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ASIA CLEAN ENERGY FORUM (ACEF) 2026 - Thematic Tack 4

Session 4.3: Digitalization and AI Accelerating Discovery and Processing of Clean Energy Inputs

Powering India's Mega Al Campuses: GW-Scale Power Connections for Al Factories Generating Tokens

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About India Smart Grid Forum (ISGF)

The India Smart Grid Forum (ISGF) has evolved as a Think-Tank of global repute on Smart Energy, Electric Mobility and Energy Transition

ISGF, established as a Public Private Partnership initiative of Government of India in 2011, is spearheading the mission to accelerate electric grid modernization, electric mobility and energy transition in India

200+ members comprising of ministries, utilities, technology providers, academia and research

8 Working Groups: Grid Modernization and Smart Cities; IoT, Smart Metering, AI and Analytics; Digital Architecture and Cyber Security; Policy, Regulations and Business Models; Renewables and Microgrids; Flexibility & Electric Mobility; Smart Gas; Smart Water

ISGF has been driving the digitalization of Utilities and is actively involved in training and capacity building and various advisory and research activities

Power Sector Scenario in India

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- **Third largest power system in the world** - Installed capacity of **539 GW (as of 01 June 2026)**, 300 million+ consumers – **1.36 GW in 1947 at the time of Independence – 397X growth in 77 years**
- **99.99% of the 1.4 billion population** is connected to the grid and all **619,000 villages in India are electrified**
- Generation capacity expected exceed 901 GW by 2032; and **2100 GW by 2047**
- Met a record power demand of **270 GW on 21st May 2026**
- Rising penetration of **air-conditioning load, EV charging, data centers, metro rail systems, and industrial growth** are driving the demand
- Renewable energy (RE) program of **500 GW by 2030 and Net Zero by 2070**
- **New RE Targets under discussion: 1500 GW by 2035!**
- **4 million rooftop solar (RTS) connections** – 27 GW; being scaled up to 10 million RTS on fast track by March 2027
- Aggregate Technical and Commercial (**AT&C) Losses brought down from >36% in 2004 to below 16% now – huge savings of over 350 Billion Units/Year**

AI Data Centers - Introduction

- The global race for **Artificial Intelligence (AI)** is driving a transformation from conventional data centres to **gigawatt-scale AI Factories**, covering square miles and producing AI Tokens which require unprecedented computing power and data processing requirements
- 15 AI models were released in 8 weeks (mid March to mid May 2026) by frontier Labs – AI is making their next generation models
- Global data creation is accelerating rapidly – 2024: 149 Zeta Bytes (ZB), 2028: 400 ZB, 2030: 612 ZB which require 874 trillion CDs – height of 1 billion km – 7 times the distance from earth to sun!

Classic DC	**5 MW**	
Hyper Scaler DC	50 MW+	
Cloud Campus	200 MW+	5-15 kW racks air-cooled
AI Campus	500 MW+	100 kW racks of GPUs; direct to chip liquid cooling
AI Factory	1-2 GW	Manufacture intelligence (tokens) across Training and Inference. Footprint: 1 Square Mile (640 Acre) or more

- **Fermi America**: 10 GW – 9 Square Miles, Wyoming/Texas
- **OpenAI Stargate**: 5 GW – 4.25 Square Miles, Abeline, Texas
- **Meta Hyperion**: 5 GW – 1.35 Square Miles, Holly Ridge, Louisiana

AI Data Centre as Token Factory

- For English text, **1 Token is 4 characters including spaces**; **750 words per 1000 tokens** – a typical 100 page report is 40,000 tokens; cost of tokens constantly falling and model efficiency is increasing – require lesser number of tokens for the same task

AI Model	Cost of 1 million Input Tokens/Output Tokens (US$) In 2025	Cost of Input Tokens/Output Tokens (US$)In 2026
ChatGPT-4o	2.50/10.00	
ChatGPT-5	1.50/10.00	
Chat GPT-5.5	-	5.00/30.00
ChatGPT-5.2	-	1.75/14.00
Gemini 2.5 Pro	1.25/10.00	
Gemini 2.5 Flash	0.30/2.50	
Gemini Flash-Lite	0.10/0.40	
Gemini 3.1 Pro	-	2.00/12.00
Gemini 3.5 Flash	-	1.50/9.00
Gemini 3.5 Flash-Lite	-	0.25/1.50
DeepSeek R1	0.55/2.19	
DeepSeek V3	0.20/0.77	
DeepSeek V3.2	0.23/0.34	
DeepSeek V4 Flash	-	0.14/0.28
DeepSeek V4 Pro		1.74/3.48
Claude Opus 4	15.0/75.00	
Claude Sonnet 4	3.0/15.00	
Claude Haiku 3.5	0.80/4.00	
Claude Opus 4.8	-	5.00/25.00
Claude Sonnet 4.6	-	3.00/15.00
Claude Haiku 4.5	-	1.00/5.00

