



# **Research Methodology and Practical Implementation**

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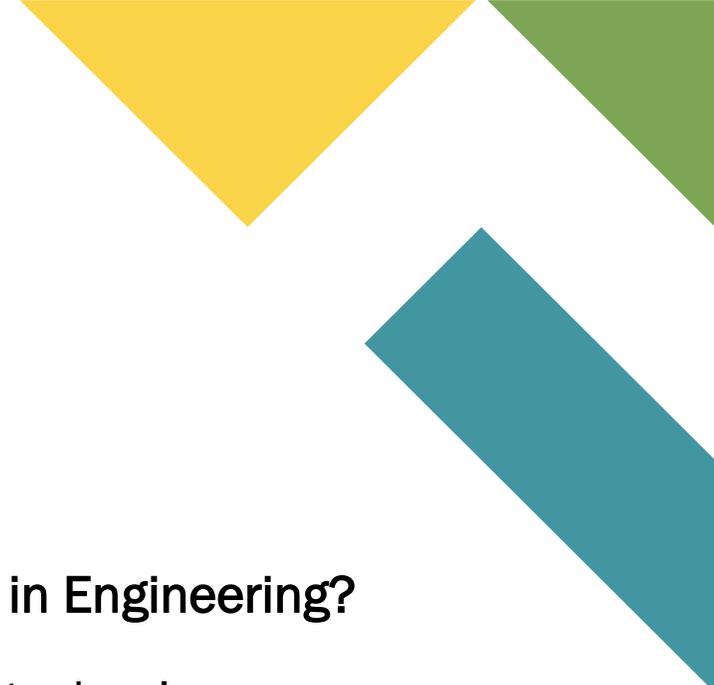
# Agenda



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- Introduction to Research
- Types of Research and Methodological Approaches
- Selecting a Research Topic and Formulating the Research Question
- Research Design and Choosing the Appropriate Methodology
- Data Collection Tools and Analytical Techniques
- Research Ethics and Referencing
- Final Q&A and Open Discussion

# Introduction to Research



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## What is Research?

- Systematic process of inquiry
- Aimed at discovering, interpreting, or revising facts and theories
- In engineering: solving real-world problems using scientific methods

## Why is Research Important in Engineering?

- Enables innovation and technology advancement
- Improves systems, products, and processes
- Supports evidence-based decision-making
- Bridges theory and real-world applications
- Drives sustainable and cost-effective solutions

# Introduction to Research



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## Forms of Engineering Research

- **Theoretical Research:** Mathematical modeling, simulations
- **Experimental Research:** Lab-based, prototype testing
- **Applied Research:** Solving industrial or societal problems
- **Design Research:** Creating and optimizing systems, tools, or products

## Who Does Engineering Research?

- Undergraduate students (senior projects)
- Graduate students (MSc/PhD theses)
- Faculty members and researchers
- Industry professionals (R&D departments)

# Introduction to Research



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## Benefits of Doing Research for Engineers

- Enhances problem-solving and critical thinking
- Opens opportunities in academia and R&D
- Builds professional reputation and networks
- Enables contribution to national goals (e.g., Vision 2030)
- Develops communication and documentation skills

## Common Areas of Engineering Research

- Power and Energy Systems
- Renewable Energy Integration
- Smart Grids and Automation
- Electronics and Embedded Systems
- Control Systems
- Materials and Manufacturing
- Sustainable Infrastructure

