Impact

Of

Large Scale Data Centres and EV Charging Stations

On

Power System

Gaurav Sharma (General Manager – NPCL)

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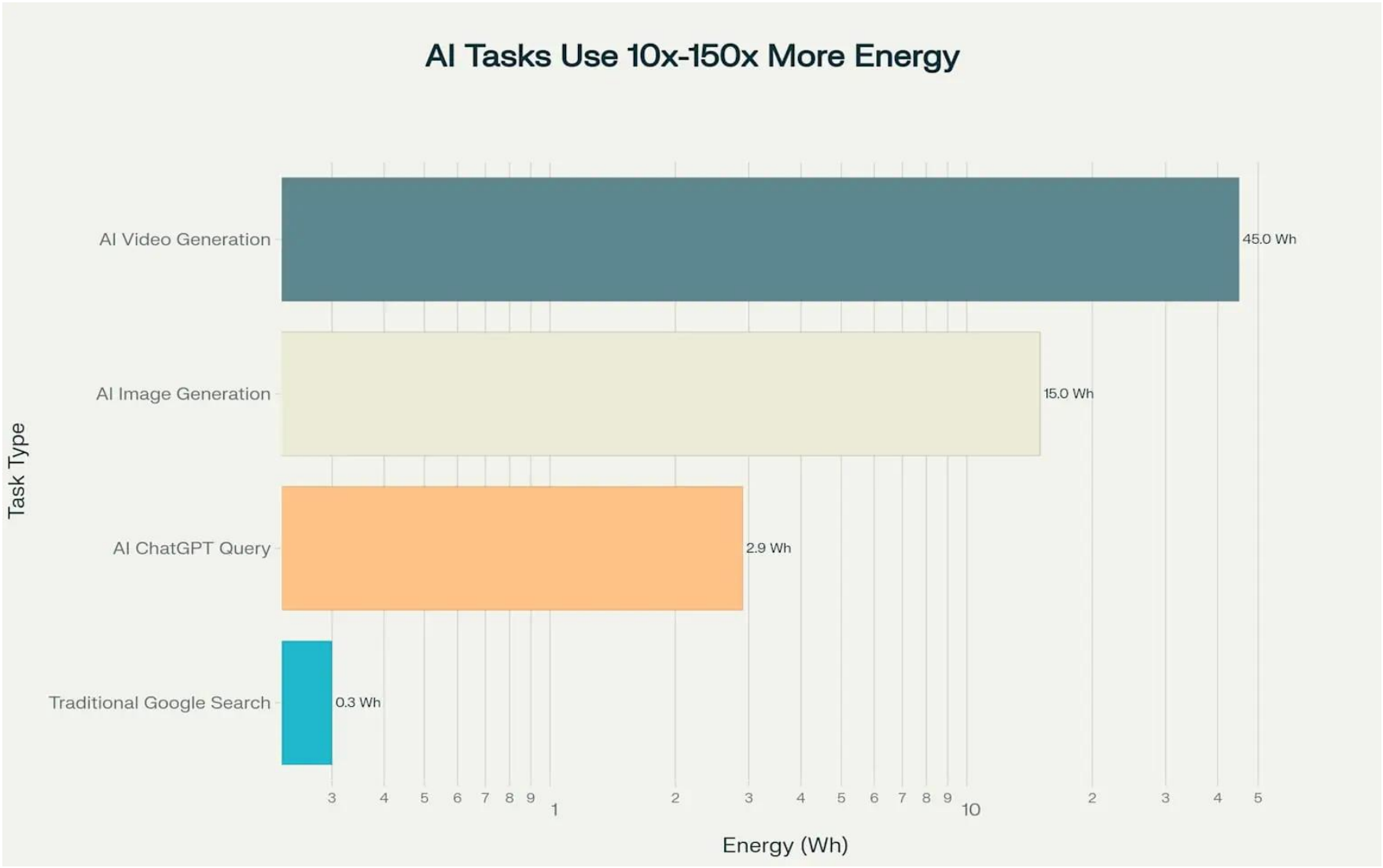
Load Characteristics – AI Data Centre



