

# Operational Excellence in Grid Management

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Best Practices and Case Studies from  
Maharashtra SLDC

07-04-2026



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Executive Director, SLDC, Maharashtra



**MAHATRANSCO**  
Maharashtra State Electricity Transmission Co. Ltd.

# Managing a 49.5 GW Power System

## Peak Load Milestone

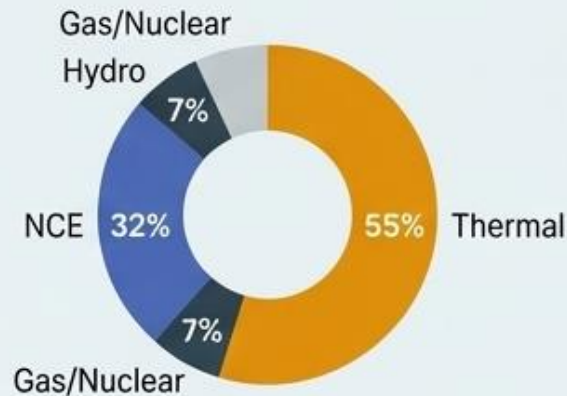
# 31,128 MW

All-time catered peak demand (March 2026)  
with zero load shedding.

## Infrastructure Scale

- 804 active substations
- 57,029 km of transmission lines
- 1,65,928 MVA transformation capacity

## Resource Mix Complexity



Balancing a heavily thermal baseline with a rapidly expanding Non-Conventional Energy (NCE) footprint.

