamics (field windings, damper windings, mechanical torque and inertia).
- **Simulate Transient Events**: Study machine response to faults, load changes, synchronization transients, and system disturbances.
- **Validate Control Strategies**: Integrate AVR (Automatic Voltage Regulators) and governors to test dynamic performance and stability.
- **Enable System Integration**: Incorporate machine models into grid simulation for studying power flow, stability, and fault tolerance.
- **Real-World Application**: Analyze how utilities and industries use dynamic models for system planning, stability studies, and controller design in smart grids and large-scale power plants.

This topic connects theoretical modeling with practical power system stability and control, essential for designing reliable and efficient energy systems.

METHODS & TECHNOLOGIES

Methods:

- **Mathematical Modeling**:
  - Use Park's transformation to convert 3-phase models to 2-axis (d-q) form for ease of simulation.
  - Develop nonlinear differential equations representing machine dynamics.
- **Simulation**:
  - Implement dynamic models in MATLAB/Simulink or Python for time-domain analysis.
  - Simulate load perturbations, synchronization, faults, and AVR response.
- **State-Space Representation**:
  - Convert the system into state-space form to analyze stability, eigenvalues, and control response.
- **Parameter Estimation**:
  - Use tests like open-circuit, short-circuit, and step response to extract machine parameters.
- **Controller Integration**:

    - Model excitation systems, turbine governors, and PSS (Power System Stabilizers) to test control performance.
- **Performance Comparison**:
    - Compare dynamic vs steady-state models in terms of accuracy and simulation speed.

Technologies & Tools:

- **Simulation Platforms**: MATLAB/Simulink, PLECS, PSAT (Power System Analysis Toolbox), PSCAD, Python (NumPy/SciPy)
- **Control Design Tools**: Simulink Control Design, MATLAB Control System Toolbox
- **Power System Simulators**: DIgSILENTPowerFactory, ETAP, EMTP-RV
- **Measurement & Validation**: Real-time testbeds using OPAL-RT or dSPACE platforms, phasor measurement units (PMUs).

MAJOR AREAS OF INTEREST

This topic spans across multiple academic fields that deal with electrical machines, dynamic systems, and control:

Electrical Engineering (Power & Machines)

- Provides knowledge of machine operation, equivalent circuits, excitation systems, and control mechanisms.

Control Systems Engineering

- Focuses on modeling dynamic behavior, tuning controllers (PID, LQR), and stability analysis.

Electrical Machines Engineering

- Integrates machine models into grid-level simulations to study frequency stability, transient response, and fault recovery.

Computational Electromagnetics

- Supports accurate modeling of flux dynamics and rotor-stator interactions during transients.

Mechatronics and Automation

Uses dynamic models in high-performance applications like robotic arms, autonomous vehicles, and industrial drives.

Embedded Systems and Real-Time Simulation

- Enables real-time simulation of machine dynamics for hardware-in-the-loop (HIL) testing of control strategies.

EDUCATIONAL OUTCOMES & CROSS-DISCIPLINARY IMPACT

This topic promotes a blend of **analytical modeling**, **simulation proficiency**, and **real-world control design**. Students will:

- Develop dynamic state-space models and simulate transient performance.
- Learn how to tune AVR and speed governors for stable system operation.

- Gain exposure to **real-time simulation platforms** and **digital control implementation**.

Cross-Disciplinary Skills Built:

- **Mathematics**: Differential equations, Laplace transforms, eigenvalue analysis
- **Software Tools**: MATLAB/Simulink, Python, PSCAD
- **Electrical Machines**: Rotor/stator modeling, flux dynamics
- **Control Theory**: Feedback design, observer models
- **Power System Stability**: Grid integration and dynamic response

Career-Ready Applications:

- Power system stability engineer (e.g., grid operators, utilities)
- Electric machine designer (for renewables, ships, aircraft)
- Simulation engineer (digital twins, real-time HIL)
- Developer of synchronous motor drives in industrial and aerospace applications.

MENTOR CONTACT INFORMATION

Dr.L.Rajasekhar Goud

Email: dr.lrajasekhargoud@iare.ac.in

PARTNERS & SPONSORS

None

Design and Optimization of Special Electrical Machines (e.g., BLDC, SRM, Axial Flux)

GOALS

The primary goal is to **design, model, and optimize special types of electrical machines** like **Brushless DC (BLDC) motors**, **Switched Reluctance Motors (SRM)**, and **Axial Flux Machines**, which offer advantages in efficiency, compactness, and torque density for next-generation applications such as **electric vehicles (EVs)**, **drones**, **robotics**, and **renewable energy systems**.