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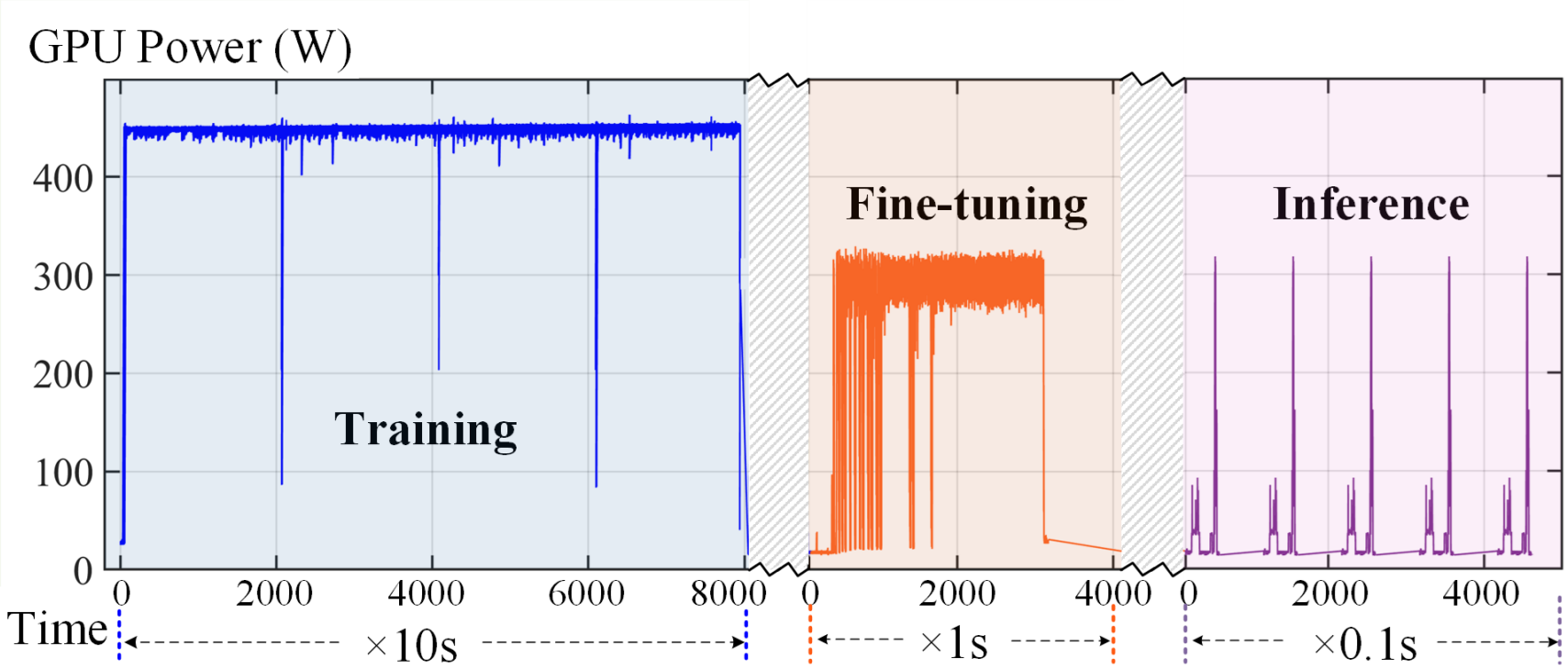
Load Characteristics – AI Data Centre