## Market Ecosystem

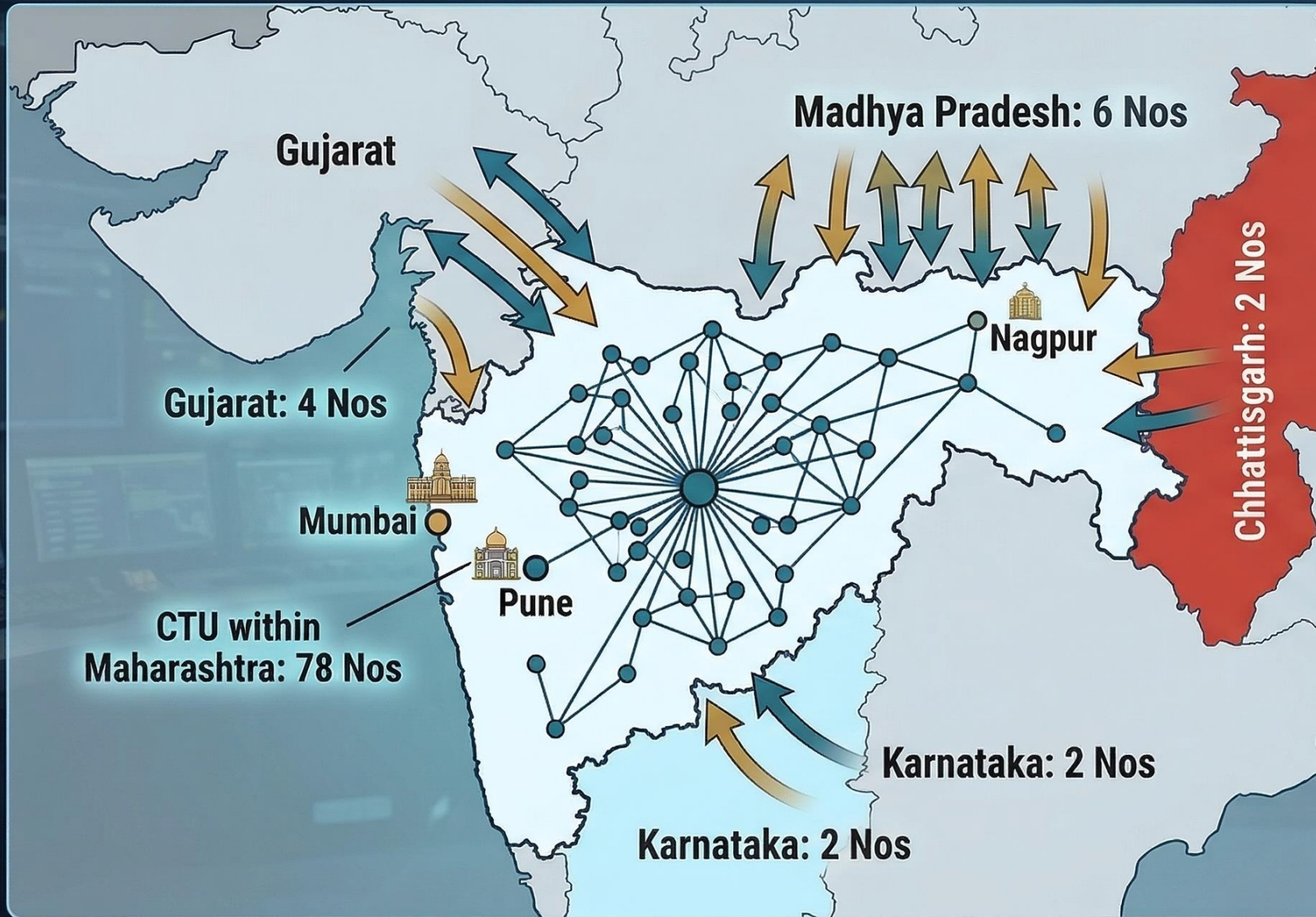
**228** Sellers

**15** Deemed Distribution Licensees

**4** Major Distribution Licensees

**92** Inter-State Exchange Points

# MAHARASHTRA STATE: TOTAL INTER STATE EXCHANGE POINTS - 92 Nos.



## INTERCONNECTION BREAKDOWN:

- Exchange with Gujarat	4 Nos
- Exchange with Madhya Pradesh	6 Nos
- Exchange with Chhattisgarh	2 Nos
- Exchange with Karnataka	2 Nos
- Exchange with CTU within Maharashtra	78 Nos



TOTAL TRANSFER CAPABILITY (TTC):

**11400 MW**



TRANSMISSION RELIABILITY MARGIN (TRM):