- **Understand Machine Architectures**: Study the unique topologies and working principles of BLDC, SRM, and Axial Flux machines.
- **Optimize Magnetic Design**: Analyze and maximize torque density, efficiency, and thermal management through optimal magnetic circuit and winding design.
- **Simulate Performance**: Create electromagnetic, thermal, and mechanical models to evaluate dynamic behavior, cogging torque, vibration, and noise.
- **Reduce Losses**: Minimize switching, core, and copper losses through topology refinement and control strategies.
- **Enable Advanced Control**: Implement FOC (Field-Oriented Control), Direct Torque Control (DTC), or hysteresis control for precise torque and speed regulation.
- **Real-World Application**: Develop custom motor prototypes and analyze their performance in electric mobility, HVAC systems, and aerospace.

Designing and optimizing these machines is crucial to meet the **lightweight, high-performance, and energy-efficient** requirements of modern electromechanical systems.

METHODS & TECHNOLOGIES

Methods:

- **Topology Analysis**:
  - Study geometry-specific behavior (e.g., double-rotor in axial flux, salient pole in SRM).
  - Compare radial vs axial flux designs based on application-specific constraints.
- **Electromagnetic Modeling**:
  - Use Finite Element Methods (FEM) to evaluate flux distribution, back-EMF, inductance profiles, and magnetic saturation.
- **Thermal Analysis**:
  - Perform loss-based thermal modeling for hotspot prediction and cooling system design.
- **Multi-Objective Optimization**:
  - Apply algorithms (e.g., Genetic Algorithm, Particle Swarm Optimization) to balance trade-offs between size, weight, efficiency, torque ripple, and cost.
- **Control Integration**:
  - Develop sensorless and sensor-based control strategies using PWM inverters, rotor position estimation, and adaptive torque control.
- **Prototype and Test**:

    - Build scaled prototypes and test torque, speed, temperature, and vibration on a dynamometer.

Technologies & Tools:

- **Simulation & Design Tools**:
    - ANSYS Maxwell, JMAG, InfolyticaMotorSolve, FEMM for EM analysis
    - MATLAB/Simulink for dynamic control and system modeling
    - SolidWorks/Creo for CAD and mechanical modeling
- **Control Hardware**:
    - Microcontrollers (TI C2000, STM32), DSPs, FPGAs for real-time control
- **Testing Equipment**:
    - Dynamometer, Thermal cameras, Vibration sensors, Oscilloscopes, Gaussmeters
- **Optimization Tools**:
    - Python (SciPy, DEAP), MATLAB Optimization Toolbox, Altair HyperStudy.

MAJOR AREAS OF INTEREST

This topic connects students with advanced machine design and modern control theory, covering a broad range of engineering domains:

Electrical Engineering (Machines and Drives)

- Focuses on machine modeling, control integration, winding layout, and switching strategies.

Electromechanical Design

- Deals with compact design of motors for lightweight and high-efficiency systems, especially in EVs and drones.

Mechatronics and Robotics

- Utilizes BLDC and SRM motors for precise actuation in robotics, 3D printers, medical devices, and UAVs.

Control Systems Engineering

- Emphasizes torque and speed control, sensorless algorithms, and embedded system development.

Thermal and Mechanical Engineering

- Ensures machine longevity and performance through thermal management, cooling systems, and mechanical stress analysis.

Renewable Energy Systems

- Designs high-torque, low-maintenance motors for wind turbines and solar-powered systems.

EDUCATIONAL OUTCOMES & CROSS-DISCIPLINARY IMPACT

Students undertaking this topic will gain end-to-end experience in **machine design**, **multi-physics simulation**, and **real-time control**. They will:

- Design and simulate high-performance machines tailored for specific applications.
- Learn to use optimization tools to improve multiple performance metrics simultaneously.

- Gain hands-on experience in prototyping and testing using control hardware.

Cross-Disciplinary Skills Built:

- **Physics**: Magnetic circuit theory, reluctance, eddy current loss
- **CAD & FEA**: Design and EM field modeling
- **Programming**: Embedded C, MATLAB, Python for control and optimization
- **Control Theory**: Real-time implementation of advanced control algorithms
- **Thermal Analysis**: Heat generation and dissipation in compact machines

Industry Applications:

- Electric vehicle power trains (Tesla, Ola, Ather, etc.)
- Aerospace actuators and drone propulsion
- Renewable energy systems (e.g., axial flux in wind turbines)
- Industrial automation and robotics.