AI Data Centres in India

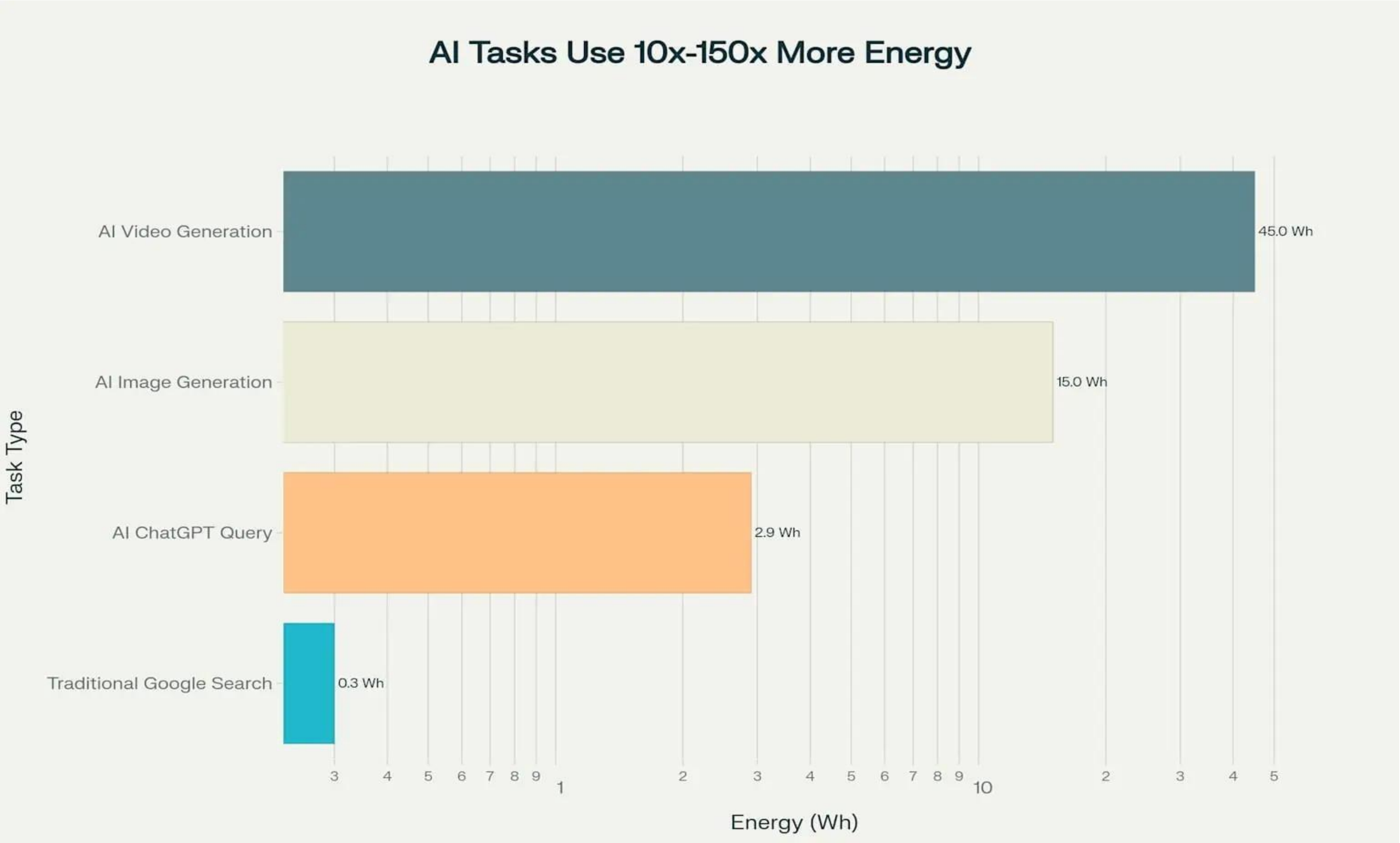
- India is emerging as a major destination for large-scale data center investments, supported by:
  - Over **1.02 billion internet subscribers**
  - Average mobile data consumption of **25 GB/user/month**, significantly above the global average and projected to double by 2030
- Data center capacity in India expanded from **520 MW in 2020 to approx 1.5 GW in 2026**, with projections exceeding **12 GW by 2030**
- Total global commitments to India AI Data Centre Infra : **$60–70 billion in next 5 years**