**600 MW**

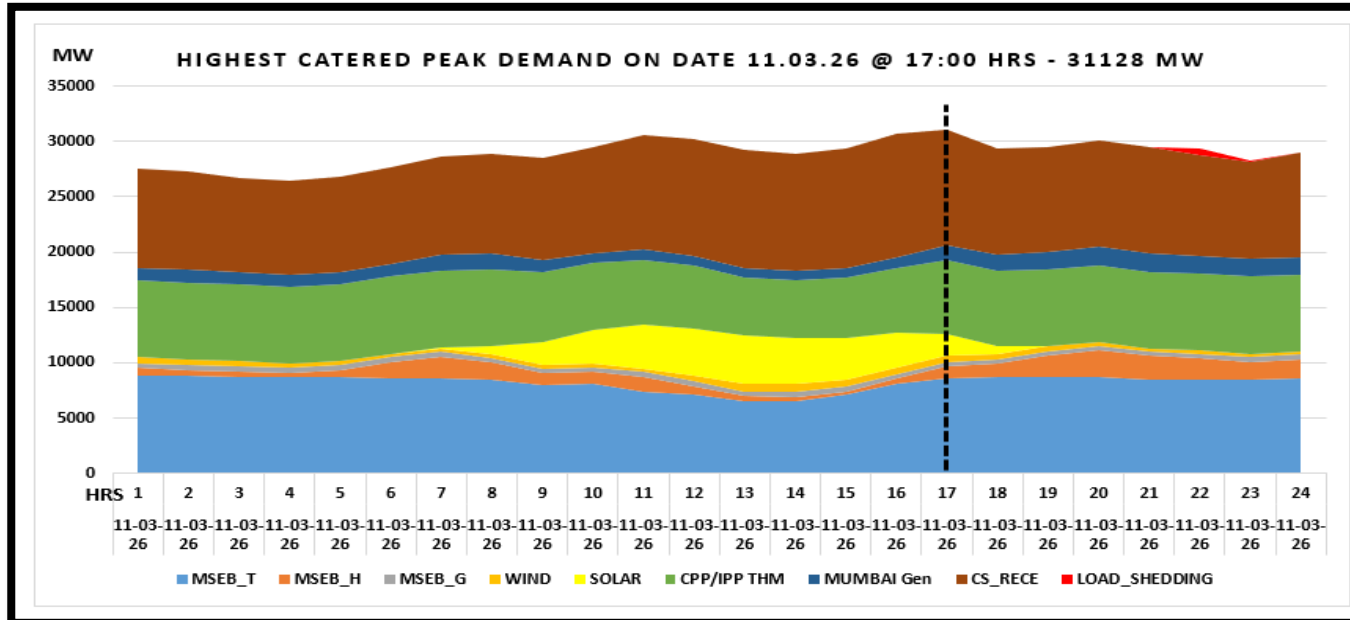
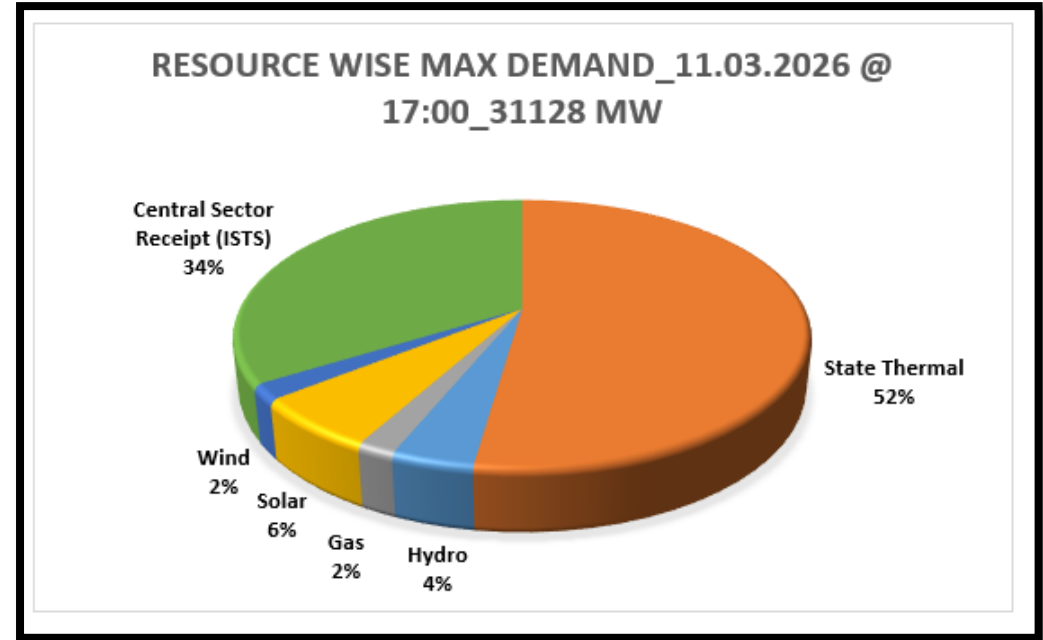
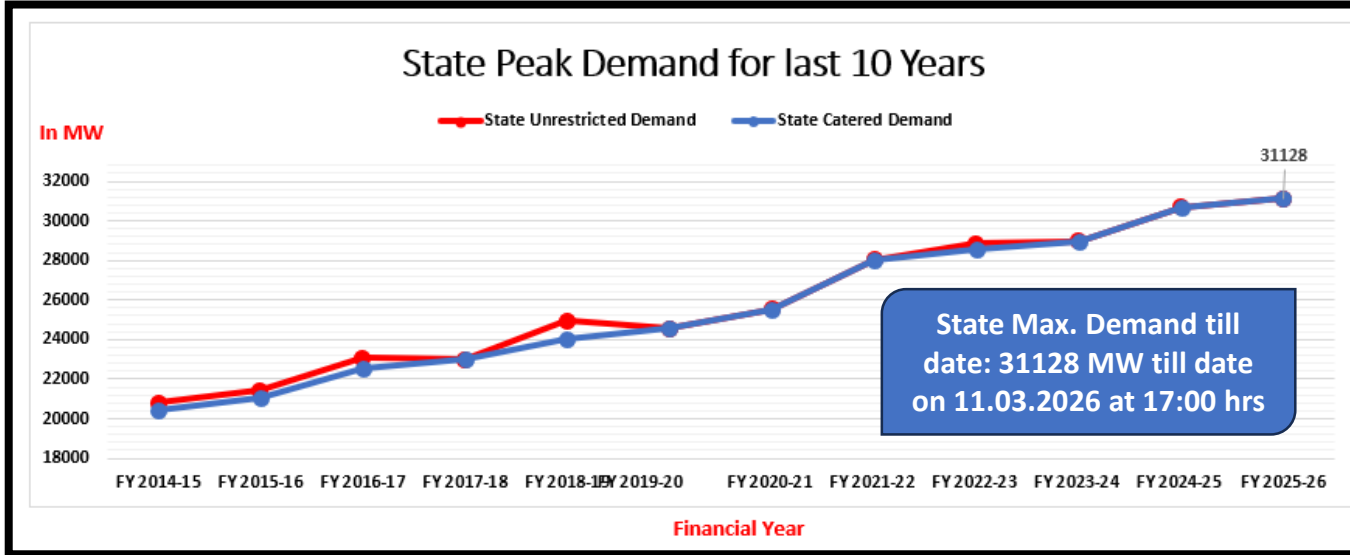


AVAILABLE TRANSFER CAPABILITY (ATC):

**10800 MW**



# Maharashtra State Demand Scenario



Source	Injection (MW)	Contribution (%)
State Thermal	16268	52
Hydro	1230	4
Gas	570	2
Solar	1949	6
Wind	573	2
Central Sector Receipt (ISTS)	10538	34