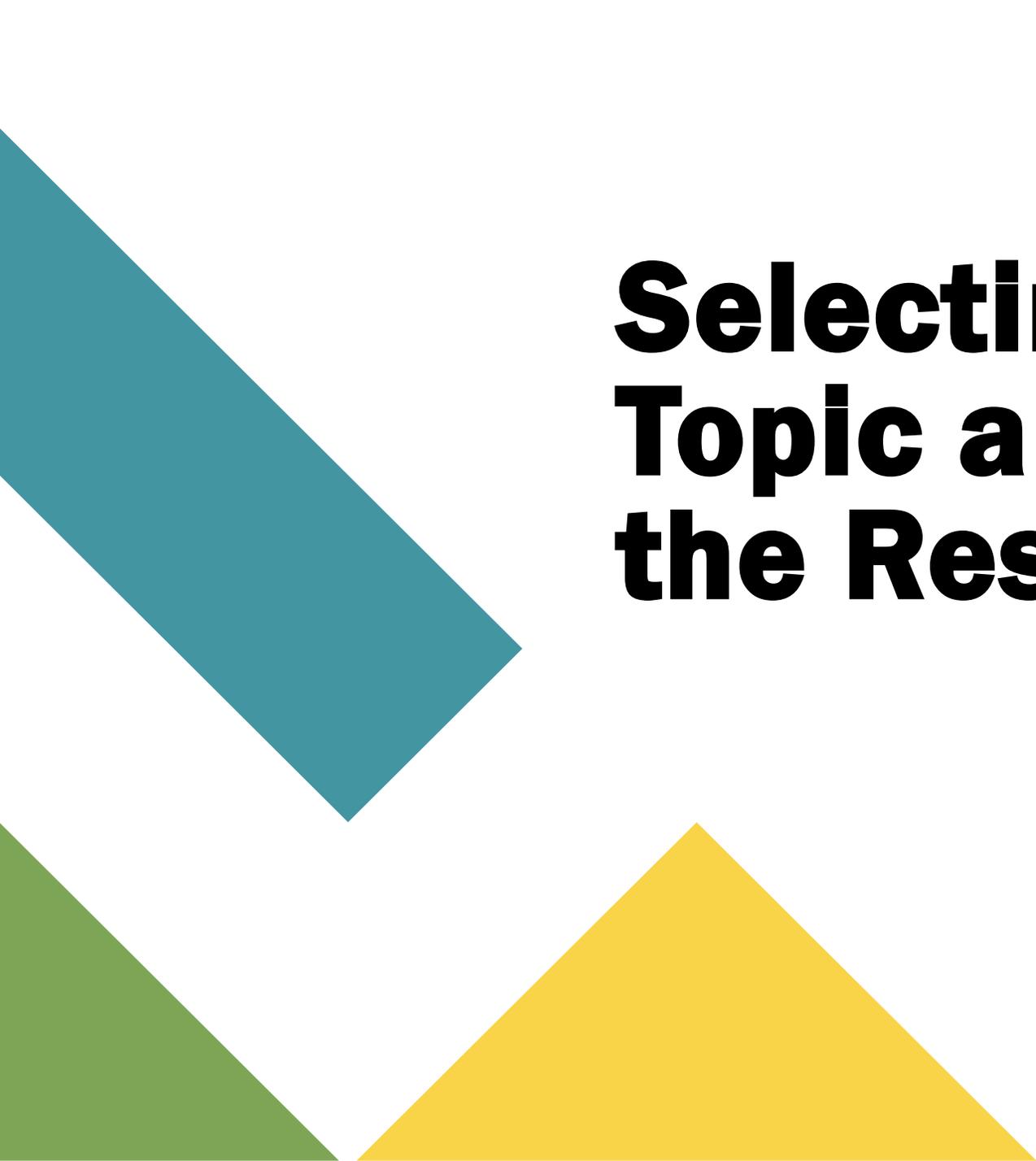
# Introduction to Research



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## Barriers to Research (and How to Overcome Them)

- Lack of time → Plan early and integrate with coursework
- Lack of resources → Collaborate with labs or faculty
- Fear of failure → Research is about learning, not perfection
- Lack of topic ideas → Explore recent publications and real problems



# Selecting a Research Topic and Formulating the Research Question

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- Where to begin your research journey
- From ideas to focused questions

# Why Choosing the Right Topic Matters

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- It defines the scope and direction of your research
  - Impacts your motivation and commitment
  - A good topic solves a real problem or fills a knowledge gap
  - The topic should align with your interests and available resources
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# Choosing the Right Topic



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## Sources of Research Topics

- Academic coursework and lecture notes
- Final year/senior design projects
- Recent journal articles and conference papers
- Industry challenges and real-world problems
- Discussions with professors or professionals
- National priorities (e.g., Saudi Vision 2030)

## Characteristics of a Good Research Topic

- Clear and specific
- Relevant to your field
- Original or adds a new perspective
- Feasible (time, resources, skills)
- Contributes to knowledge or solves a problem

# From Topic to Research Question

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- **Topic:** General area of interest
- **Problem Statement:** What's the issue or gap?
- **Research Question:** A focused question your research aims to answer

## Example:

- Topic: Power Quality in Renewable Energy Systems
- Problem: Voltage fluctuations reduce system stability
- Research Question: How can dynamic voltage control improve power quality in PV-connected systems?