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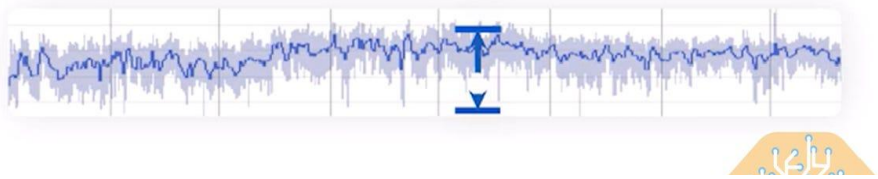
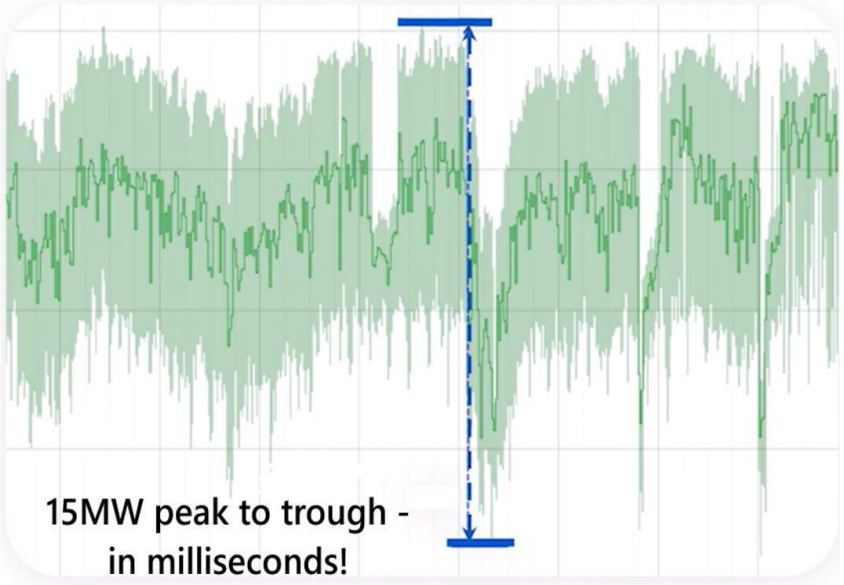
Load Characteristics – Non AI Vs AI Data Centre

Non-AI Workloads



AI Workloads



Aspect	Traditional	AI Workloads
Power Density	10-15 kW/rack	30+ kW/rack
Load Variability	Stable, predictable	Highly variable, bursty
Computational Intensity	Moderate	Extremely high
Data Dependency	Moderate	High
Phase Change	Rare	Training/Fine-tuning/Inference

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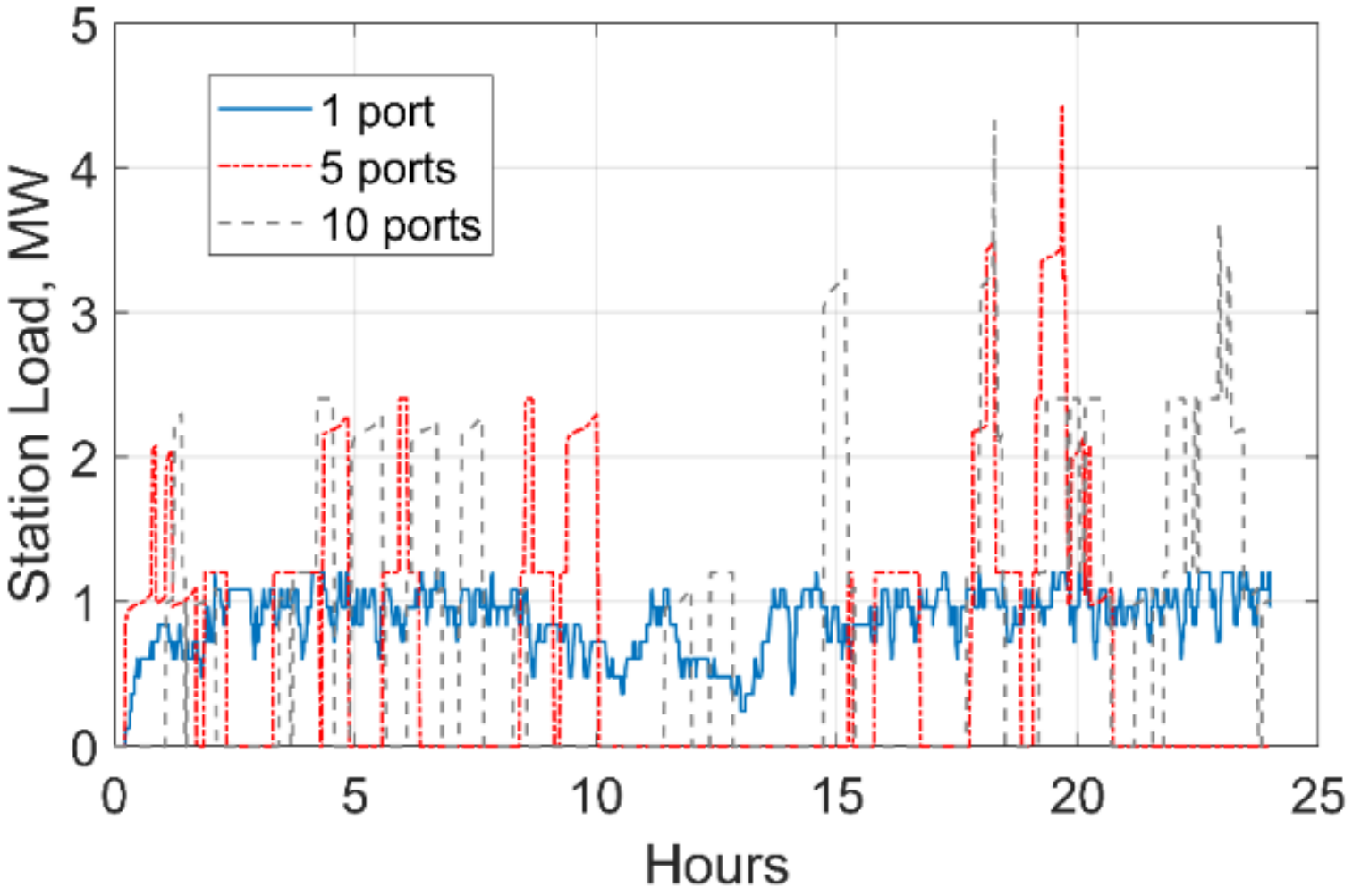
Load Characteristics – EV Chargers