Project/Company	Location	Capacity	Site Area	Investment/Key Facts
Adani–Google AI Campus	Visakhapatnam, Andhra Pradesh	1 GW	480 acre	$15B Investment
Reliance Jio AI Campus	Jamnagar, Gujarat	Expandable to 3 GW	Multi-site campus	$110B investment plan; 120 MW online in H2 2026
L&T × NVIDIA AI Factory	Chennai + Mumbai	GW-Scalable	Chennai, Mumbai + other locations	India AI Mission; 30 MW Chennai + 40 MW Mumbai completed
Microsoft Azure Hyderabad	Hyderabad (South Central)	Hyperscale	Largest by MS region in India	$17.5B over 2026–2029; India South Central live mid-2026
Amazon AWS Hyderabad	Hyderabad, Telangana	Hyperscale	Multi-zone campus	$35B by 2030 total; $7B for Hyderabad region specifically
YEIDA AI Supercomputing Hub	Greater Noida, UP	1.2 GW	YEIDA	Uttar Pradesh Government Initiative

Impacts of AI Loads on the Power System (1/5)

- AI Loads are now called **Large Dynamic Digital Loads (LDDL)**
- This is a new phenomenon for Power System Planners and Operators – Several Industry Consortiums are studying the impacts of AI Data Centres on the power system:
    - EPRI Open Power AI Consortium
    - Open Compute
    - Emerge Alliance
    - NERC – Large Load Task Force
    - ERCOT Large Load Working Group
    - PJM Interconnection Initiatives
- Multiple university, national labs and other groups are trying address the various challenges:
    - Technical: Power, water, cooling, real estate, and integration, etc.
    - Supply chain disruptions and concentration
    - Generation/facility interconnection queues
    - Policy considerations such as tariffs and grid upgrade costs

Impacts of AI Loads on the Power System (2/5)



Impacts of AI Loads on the Power System (3/5)

Real Time Impact

- Frequency Variation
- Voltage Variation
- Power Quality Issues (THD, Flicker)

Short Term Impact

- Load Forecasting Issues

Long Term Impact

- Grid Capacity Constraints
- Power Quality Issues (Equipment Aging)

Impacts of AI Loads on the Power System (4/5)