# Types of Research Questions

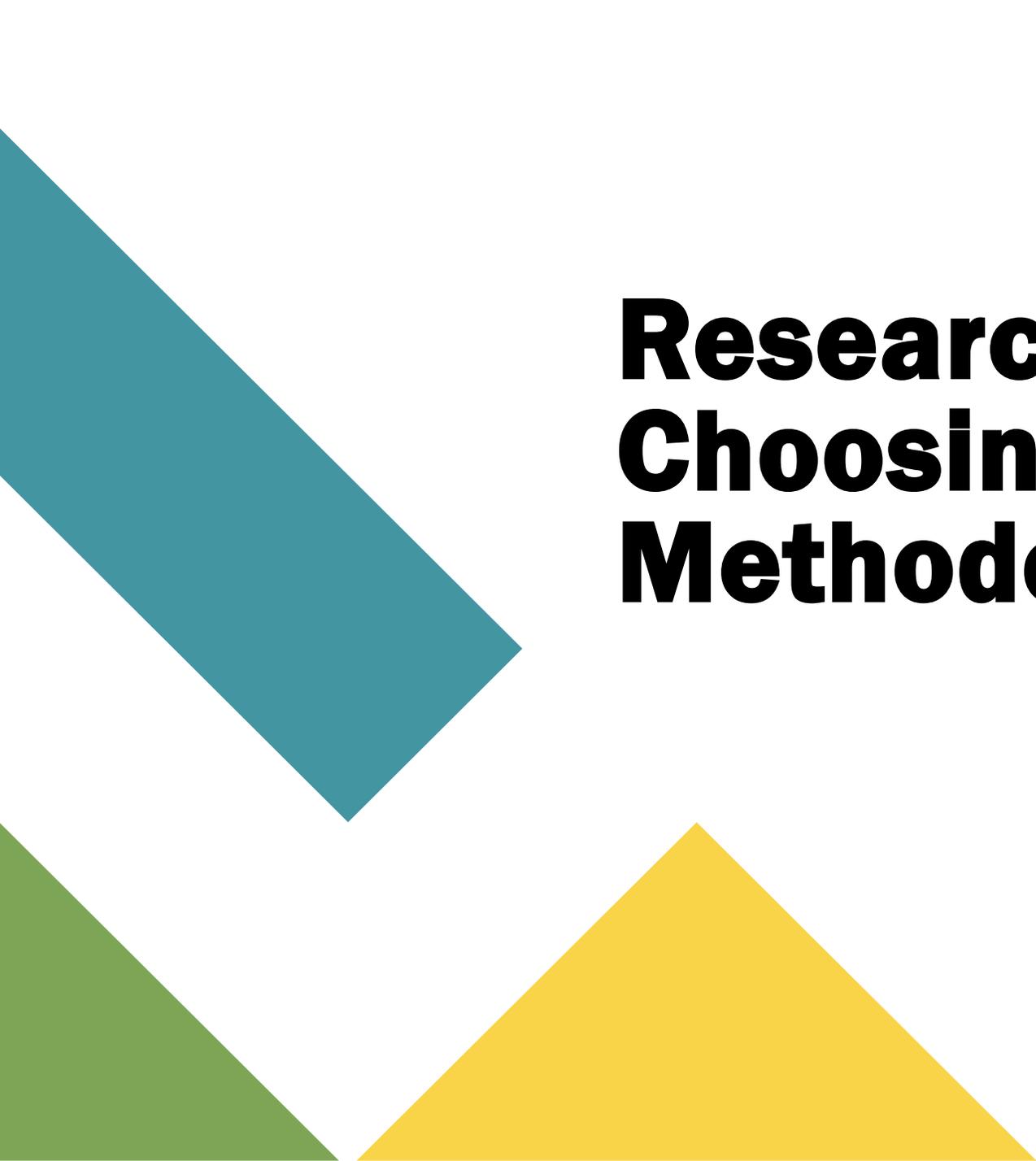
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- **Descriptive:** What is happening?
- **Comparative:** Which method performs better?
- **Causal:** What causes this effect?
- **Design-Oriented:** How to build a better system?