MENTOR CONTACT INFORMATION

Dr.S.K.Abdul Pasha

Email: dr.skpasha@iare.ac.in

PARTNERS & SPONSORS

None

Speed Control and Drives for AC and DC Machines

GOALS

The primary goal is to explore, model, and implement effective **speed control techniques** for **AC and DC electric machines**, using both classical and modern **power electronic drive systems**. Speed control is essential for achieving desired performance in **industrial automation**, **electric vehicles**, **HVAC systems**, and **robotics**.

- **Understand Machine Characteristics**: Analyze the natural speed-torque characteristics of DC motors, Induction motors, and Synchronous motors.
- **Classify Control Methods**: Study scalar (V/f), vector (FOC), and direct torque control (DTC) for AC machines; and armature, field, and chopper-based methods for DC machines.
- **Design Drive Systems**: Build power electronic interfaces (rectifiers, choppers, inverters) for speed control.
- **Implement Control Algorithms**: Use PID, PI, and advanced control (e.g., Fuzzy, Sliding Mode) to regulate speed and torque.
- **Real-World Integration**: Apply these methods to conveyor belts, cranes, e-bikes, lifts, and CNC machine tools.
- **Compare Performance**: Evaluate the effectiveness of different control techniques under variable loads, speeds, and fault conditions.

A deep understanding of speed control and drives ensures precise, energy-efficient, and reliable motion control in complex electromechanical systems.

METHODS & TECHNOLOGIES

Methods:

- **DC Machine Control**:
  - **Armature Voltage Control** (for below-rated speeds using phase-controlled rectifiers or choppers)
  - **Field Flux Control** (for above-rated speeds using field weakening)
  - **Ward-Leonard System**, **Chopper Drives**, and **Feedback Control** using sensors
- **AC Machine Control**:
  - **Induction Motor Drives**: Scalar (V/f) and Vector (FOC) control
  - **Synchronous Motor Drives**: Brushless operation with permanent magnets and sinusoidal control
  - **Slip Control** and **Rotor Resistance Control** in wound-rotor IMs
- **Simulation**:
  - Develop dynamic models in MATLAB/Simulink for control design and tuning

- **Closed-Loop Feedback**:
    - Implement tachometers, encoders, or Hall sensors for real-time feedback
    - Use control algorithms (PI, PID, Model Predictive Control) for speed regulation

Technologies & Tools:

- **Simulation Platforms**: MATLAB/Simulink, PSIM, LTSpice, Scilab/Xcos
- **Hardware Components**:
    - IGBT-based inverters, SCR-controlled rectifiers, chopper circuits, VFDs
    - Motors: PMDC, separately excited DC, squirrel-cage IM, PMSM
- **Control Hardware**:
    - Microcontrollers (STM32, Arduino, TI C2000), DSPs, and FPGA-based drives
- **Sensors**:
    - Hall-effect sensors, encoders, tachometers for speed/position sensing
- **Lab Equipment**:
    - Dynamometers, Oscilloscopes, Power analyzers, Current probes for testing.

MAJOR AREAS OF INTEREST

This topic spans multiple engineering disciplines related to machines, automation, and embedded systems:

Electrical Engineering (Machines & Drives)

- Focuses on the principles of energy conversion, drive design, and speed-torque analysis.

Power Electronics

- Enables the hardware interface for speed control using controlled converters and inverters.

Control Systems Engineering

- Emphasizes real-time feedback control, algorithm design, and closed-loop tuning.

Mechatronics and Robotics

- Integrates machine speed control into robotic arms, mobile robots, CNC machines, and servo systems.

Embedded Systems Engineering

- Implements the control logic on real-time platforms like microcontrollers and FPGAs.

Industrial Automation

- Applies drive control in process control systems, assembly lines, and material handling.

EDUCATIONAL OUTCOMES & CROSS-DISCIPLINARY IMPACT

This topic blends **electromechanical design**, **control systems**, and **embedded implementation**, promoting hands-on and interdisciplinary learning. Students will:

- Learn practical methods to control and regulate speed in motors for different applications.
- Simulate and compare performance of different control strategies and drive circuits.
- Implement controllers in real-time using microcontrollers or DSPs.

Cross-Disciplinary Skills Built:

- **Electrical Machines**: Understanding speed-torque behavior and control principles
- **Power Electronics**: Building converters and selecting drive topologies
- **Control Systems**: Tuning and implementing dynamic feedback loops
- **Programming**: Writing embedded C or Simulink code for real-time control
- **Testing & Instrumentation**: Measuring performance parameters like speed, current, efficiency

Career-Relevant Applications:

- Motor control engineer in automotive (EV drive systems)
- Automation specialist for industrial plants
- Drive system designer for HVAC, cranes, elevators
- Embedded control developer for robotic platforms and drones

MENTOR CONTACT INFORMATION

Mr G.Viswanadh
Email: g.viswanadh@iare.ac.in

PARTNERS & SPONSORS

None

Transients and Switching Surges in Transformers and Induction Motors

GOALS

The primary goal is to analyze, simulate, and mitigate the impact of **electromagnetic transients and switching surges** in **transformers** and **induction motors**, which occur during energization, de-energization, faults, and load variations. These transients can lead to **insulation stress**, **mechanical vibrations**, **core saturation**, and **nuisance tripping**, affecting the lifespan and reliability of the equipment.