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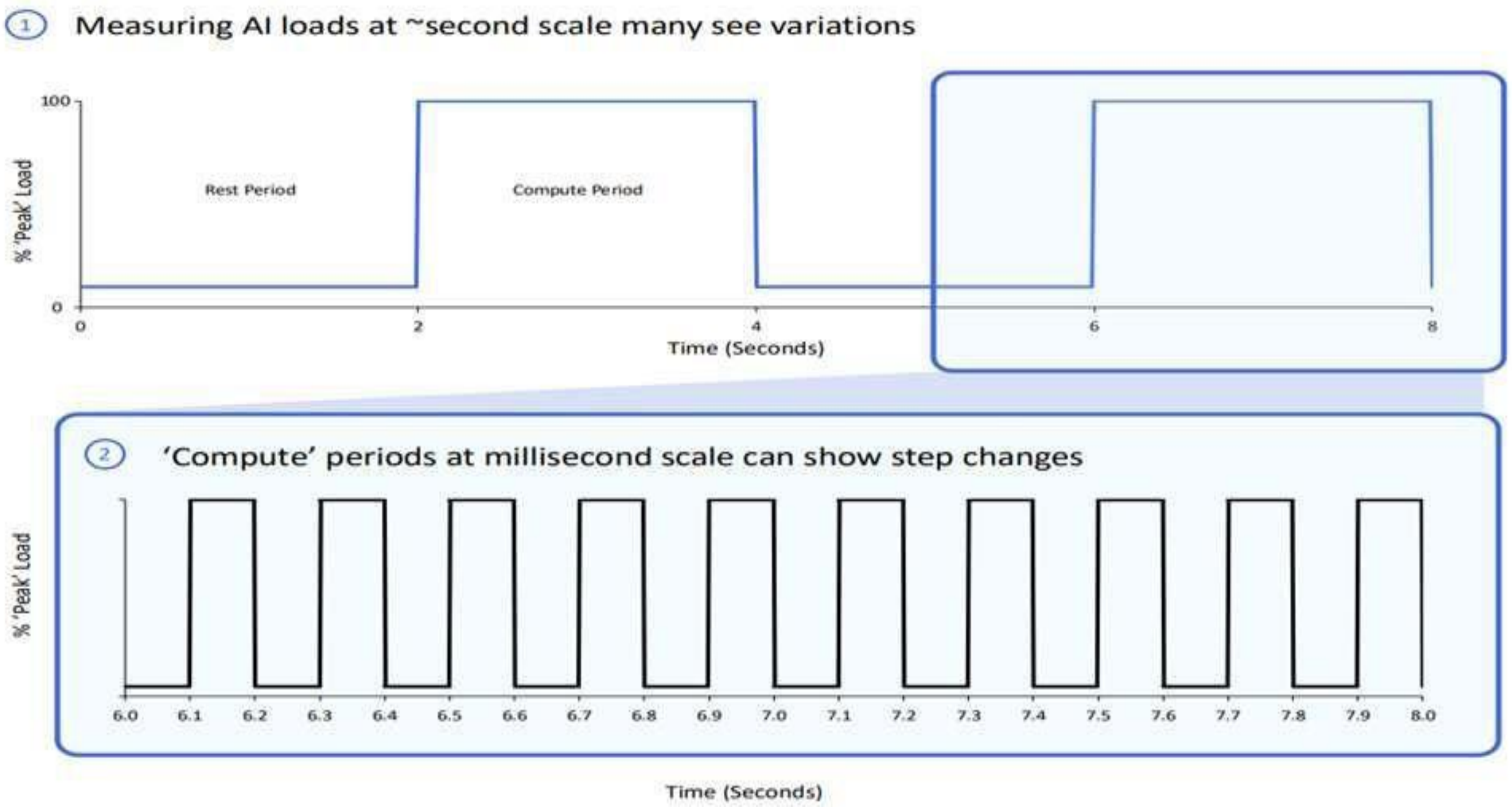
- Reliability of power supply for advanced AI data centers: Training: 99.9% and Inference: 99.999%
- AI Inference is latency-sensitive - least flexible on compute, but still has power/thermal flexibility
- Training Cluster is not a steady load - 1000s of GPUs ramp up and down in unison depending on training steps
- Training Burst Swings: 500 MW to 100 MW in seconds to minutes – 80% variation in seconds
- Present Grid can not handle >20% swings in seconds



Characteristics and Risks of Emerging Large Loads Task Force White Paper July 2025

PJM Incident in July 2024

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- 10 July 2024 (7pm) in Virginia (PJM System) – failure of a Lightning Arrestor of a 230 kV Line:
  - 3 seconds voltage fluctuation
  - Automatic disconnection of 60 data centers
  - Loss of 1.5 GW Load
  - Frequency shot up to 61.2 Hz (from normal 60 Hz in North America)

- Studies by ERCOT and others indicate swings of up to 1 GW can happen multiple times per minute!

- Two failure modes:
  - Load swings stressing voltage/frequency in normal operations
  - Mass disconnection (poor fault ride through) turning a lost load in to a generation surplus scenario leading to sharp rise in frequency

Mitigation Strategies – 1: STATCOM at the HV (1/2)

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Two main strategies here:

- **E-STATCOM with energy-stored**
- **STATCOM with GFM capabilities**

- E-STATCOM with energy storage can provide management of power transients as well as ramp management
- STATCOM with GFM can provide black start capabilities, Voltage and Frequency Control, and Inertia support
- Typical unit size (in USA) 115 MVA divided - 50% MVAr and 50% MW power cycling
- Typical Voltage range (in USA): 34.5 kV – 750 kV Modular, scalable multiple units based on MMC converter and Valve technology

Mitigation Strategies – 1: STATCOM at the HV (2/2)

- **STATCOM: Static Synchronous Compensator –** This is shunt connected FACTS built around Voltage Source Converters (VSC) for dynamic reactive power compensation and voltage regulation. The DC capacitor on its DC side synthesizes a controllable AC voltage:
  - If converter voltage is higher than grid, VSC injects reactive power (capacitive, raised voltage)
  - If converter voltage is lower than grid, it absorbs reactive power (inductive, lowers voltage)
- **E-STATCOM: Enhanced STATCOM with Energy Storage integrated – a battery + super capacitor or flywheel**
  - **Power Oscillation Damping (POD):** inject/absorb active power to damp inter-area oscillations
  - **Frequency support/fast frequency support:** act like synthetic inertia/primary frequency control
  - Peak shaving, load levelling, ride-through and smoothing of intermittent RE