# Common Mistakes in Research Topic Selection

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- Too broad or too narrow
- Not researchable or measurable
- Not aligned with field or interest
- Lacks practical or scientific value
- Duplicating existing research without novelty

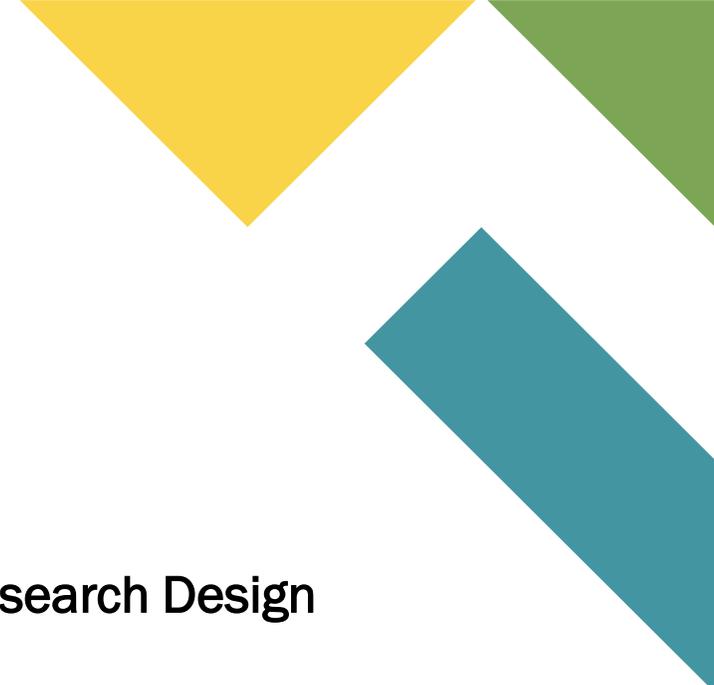


# Research Design and Choosing the Appropriate Methodology

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- How to structure your research
- Matching the design with the problem and purpose

# Research Design



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## What is Research Design?

- The **blueprint** for conducting a research study
- Describes how to collect, measure, and analyze data
- Ensures **validity, reliability, and accuracy**
- Helps avoid bias and confusion during execution

## Key Components of Research Design

1. Research Objectives
2. Variables and Parameters
3. Data Sources and Collection Methods
4. Sampling (if applicable)
5. Data Analysis Plan
6. Timeline and Resources

# Common Types of Research Design

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Type	Description	Example
<b>Descriptive</b>	Describes characteristics or conditions	Survey on students' energy usage habits
<b>Correlational</b>	Explores relationships between variables	Link between load type and voltage drop
<b>Experimental</b>	Manipulates variables to test effects	Test effect of filter type on harmonic distortion
<b>Simulation-Based</b>	Uses software to replicate system behavior	Simulating fault response using MATLAB

# Choosing the Right Design

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- Depends on:
  - The **research question**
  - The **type of data** available
  - **Timeframe** and **resources**
  - Desired **depth and accuracy**
- Sometimes **mixed designs** are appropriate
- **Avoiding Poor Design Practices**
  - ✗ Unclear objectives
  - ✗ No link between question and method
  - ✗ Ignoring validation
  - ✗ Inadequate sample size or simulation setup