# Installed Capacity of VRE Capacity:

Total VRE Installed Capacity monitored by MSLDC: 12 GW

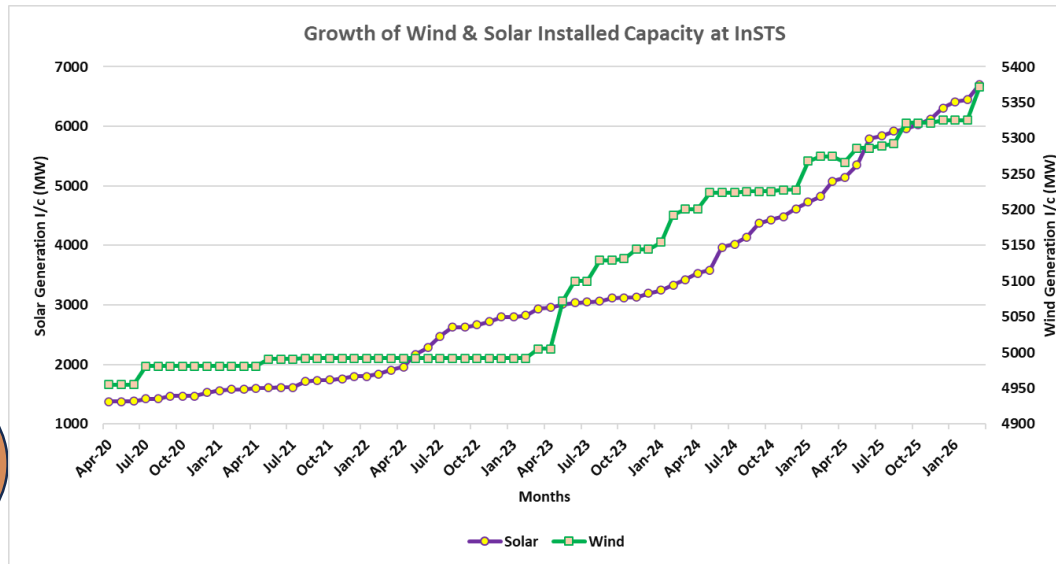
Solar: 6.7 GW

Wind: 5.3 GW

No. of PSS: 190 Nos.

No. of Individual Generating Companies > 1500 Nos.

No. of Individual Generating Units (WTG/Invertors) > 6000 Nos.