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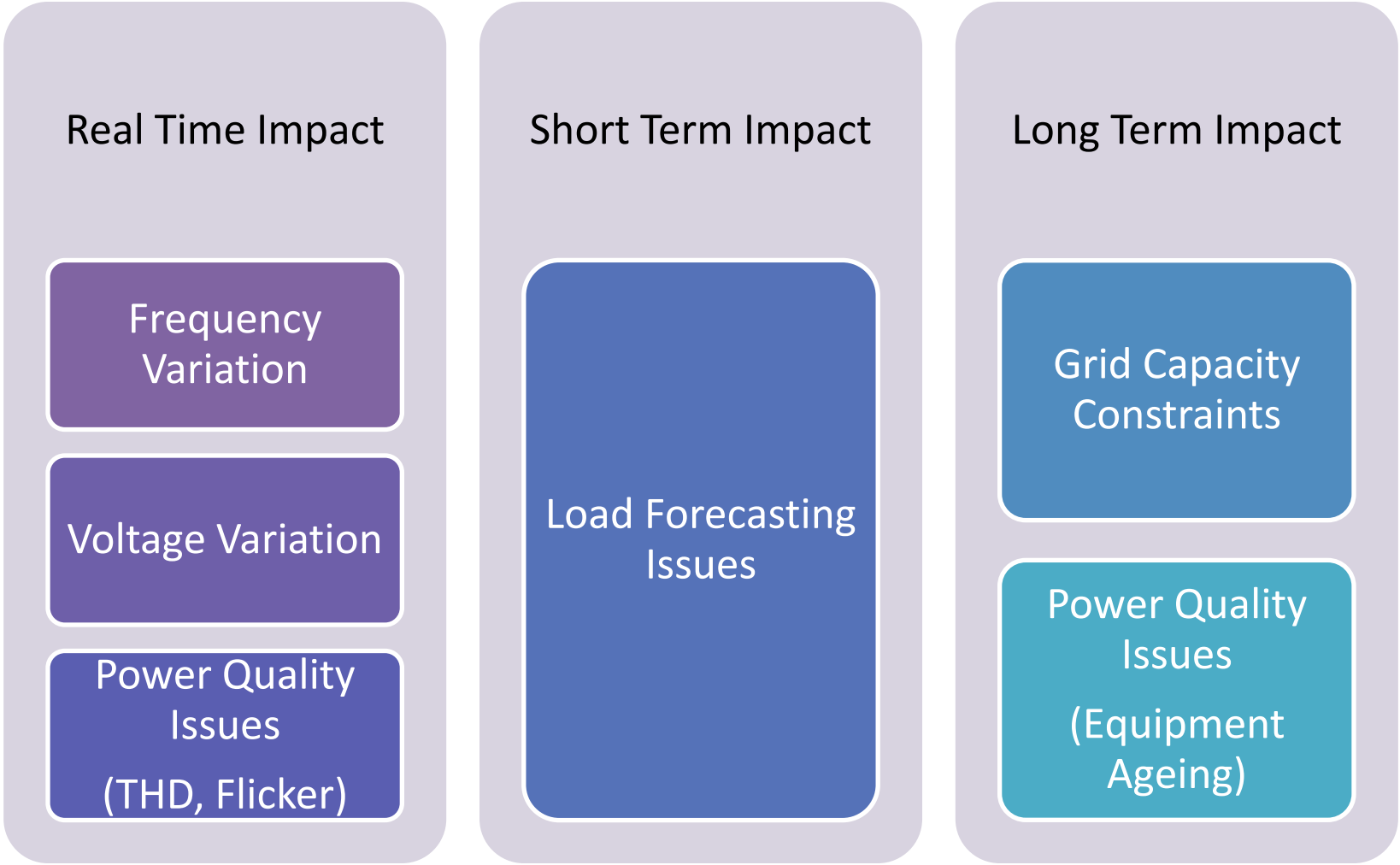
Large Scale AI Datacentre & EV Load - Impact on Grid