# Research Design



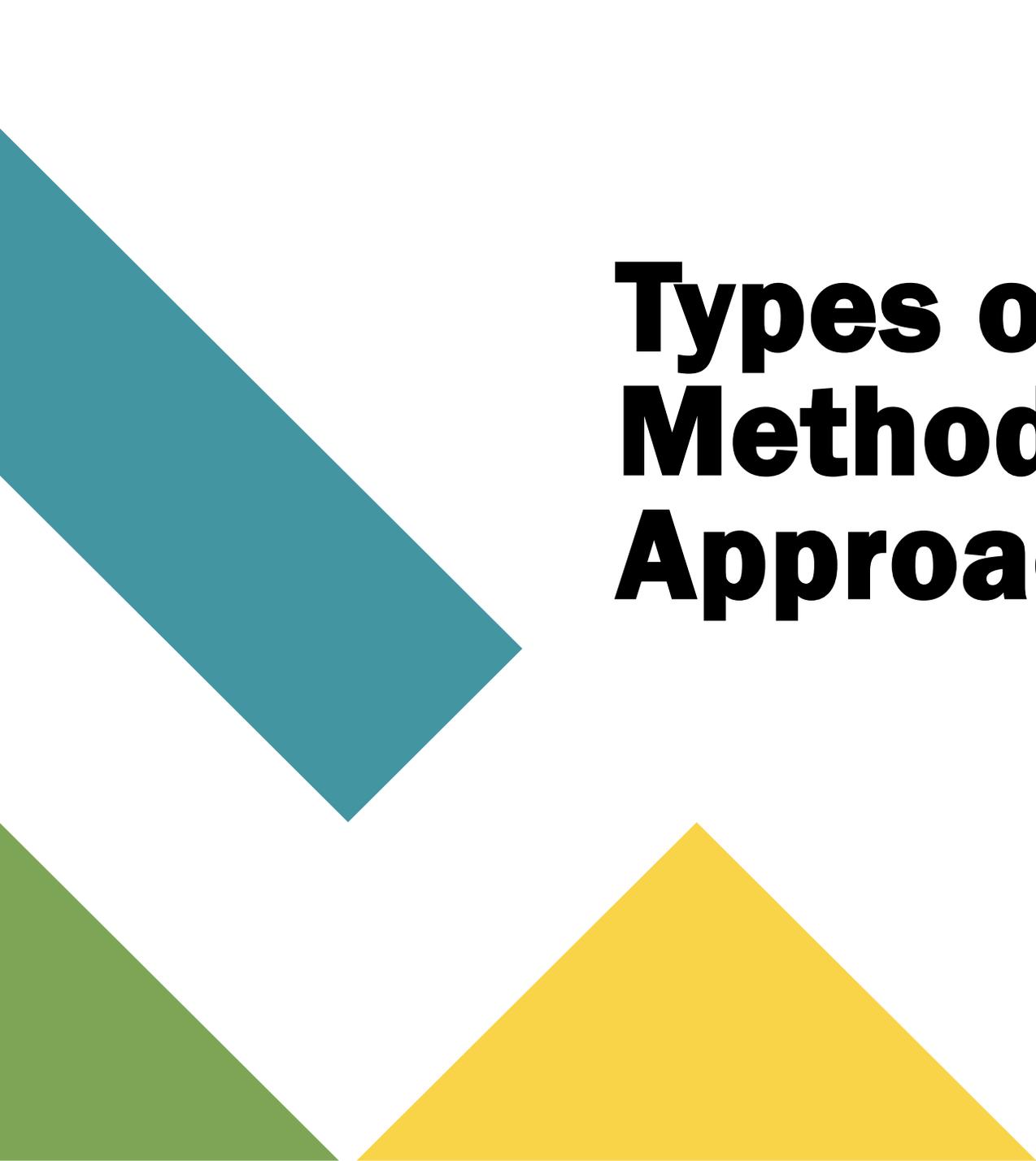
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## Methodology vs. Methods

- **Methodology:** The overall approach/philosophy of the research
- **Methods:** The actual tools and techniques used
- Example:
  - Methodology = Quantitative
  - Methods = Survey, Statistical Analysis

## Examples of Methodology Use

- **Quantitative + Experimental:**  
Measure THD before/after adding active filter
- **Qualitative + Descriptive:**  
Interview engineers about their maintenance practices
- **Simulation + Analytical:**  
Simulate fault current response in power grid



# Types of Research and Methodological Approaches

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- Understanding different types of research in engineering
- How to choose the right research methodology

# Types of Research



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## Basic Classification of Research Types

1. Basic (Theoretical) Research
2. Applied Research
3. Developmental (Design-based) Research

## Choosing the Right Research Type

- What is the **research problem**?
- Is the goal to **understand, solve, or build**?
- Are you working with **real data, models, or users**?
- What resources are available (labs, software, tools)?