Solar Roof-Top: 5369 MW

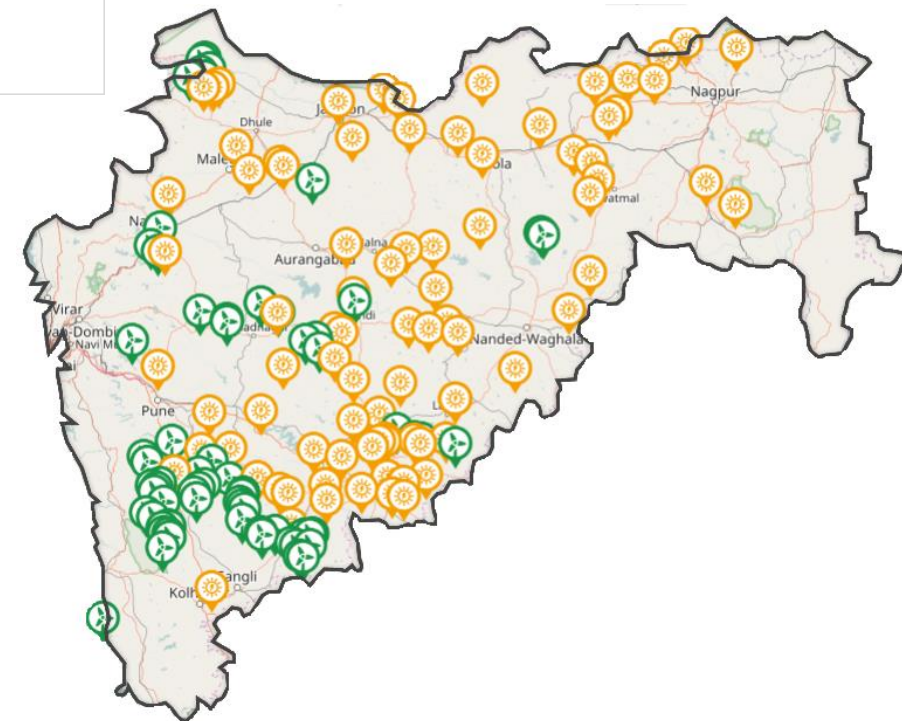


MSKVY: 2577 MW

## Districts with Major VRE Installation:

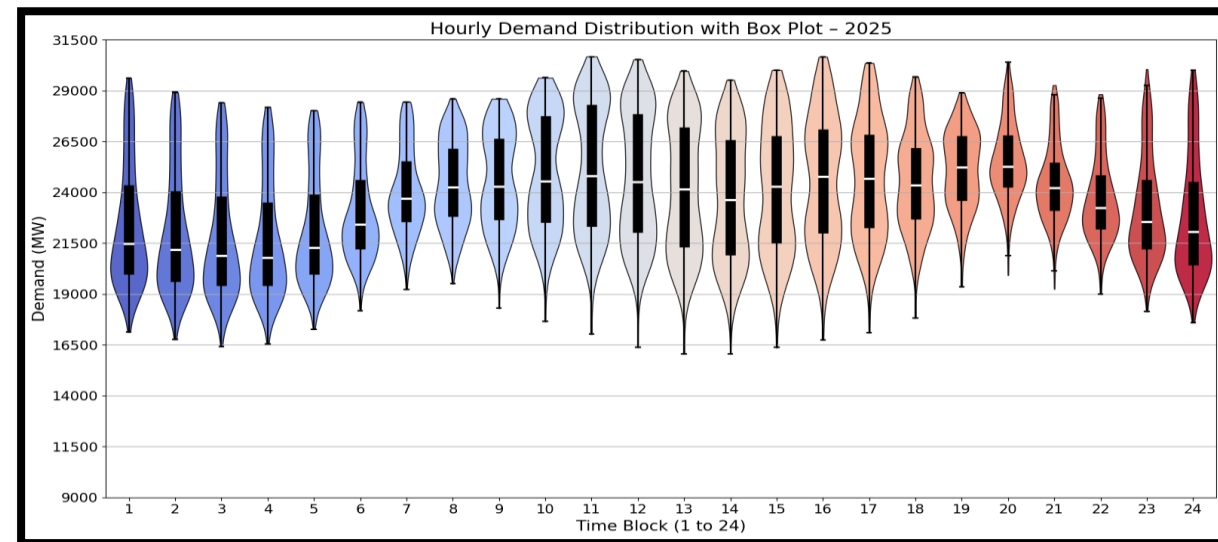
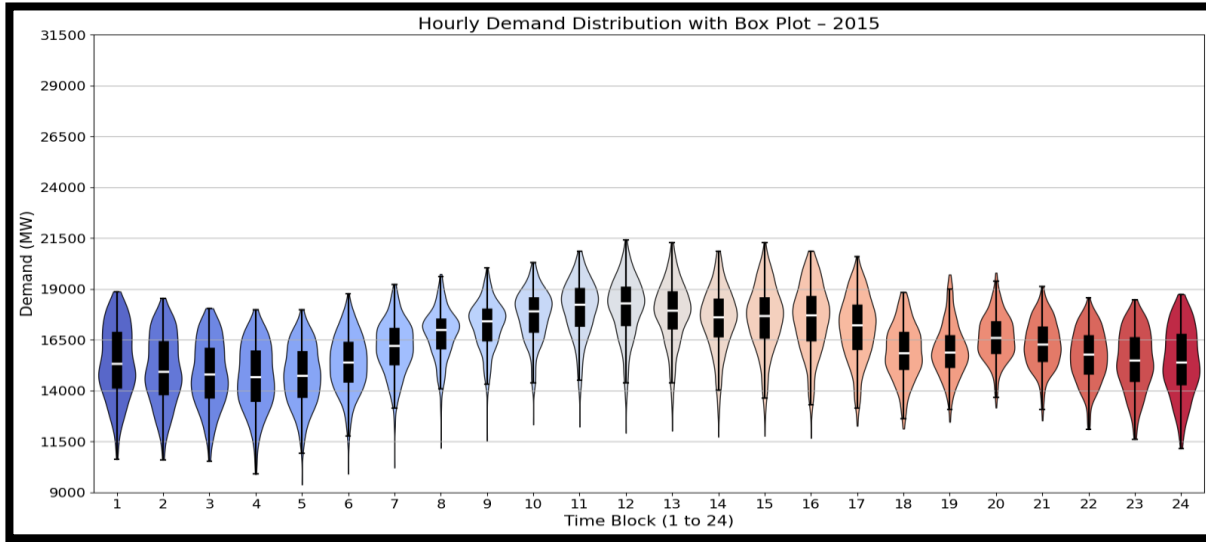
Satara, Sangli, Dhule, Nandurbar, Beed, Osmanabad, Solapur, Jalgaon

