AI Applications in Power System Stability Studies and Unit Commitment

7th Semester

Introduction

- Stability studies and unit commitment are critical in power system operation.
- Traditional methods: Numerical optimization, differential equation solvers.
- Challenges: Complexity, uncertainty, renewable integration.
- AI offers fast, adaptive, and intelligent decision-making.

Power System Stability Basics

- Stability: Ability of the system to maintain synchronism and voltage.

Types:

- Rotor Angle Stability
- Voltage Stability
- Frequency Stability

- Traditional approaches: Time-domain simulations, Lyapunov methods.

Role of AI in Stability Studies

- AI can predict stability margins faster than simulations.
- AI techniques used:
  - Neural Networks (ANN)
  - Fuzzy Logic
  - Reinforcement Learning

Applications:

- Predicting transient stability.
- Adaptive protection and control.
- Early warning systems for instability.

Example: ANN in Stability Studies

- ANN trained on historical fault and disturbance data.
- Predicts system stability after fault within milliseconds.
- Replaces time-consuming time-domain simulations.
- Real-life: Used in online stability monitoring tools in smart grids.

Unit Commitment Basics

Objective: Decide which generating units to turn ON/OFF and at what levels.

- Constraints:
  - Load demand balance
  - Minimum up/down times
  - Ramp rate limits
  - Reserve requirements
- Traditional methods: Mixed-Integer Programming, Dynamic Programming.

Role of AI in Unit Commitment

- AI handles uncertainty and complexity better than classical methods.
- Techniques:

- Genetic Algorithms (GA)
- Particle Swarm Optimization (PSO)
- Reinforcement Learning (RL)

Benefits:

- Reduced computation time
- Improved handling of renewables
- Adaptive scheduling.

Example: GA in Unit Commitment

- GA optimizes unit schedules by mimicking natural selection.
- Finds near-optimal solutions where classical methods struggle.
- Example: GA-based UC reduces cost and improves reliability in renewable-integrated grids.

Real-life Applications

- Smart Grids: AI-based predictive stability analysis.
- Renewable Integration: AI ensures stability under fluctuating wind/solar.
- Market Operations: AI-based UC reduces cost and increases efficiency.
- Micro-grids: RL optimizes unit commitment with storage and demand response.

Case Study: AI for Unit Commitment in Renewable-rich Systems

- Problem: Renewable variability complicates UC decisions.
- AI Solution: PSO-based UC handles uncertainty in demand and generation.
- Outcome: Reduced operating costs, improved renewable utilization, higher reliability.

Future Directions

- Hybrid AI models for stability + UC.
- Integration of AI with IoT-enabled grids.
- Edge AI for real-time stability control.
- AI in decentralized energy markets and peer-to-peer trading.

Conclusion

- AI enhances stability studies and unit commitment.
- Provides faster, adaptive, and cost-effective solutions.
- Critical for renewable integration and future power systems.
- AI-driven operation is key for smart, resilient, and sustainable grids.