# Types of Methodologies



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## Methodological Approaches in Engineering Research

1. Quantitative Research
2. Qualitative Research
3. Mixed-Methods Research
4. Experimental Research
5. Simulation-Based Research
6. Analytical Research

# Comparison between Methodologies

Type	Purpose	Data Type	Tools/Methods Used	Typical Output	Example
Quantitative Research	Measure variables, test hypotheses	Numerical	Surveys, sensors, simulations, statistical tools	Graphs, statistics, trends	Measuring voltage drop across different cable lengths
Qualitative Research	Explore perceptions, behaviors, or experiences	Textual/Descriptive	Interviews, focus groups, observation	Themes, patterns, conceptual understanding	Interviewing engineers about challenges in maintenance
Mixed-Methods Research	Combine numeric data with context or interpretation	Both numerical & textual	Surveys + interviews, experiments + open feedback	Integrated findings	Studying user behavior with data logging and interviews
Experimental Research	Test cause-effect relationships	Numerical	Controlled lab experiments	Performance metrics under controlled changes	Testing power loss before and after using a voltage regulator
Simulation-Based	Model complex systems and scenarios	Virtual/Numerical	MATLAB, Simulink, PSCAD	Simulated performance data	Simulating grid faults under varying PV conditions
Analytical Research	Solve problems using theoretical or mathematical tools	Symbolic/Mathematical	Equations, modeling, optimization techniques	Equations, derivations, graphs	Deriving power factor correction formula



# **Data Collection Tools and Analytical Techniques**

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# Data Collection



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## Why Data Collection Matters

- Data drives results and conclusions
- Poor data = misleading findings
- Ensures validity and reproducibility
- Helps answer the research question accurately

## Considerations When Collecting Data

- Accuracy and calibration of instruments
- Sampling rate and frequency
- Environmental conditions
- Data recording format and backup
- Ethics and consent (if involving people)

# Data Collection

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## Types of Data in Engineering Research

- **Primary Data:** Collected firsthand by the researcher (e.g., experiments, surveys, measurements)
- **Secondary Data:** Already existing data from reports, literature, standards, etc.

## Common Data Collection Tools

- **Sensors and Measuring Instruments** (e.g., voltmeter, oscilloscope)
- **Simulation Software** (e.g., MATLAB/Simulink, PSCAD)
- **Surveys and Questionnaires** (for user behavior or system usage)
- **Experiments and Lab Setups**
- **Observation Logs and Field Notes**

# Data Analysis



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## Common Analytical Techniques in Engineering:

- **Statistical Analysis** (mean, standard deviation, regression)
- **Fourier Analysis** (for signals and harmonics)
- **Time-Domain vs Frequency-Domain Analysis**
- **Root Mean Square (RMS) Calculations**
- **Error Analysis and Uncertainty Estimation**
- **Simulation Validation and Result Comparison**

## Tools for Data Analysis:

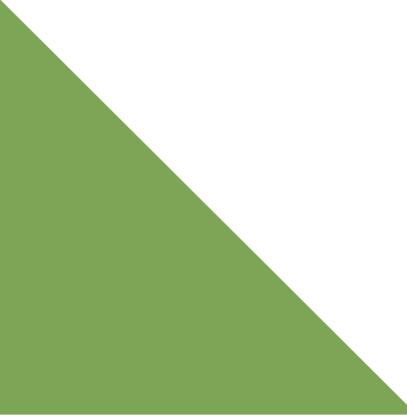
- **MATLAB** – Signal processing, simulations
- **Excel** – Quick statistical summaries
- **Python** – Flexible and powerful for big data
- **Origin, SPSS** – Advanced statistical tools
- **ETAP / DigSILENT** – Electrical system analysis

# Data Presentation



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- Use graphs, tables, and charts
- Label clearly: units, axes, legends
- Highlight key trends and anomalies
- Avoid clutter and overcomplication



# **Case Example in Engineering Research**

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# Case Study: Analyzing the Effect of Cable Length on Voltage Drop in Low-Voltage Residential Circuits

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## First: Research Problem

- Voltage drop is a common issue in residential circuits
- Long cable runs cause significant voltage reduction
- This may damage appliances or reduce efficiency

## Second: Research Question & Objectives

**Question:** How does cable length affect voltage drop in a single-phase 230V circuit?

### Objectives:

- Measure voltage drop across different cable lengths
- Compare results with standard allowable limits
- Recommend cable sizing guidelines for residential design