	STATCOM	E-STATCOM
DC Side	Capacitor only	Capacitor + Battery
Power Exchange	Reactive only	Active and Reactive
Core Functions	Voltage Regulation, VAR support	Voltage Regulation, VAR and Oscillation Damping

Mitigation Strategies – 2: Microgrids and BTM Assets

Ability to operate a part of the electric grid with a specified control boundary is a microgrid:

- Campus microgrid with defined islanding control boundary
- Supercapacitors for ultra-fast transient suppression at rack level
- Behind-the-meter (BTM) DER (solar) for resilience and power quality
- Critical loads are the key load groups including processors, thermal, and fire management

- Specific design and operational considerations such as Grid Forming (GFM) Assets, diesel/Natural Gas Generation, coordination and controls, and protection are key considerations

Mitigation Strategies – 3: Load Forecasting Issues

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Load Characteristics

- Workload-driven, random
- Load uncertainty

Impact on Grid

- Forecasting models not yet trained on AI 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**

Mitigation Strategies – 4: Grid Capacity Constraints

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Load Characteristics

- **GW scale demand**

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**

Mitigation Strategies – 5: Power Quality Issues

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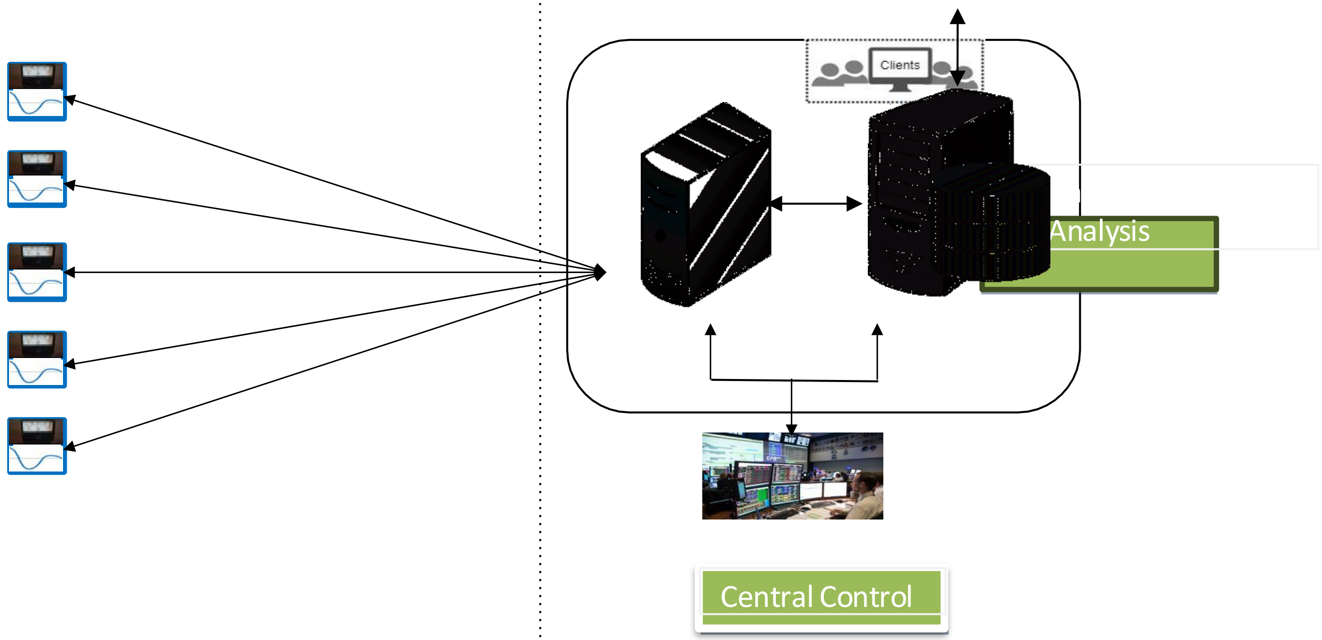
Mitigation through constant monitoring of Power Quality with PQ Meters