- **Understand Transient Phenomena**: Study the origin, types, and propagation of transients caused by switching operations, faults, lightning, and load changes.
- **Characterize Equipment Response**: Analyze how transformers and motors react to voltage spikes, inrush currents, and resonance.
- **Simulate Switching Events**: Use digital simulation tools to model time-domain waveforms under normal and abnormal switching conditions.
- **Identify Harmful Effects**: Explore insulation failure, torque pulsations, noise, and heating due to transients.
- **Develop Protection Strategies**: Implement snubber circuits, surge arresters, pre-insertion resistors, and controlled switching.
- **Real-World Relevance**: Examine case studies from power utilities and industries where transients caused unexpected shutdowns or equipment failures.

Studying these effects is essential for ensuring **reliable**, **safe**, and **cost-effective operation** of electrical Electrical Machines and industrial motor drives.

METHODS & TECHNOLOGIES

Methods:

- **Theoretical Analysis**:
  - Study transformer energization transients, ferroresonance, and inrush currents using equivalent circuits.
  - Model motor starting and stopping behavior including transient torque and current surges.
- **Simulation Techniques**:
  - Use EMTP, PSCAD, or MATLAB/Simulink to simulate switching events, breaker operations, and load changes.
- **Transient Recording and Measurement**:
  - Capture high-frequency waveforms using Digital Fault Recorders (DFR), Oscilloscopes, and Rogowski coils.
- **Frequency Analysis**:
  - Analyze harmonic content and resonance using FFT and spectrum analysis.
- **Design Solutions**:

    - Apply controlled switching (zero-voltage or zero-current), core pre-magnetization, and surge suppression methods.

Technologies & Tools:

- **Simulation Platforms**: PSCAD, EMTP-RV, MATLAB/Simulink, ANSYS Simplorer
- **Measurement Instruments**: Oscilloscopes, Power Quality Analyzers, Transient Recorders
- **Protection Devices**:
    - Surge Arresters (ZnO type), MOVs, Snubber Circuits
    - Pre-insertion resistors and synchronous closing relays
- **Switching Equipment**: SF6 breakers, vacuum interrupters with pre-triggering
- **Motor Starters**: Soft-starters, VFDs with controlled ramp-up and ramp-down.

MAJOR AREAS OF INTEREST

This topic intersects multiple fields concerned with power quality, insulation coordination, and motor behavior:

Electrical Power Engineering

- Involves modeling and mitigation of transient effects in power system equipment and networks.

High Voltage Engineering

- Addresses insulation coordination, surge handling, and dielectric stress due to switching surges.

Machine Dynamics

- Explores mechanical torque oscillations and winding stress in motors during transients.

Electromagnetic Field Theory

- Models transient magnetic field behavior in transformer cores and motor stators during inrush or switching.

Power Electronics and Drives

- Studies the impact of power electronic converters on motor transients and switching harmonics.

Protective Relaying and System Stability

- Designs protection schemes to detect and isolate transient-induced faults.

EDUCATIONAL OUTCOMES & CROSS-DISCIPLINARY IMPACT

This topic equips students to understand and manage transient events in practical settings, combining **simulation**, **hardware analysis**, and **protection engineering**. They will:

- Simulate and visualize transient conditions in transformers and motors.
- Learn to select and design appropriate mitigation and protection systems.
- Analyze field data to diagnose the cause and severity of switching surges.

Cross-Disciplinary Learning Includes:

- **Electrical Machines**: Reaction of windings and magnetic cores to fast-changing fields
- **Power Systems**: Grid-wide transient behavior and impact on neighboring loads
- **High Voltage Insulation**: Dielectric breakdown risk and protection coordination
- **Instrumentation**: High-speed recording and waveform analysis
- **Power Quality**: Harmonics, notching, and voltage sags/surges

Industry-Relevant Applications:

- Utility substation design and transformer commissioning
- Industrial motor startup analysis (pumps, compressors)
- Railway traction and heavy load switching systems
- Renewable integration with smart grid (e.g., wind turbine transients)

MENTOR CONTACT INFORMATION

Dr.Damodhar Reddy
Email: dr.damodharreddy@iare.ac.in

PARTNERS & SPONSORS

None