Existing Intra-State VRE is 26% of total installed capacity

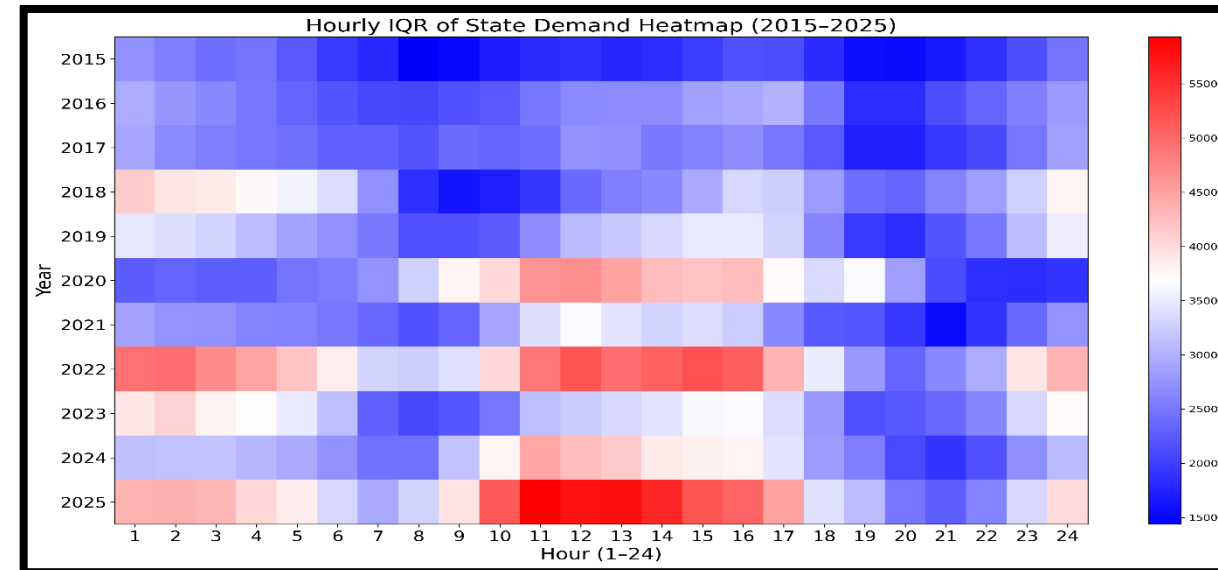
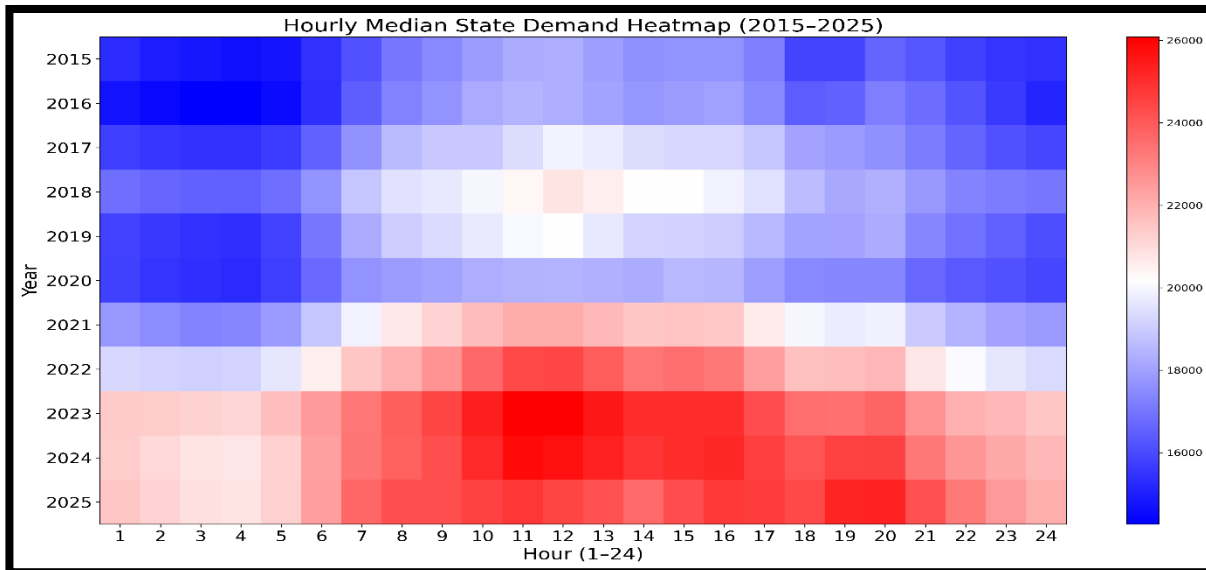


Compared to Wind, capacity addition of Solar capacity is increasing with more pace

# Demand Evolution of Maharashtra in Last Decade



- **Interquartile Range, IQR (Thick Black Bar): 25<sup>th</sup> to 75<sup>th</sup> percentile** — shows the spread of middle 50% of demand values.
- **Median (White line inside the black box)** - The middle demand value at that hour, considering all days of that year.