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Frequency Variation (Real Time Impact)

Load Characteristic

- AI: Sub-second to seconds-scale fluctuations
- EV: Step changes within seconds–minutes

Impact on Grid

- Fossil fuel generators have ramp rates of 5-50 MW/minute
- Managing hundreds of MWs variation in fraction of a second is not feasible
- Power-angle oscillations in nearby generators.
- Frequency changes with high rate of change of frequency.
- Risk of underfrequency load shedding or system trips.

Mitigation Strategy:

- **Fast Frequency Response (FFR)**: Deploy on site grid-scale batteries
- **AI load modulation:** Control of compute cycles in sync with grid frequency
- **Smart charging control:** EV Charging rate coupled to grid frequency

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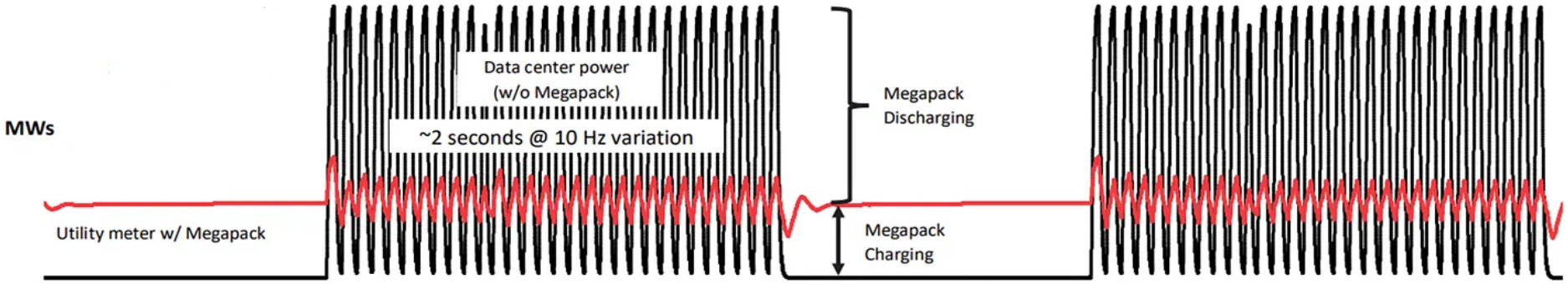
Frequency Variation - Mitigation Through BESS



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Voltage Variation (Real Time Impact)

Load Characteristic

- AI Data Centers Contain large UPS systems and cooling compressors
- Fast reactive power swings when clusters activate simultaneously.

Impact on Grid

- Traditional tap changers or capacitor banks -too slow for real-time dips.
- Inability to comply with voltage regulation standards
- Degraded power delivery to nearby industrial or sensitive customers.
- Possible stalling of motors or tripping of voltage-sensitive equipment.

