AI application in transmission and distribution line protection

7th Semester

Objectives of the Lecture

- Understand the **role of protection systems**.
- Explore **AI techniques** used in fault detection & protection.
- Real-life examples in **transmission & distribution grids**.
- Future role of **intelligent protection systems**.

Traditional Protection Systems

- Relays + Circuit breakers.
- Based on **thresholds**: Current, Voltage, Frequency.
- Challenges:
  - Slow response to complex faults.
  - Difficulty in detecting high impedance faults.
  - Limited adaptability to **renewables and smart grids**.

Why AI in Protection?

- Handles **nonlinear and complex fault patterns**.
- Learns from **historical fault data**.
- Provides **fast classification** of faults.
- Adaptable to **changing grid topologies**.
- Enables **predictive protection** (fault prevention).

AI Techniques Used

- **Artificial Neural Networks (ANNs):** Fault classification.
- **Fuzzy Logic:** Decision-making under uncertainty.
- **Support Vector Machines (SVM):** Fault location.
- **Deep Learning (CNN, LSTM):** Pattern recognition from PMU data.
- **Hybrid AI Systems:** Combining ANN + Fuzzy/SVM.

Transmission Line Protection with AI

- Detects **single line-to-ground, double line, three-phase faults**.
- Uses **PMU and traveling wave data**.
- AI-based classifiers achieve **faster response** than conventional relays.
- Example: ANN-based scheme reduced fault classification time by **40%**.

Distribution Line Protection with AI

- **Challenges:**
  - Radial structure, multiple feeders.
  - High impedance faults not easily detected.
- **AI-based approach:**
  - Smart meters + sensors collect data.
  - AI algorithms identify fault type and feeder section.
- Example: Fuzzy-based fault locator in distribution systems.

Real-Life Applications

- **Wide-Area Monitoring Systems (WAMS):** AI for protection coordination.
- **Smart Grids:** Self-healing networks with AI-based relays.
- **Microgrids:** AI enables adaptive islanding and reconnection.
- **Case Study:** Indian grid integration of renewables – AI-assisted protection improved fault detection under solar/wind fluctuations.

Case Study – ANN for Fault Classification

- Input: Current & voltage waveforms.
- ANN trained with fault database.
- Output: Type of fault (SLG, LLG, LLL).
- **Result:** 98% accuracy, <50 ms decision time.

Challenges in AI-based Protection

- Need for **large, high-quality training datasets**.
- Cybersecurity risks in AI-driven grids.
- Integration with existing **relay hardware**.
- Risk of **false positives/negatives** in rare events.

Conclusion

- AI significantly improves **fault detection, classification, and location**.
- Transmission: Faster & more accurate fault classification.
- Distribution: Detects complex/high impedance faults.
- AI will play a **central role in smart grid protection**.