# THREE PILLARS OF OPERATIONAL EXCELLENCE



## Technical Excellence

- Strengthening SCADA architecture
- Renewable Energy Management Centre
- ML based RE forecasting
- Web Based Scheduling
- Web Based Outage Management
- Security Constrained Economic Despatch
- Digitalization - DRISHTI Portal
- Automated Meter reading
- Cyber Security Operation Centre



## Capacity Building

- Certified operators and experts
- Special incentive for SLDC teams
- Inhouse trainings and workshops
- Participation in trainings at national and international institutes
- SLDC Summit initiative for multiple states
- Deep academic integration with IIT Bombay
- (Placeholder for extra space)

## Policy Advisory as System Observer



System Studies for MSKVY 2.0



Security Constraints Economic Despatch pilot



Study for Intrastate ancillary service regulation



Study of data centre loads



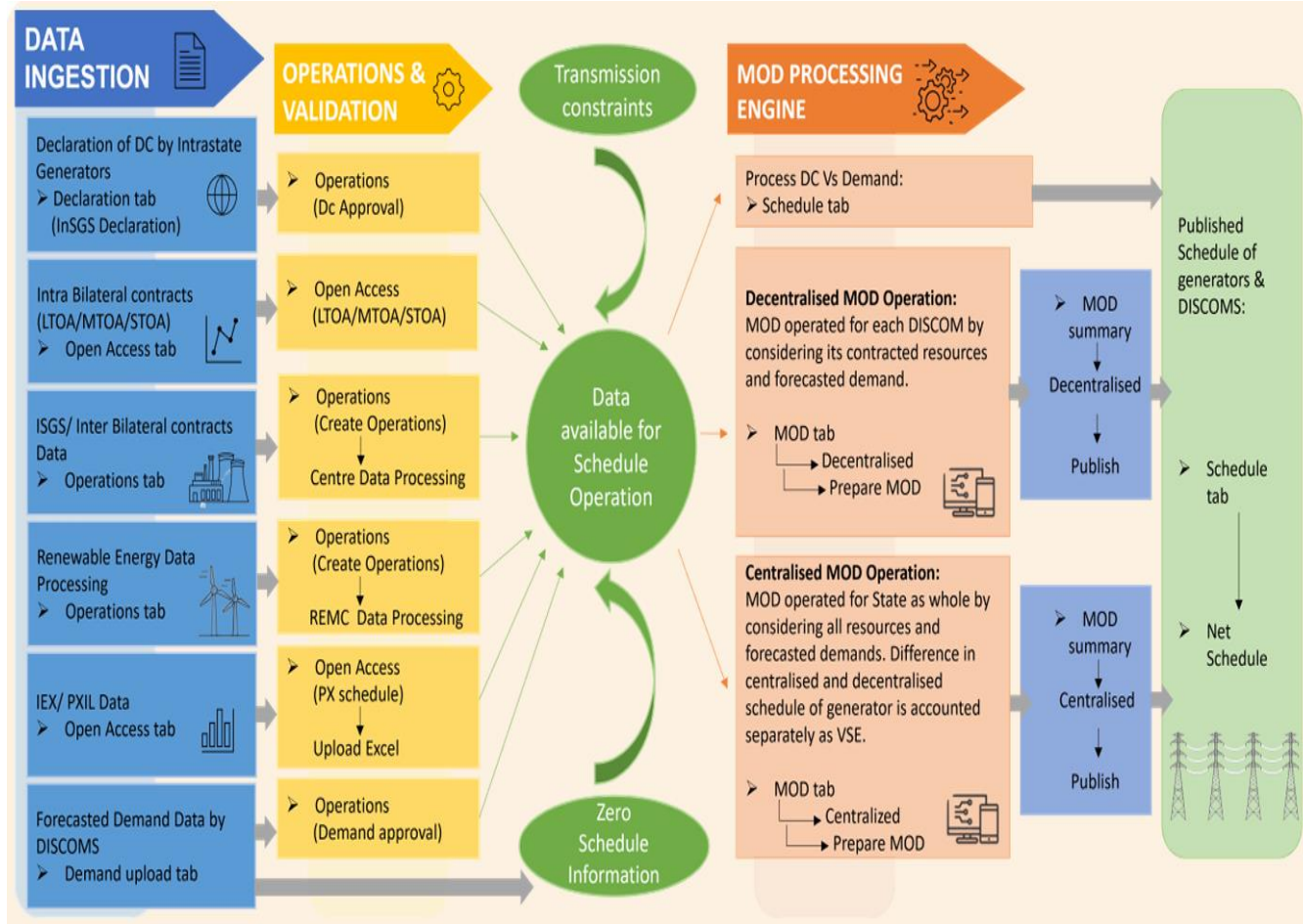
Impact of rooftop solar on system demand