Mitigation Strategy:

- Install **STATCOMs/SVCs** for fast dynamic voltage support

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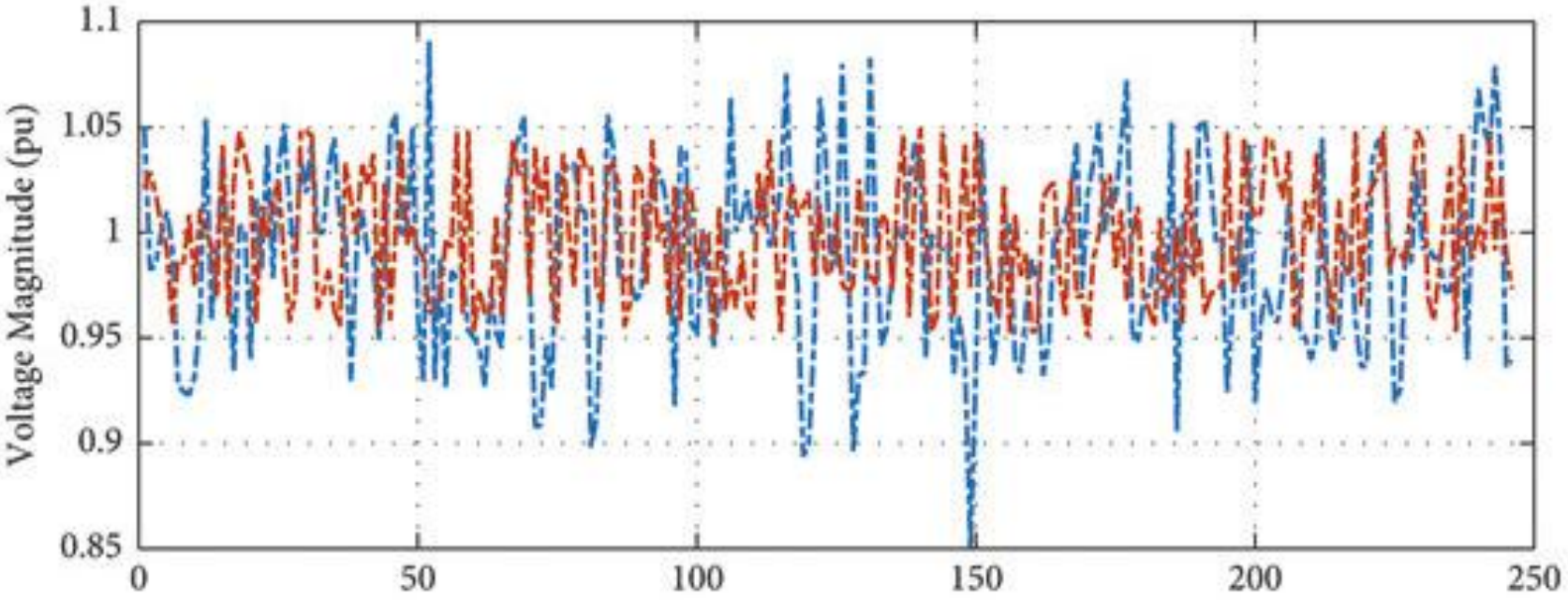
Voltage Variation - Mitigation Through STATCOM



Voltage Analysis of 250 Bus System - Pre Vs Post Optimal STATCOM Placement

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Power Quality Issues (Real Time/Long Term Impact)

Load Characteristic

- **AI Centres:** Thousands of SMPS and UPS units introduce current harmonics
- **EV Chargers:** Nonlinear converters produce distorted current waveforms.

Impact on Grid

- Increased Total Harmonic Distortion (Real time)
- Maloperation of protection relays (Real time)
- Flicker and electromagnetic interference (Real time)
- Overheating of equipment and insulation stress (Long term)
- Accelerated ageing and reduced equipment lifespan (Long term)