PQ Meters

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

Enterprise Level Data Acquisition and Management Software

Power Architecture and Green Targets for Data Centers

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DC Power Architecture

- Transition from 50V to 800 VDC within rack power delivery (800 VDC architectures minimize energy losses due to multiple AC-to-DC conversion steps and maximize tokens per watt in AI factories)
- Reduce conversion losses, improve efficiency by 15–20%
- HVDC for long-distance bulk power transmission to AI campuses

BESS for AI Data Centres

- Response time: <100 ms
- Minimum Capacity: 200 MWh
- Discharge: 30-60 mins

Green Data Centre Targets

- Power Usage Efficiency (PUE): ≤ 1.2 (maximum 20% extra for cooling and other auxiliaries)
- Water Usage Efficiency (WUE): <0.5 Liter/kWh
- Carbon Free Energy (CFE): >90%
- Zero Liquid Discharge (ZLD)

Immediate Regulatory Interventions Required

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- Current Regulations in India (same for most countries) not designed for Single Loads above 200~300 MW
- Reclassify AI Factories as Large Special Consumers OR Large Dynamic Digital Loads (LDDL)
- Mandate Real-time Telemetry and Low Voltage Ride-Through (LVRT) compliance for LDDL
- Immediately **Amend:**
  - **Connection Agreements**
  - **Scheduling Protocols**
  - **Deviation Settlement Mechanisms**
- GPU load scheduling should be coordinated with BESS SoC and Generation Dispatch
- Mandate **'Advance Load Notification' Protocol**: AI campuses notify the Grid Controller at least 1 hour before large jobs
- **Strategic Grid Planning**
  - Locate AI campuses near existing 400/765 kV grid corridors
  - Long-term interconnection planning with Transmission companies
  - Dedicated feeders with **N+2 redundancy** + inter-regional balancing

India AI Stack and Policy Framework

The 5-Layer Architecture Enabling AI at Population Scale

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India AI Stack – Five Enabling Layers

- **Energy Layer** *(This layer keeps the entire AI stack running)* 539 GW installed (June 2026); 54.5% non-fossil; 154 GW Solar
- **Data Centre and Network Layer** *(This layer forms the home and highways of AI)* 1.5 GW today → ~12 GW by 2030; 5G in 99.9% districts; Optical fibre backbone
- **Compute Layer** *(The muscle of AI; it provides the computing power required to train and run AI models)* USD 1.1 billion **IndiaAI Mission**; 38,000 GPUs + 1,050 TPUs; National Supercomputing Mission 40+ Peta-flops
- **AI Model Layer** *(It acts as the brain of AI systems)* several indigenous models
- **Application Layer** *(The application layer represents the user-facing component of the AI stack)* AI apps in healthcare, agriculture, education, justice and governance

Policy and Regulatory Framework for GW-Scale AI

- **IndiaAI Mission** — US$ 1.1 billion for 5 years; subsidised compute at ₹65/hr vs global ₹200+/hr
- **India Semiconductor Mission** — US$ 8 billion outlay; 10 semiconductor projects approved including chip fabrication and ATMP units
- **SHANTI Act (Nuclear)** — Private sector participation in nuclear; Small Modular Reactors for 24x7 clean baseload to AI campuses
- **Special AI Power Zones (SEZ-P)** — Proposed dedicated power economic zones with converged IT + Power + Environment regulatory approvals
- **Open Access Reform** — Streamlined renewable energy wheeling; direct PPAs for hyper scalers; reduce barriers to GW-scale green procurement
- **Sovereign AI Mandate** — Critical data, models and workloads hosted within India; interoperable with global ecosystems – **'AI in India for India'**

ISGF Annual Events

India Smart Utility Week

(Since 2015 : Held in March)

- International Conference and Exhibition on Smart Grids, Renewable Energy, E-Mobility and Smart Cities
- Knowledge sharing platform for Policy Makers and Regulators, Utilities, Technology Providers, Academia and Research, Entrepreneurs and Technology Enthusiasts
- Best practices and show case next generation technologies and products
- Website: www.isuw.in
- Glimpse of ISUW 2024 - https://youtu.be/yaR52tVhwzI?si=hKpS6-CV-o74l0tT

Distribution Utility Meet

(Since 2017: Held in November)

- DUM is the unified voice of the DISCOM community to influence policy and regulations for grid modernization
- DUM provides an effective platform to DISCOMs to leverage each other's experiences and resources for successful nationwide smart grid rollouts
- Website: www.dumindia.in

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