Power & Energy Management-II or Algorithms for Power Grid -II

Spring 2025-26 — Power System Optimization

Annotated Version.

Instructor: Parikshit Pareek

Department of Electrical Engineering,
IIT Roorkee

Lecture 0: Course Logistics & Overview

Logistics

We will be covering: **Optimization Algorithms applied to Power Systems**

- Instructor: Parikshit Pareek (pareek@ee.iitr.ac.in)
- Teaching Assistant: Ayushi Jolotia (ayushi_j@ee.iitr.ac.in)
- Course Website: https://psquare-lab.github.io/teaching/course_EET110/

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- **Tools:** Python (Pyomo/Pandapower) or Julia (JuMP/PowerModels.jl).

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- **Tools:** Python (Pyomo/Pandapower) or Julia (JuMP/PowerModels.jl).
- **Philosophy:** "Math First, Grid Second." We learn the algorithm (LP/MILP/NLP), then we solve the grid problem. Then move to ML Proxies for Optimization
- **Discussions:** Piazza; Use class hours effectively for office hours too.

Prerequisites

- **Optimization:** Linear Algebra (Matrices, Eigenvalues), Calculus (Gradients, Hessians).
- **Power Systems:** EET-109+ Power Systems I and II
- **Coding:**

  Proficiency in **Python** or **Julia** is non-negotiable.
  We will use solvers like Gurobi, IPOPT, and HiGHs.
  But I will not cover these in class/discussion.

→ piazza

Evaluation Policy (Tentative)

Type	CWS+PRE+PRS	Mid Term	End Term
Total Marks	50	20	30
Components	Lab Assignments (20) Term Paper / Project (30)	Exam	Exam

– **Note:** Term paper will have spill over effect in Mid and End Terms

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The Lab Assignments (Coding Tasks):

- Lab 1: Linear Programming (Dispatch)
- Lab 2: MILP (Unit Commitment)
- Lab 3: NLP (AC-OPF)
- Lab 4: Relaxations (SOCP/SDP)
- Lab 5: ML Proxy for Optimization

– **Warning:** Plagiarism in code will result in an immediate **Zero**.

– **Homework Policy:** No Submission Needed; Part of Syllabus

Course Roadmap

- ➢ **Module 1: Optimization Foundations**
  - ✓ Linear Programming (Simplex, Duality, Shadow Prices)
  - ✓ Mixed Integer Linear Programming (Branch & Bound)
  - ✓ Nonlinear Programming (KKT Conditions, Newton-Raphson)

Course Roadmap

- **Module 1: Optimization Foundations**
  - ✓ Linear Programming (Simplex, Duality, Shadow Prices)
  - ✓ Mixed Integer Linear Programming (Branch & Bound)
  - ✓ Nonlinear Programming (KKT Conditions, Newton-Raphson)
- **Module 2: Transmission System Applications**
  - ✓ DC-OPF, Economic Dispatch, & Markets (LMPs)
  - ✓ Unit Commitment (Generator Scheduling)
  - ✓ AC-OPF (The Non-convex Physics)

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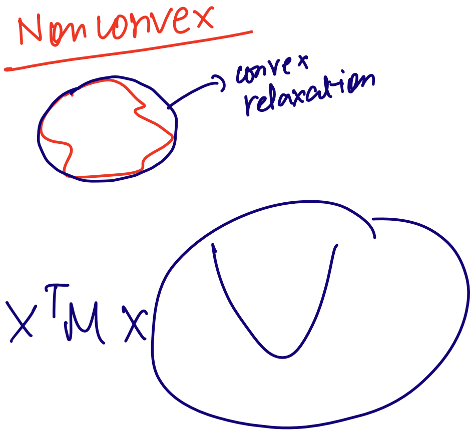
- **Module 3: Advanced Architectures**
  - ✓ Convex Relaxations (SOCP, SDP)
  - ✓ ML Proxies for Optimization

semi definite prog.

Second order cone

Research Papers



Textbooks and References

Course Material

There is **no required textbook** for this class. Will share these slides.

Reference Books:

- **S. Boyd and L. Vandenberghe.** *Convex Optimization.* Cambridge University Press, 2004.

  Available for free: stanford.edu/∼boyd/cvxbook/

- **H.P. Williams.** *Model Building in Mathematical Programming*, 5th Edition. Wiley, 2013.

Designing Your Term Paper: 3 Paths

I will not give a topic

→ Earliest

Path A: The Replicator

"Verify the Truth"

- Pick a top-tier paper (IEEE TSG, TPWRS) from last 5 years.
- Re-implement their formulation.
- Reproduce their results on the same test system.

Designing Your Term Paper: 3 Paths

Qualify & Quantify

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Path B: The Improver

"Make it Faster/Better"

paper taken

- Take a standard problem (e.g., Unit Commitment).
- Apply a new technique (e.g., Decomposition, ML-accelerated warm start).
- Compare computation time vs. standard solvers.

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Publication

↑ Hardest

Path C: The Explorer

"New Constraints"

- Add a **new** physical constraint to OPF Eg. EV Fleets or **new way** to add a contraint
- Formulate the math and solve.
- Build ML Proxy or ML-embedded Optimization to solve better

Deliverable: Usable Code Repo + Comparison Plots + Clean Report + Slides.

Notebook

Teams: 1-5 Members; Ayushi will share a Google Form; finish it before Next Week's class.

Term Paper: Timeline & Deliverables

Week	Milestone	Requirement
Week 4	**Proposal**	1-page abstract + Selected "Base Paper".
Week 8	**Update**	Mathematical Formulation finalized (LaTeX).
Week 10	**Code Check**	Working Code (In a Notebook; Will be made public)
Week 12	**Final**	Final Report + 10 min Presentation.

Flow chart

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Abstract & Report

Abstract: One page having brief intro and objectives

Final Report: IEEE Journal Format: 6 Page. max

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Grading Criteria:

- **Reproducibility (40%):** Can I run your code and get your graphs?
- **Complexity (30%):** Did you just run DC-OPF, or did you try something hard?
- **Clarity (30%):** How well is the math explained in the report & presentation?

Resources for Term Paper

- **Datasets:**
  - MATPOWER / PGLib-OPF (Standard IEEE Grids).
  - Pecan Street (Load Data).
  - NREL (Solar/Wind profiles).
- **Literature:**
  - IEEE Transactions on Power Systems (TPWRS).
  - IEEE Transactions on Smart Grid (TSG).
  - arXiv: `eess.SY` (Systems and Control).
  - ICML, ICLR, NeurIPS etc top ML conferences

  IEEE Trans. sustainable Energy

  Applied Energy
- **Tools:**
  - PowerModels.jl (The Gold Standard for Power System Research).
  - Pandapower (Python-based).

Questions?

”Civilization depends on the grid. The grid depends on optimization.”