Mitigation Strategy

- Use of active harmonic filters at load end
- Enforce Power Quality monitoring

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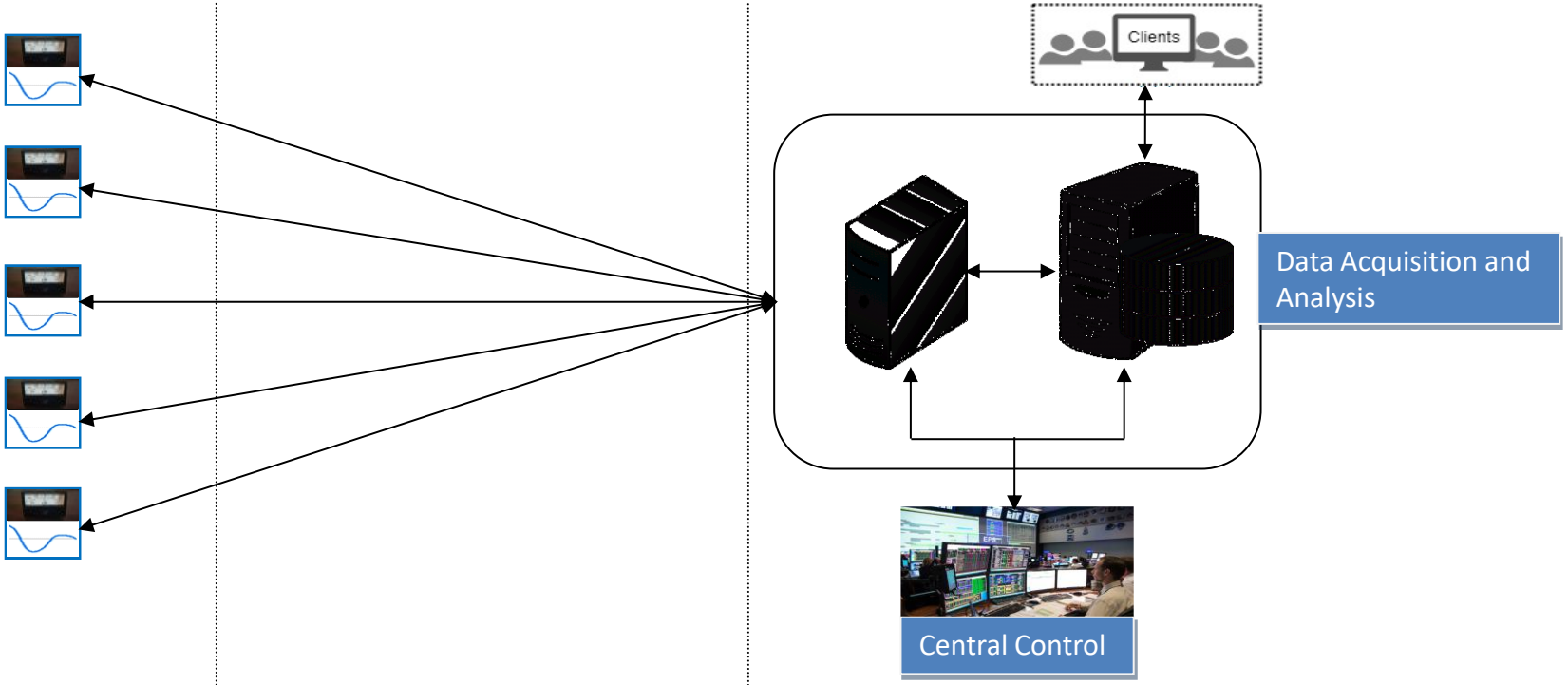
Power Quality Issues – Mitigation Through PQ Monitoring



PQ Meters

Communication Protocol- IEC 61850 and Medium- Ethernet/ cellular (4G)

Enterprise Level Data Acquisition and Management Software

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Load Forecasting Issues (Short Term Impact)

Load Characteristic

- AI: Workload-driven, random
- EV: Arrival-driven, fleet/traffic dependent
- Load uncertainty

Impact on Grid

- Forecasting models not yet trained on AI + EV composite demand patterns.
- Uncertain forecasts challenge dispatch planning.
- Stress on generation ramping and reserves.

Mitigation Strategy

- Use machine-learning-based load forecasting tuned to AI load profiles.
- Set connection ramp-rate limits in grid agreements.
- Integrate on-site renewables and BESS for smoothing.
- Implement demand response with flexible job scheduling.

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Grid Capacity Constraints (Long Term Impact)

Load Characteristic

- AI: 100 MW–1 GW dense demand
- EV: 5–50 MW, concentrated sites

Impact on Grid

- Network Capacity Challenges
- Equipment overload
- Lack of adequate redundancy

Mitigation Strategy

- Strategic siting near substations
- Network Upgrades
- Hybrid renewable + storage projects
- Long-term interconnection planning

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Thanks

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