# Case Study: Analyzing the Effect of Cable Length on Voltage Drop in Low-Voltage Residential Circuits

## Third: Methodology

- **Type:** Experimental Research
- **Setup:** Power supply → Cable (varied lengths) → Load (lamp or resistive heater)
- **Measurement:** Voltage at source and at load using multimeter
- **Data Points:** Cable lengths = 5m, 10m, 20m, 30m

## Forth: Results

Cable Length (m)	Voltage at Source (V)	Voltage at Load (V)	Voltage Drop (V)
5	230	229.6	0.4
10	230	228.8	1.2
20	230	226.5	3.5
30	230	224.0	6.0

# Case Study: Analyzing the Effect of Cable Length on Voltage Drop in Low-Voltage Residential Circuits

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## Fifth: Analysis and Interpretation

- Voltage drop increases **nonlinearly** with cable length
- Exceeds recommended limits (3-5%) at 20m+
- Need for **thicker cables** or **shorter runs** in real installations

## Sixth: Practical Recommendations

- For lengths >15m, increase cable size
- Use voltage drop calculators in design
- Follow IEC or local electrical standards
- Educate homeowners and electricians on proper cable sizing



# Research Ethics and Referencing

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- Understanding integrity in research
- Citing sources and avoiding plagiarism

# Research Ethics



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## What is Research Ethics?

- Set of principles guiding responsible research conduct
- Ensures respect for people, data, and intellectual property
- Promotes trust, credibility, and reproducibility

# Research Ethics



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## Core Ethical Principles

- **Honesty:** Report data truthfully
- **Integrity:** Avoid manipulation or selective reporting
- **Confidentiality:** Protect private or sensitive data
- **Respect:** Acknowledge all contributors
- **Responsibility:** Follow university and institutional guidelines

## Research Misconduct Examples

- ✗ Fabricating data
- ✗ Falsifying results
- ✗ Ignoring ethical review
- ✗ Self-plagiarism (reusing your own published work without mention)

# Plagiarism

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## What is Plagiarism?

- Using someone else's work or ideas without proper credit
- Includes:
  - Copy-paste without citation
  - Paraphrasing without acknowledgment
  - Submitting someone else's work as your own

## How to Avoid Plagiarism

- Always cite your sources
- Use quotation marks when copying directly
- Paraphrase properly and still cite
- Use plagiarism detection tools (e.g., Turnitin, Grammarly)
- Keep track of references during research

# Referencing

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## Referencing Styles in Engineering

- **IEEE** (most common in electrical/engineering fields)
- **APA, MLA, Chicago** (used in interdisciplinary contexts)
- Each style has its own format for:
  - In-text citations
  - Bibliography or reference list

## Tools for Referencing

- **Zotero** – Free, integrates with browsers and Word
- **Mendeley** – Widely used reference manager in academia
- **EndNote** – Professional (paid) tool with advanced features
- **CiteThisForMe / EasyBib** – Quick online reference generators
- **Turnitin / Grammarly** – Tools to detect plagiarism and check citations

# Referencing

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- IEEE Style (*Engineering Standard*)

In-text: [1]

Reference:

[1] S. F. Al-Gahtani, "Voltage compensation...", *J. Power Electron.*, 2022.

- APA Style (*Interdisciplinary*)

In-text: (Al-Gahtani, 2022)

Reference:

Al-Gahtani, S. F. (2022). *Journal of Power Electronics*, 22(3), 345–352.

# Referencing

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- **MLA Style**

**In-text:** According to Al-Gahtani...

**Reference:**

Al-Gahtani, Saad F. "Voltage Compensation..." *Journal of Power Electronics*, 2022.

- **Chicago Style**

**In-text:** ...discussed in recent literature<sup>1</sup>

**Footnote:**

- Saad F. Al-Gahtani, "Voltage Compensation...", *J. Power Electronics*, 2022.



# Final tips & Remarks

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- Understanding integrity in research
- Citing sources and avoiding plagiarism

# Final tips & Remarks

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## Tips from Experience

- Start simple, but be systematic
- Choose a problem that matters to you
- Don't hesitate to ask for help or guidance
- Research is not perfect—iteration is part of the process
- Document everything, even failed trials

## Closing Remarks

- Research is a journey of curiosity, patience, and discovery
- As future and current engineers, your contribution can solve real-world problems
- Keep exploring, asking, and experimenting
- You don't need to be perfect—just committed

**Thank you**