- Policy input to state energy policies

# Transition to Security Constrained Economic Dispatch in Maharashtra

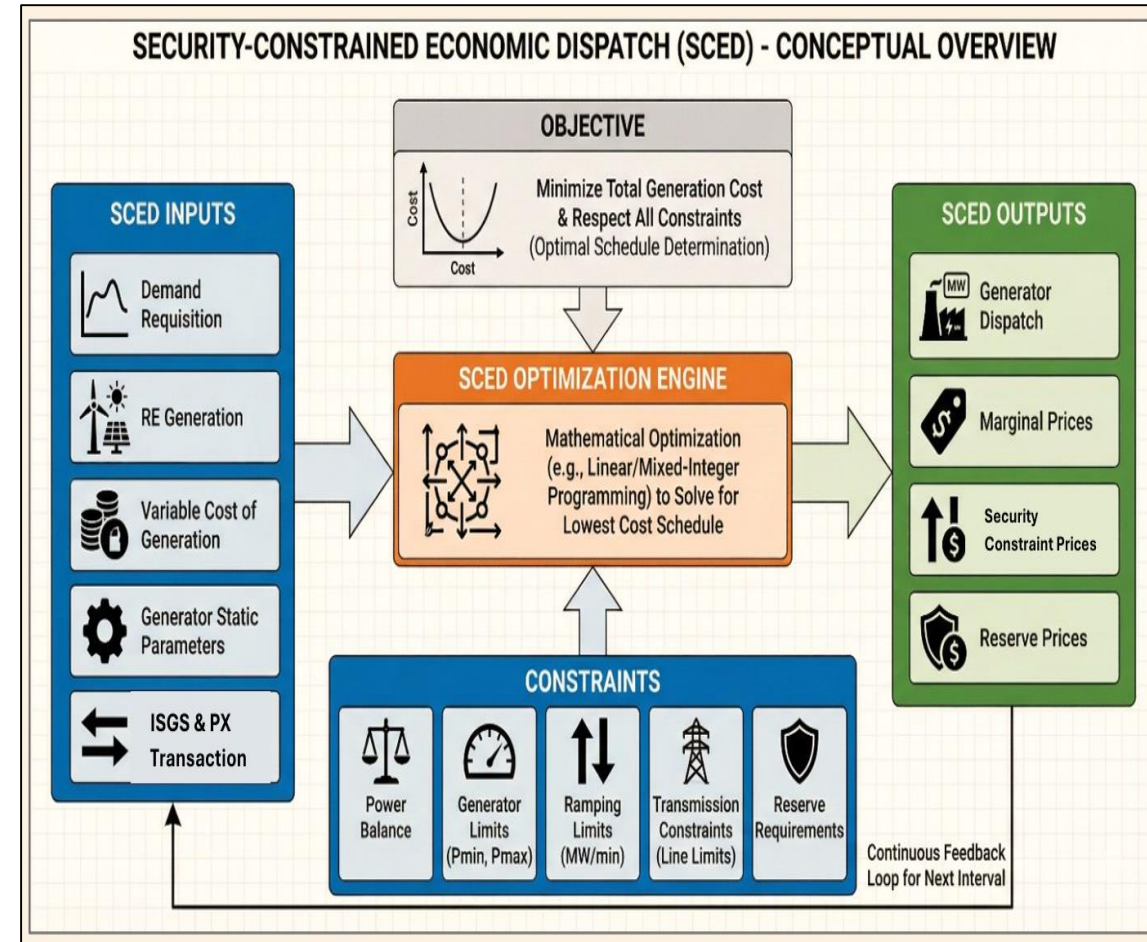
## Existing Scheduling System:

- Merit Order Despatch (MOD) mechanism (Decentralized & Centralized)
- Regulatory mandate under MEGC, 2020, Part 'E': S&D Code
- Honoring Multiple decentralized Bilateral Contracts (~100 ISGS, ~200 InSGS, ~60 (STOA, MTOA, LTOA), ~400 REMC, ~6 **Inter Discom Trade**)



## Evolving Scheduling System:

- Security Constrained Economic Dispatch (SCED)
- Regulatory mandate under IEGC, 2023, S&D Code: 49(2)
- Aligned with FoLD's "My SCED" Initiative & Hon'ble **MERC's** Regulatory directions for Pilot Study.



- **Virtual State Entity (VSE):** A pool-based settlement mechanism acting as a counterparty to manage network constraints and deviations via incremental/decremental despatch.

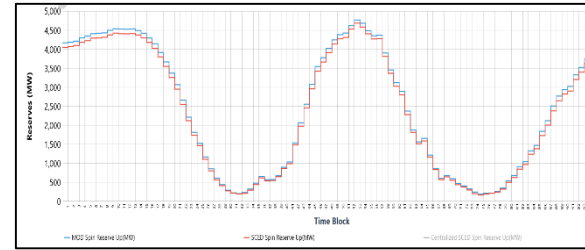
# DRISHTI

## Digital Intelligence for Secure & Economic Grid Operation

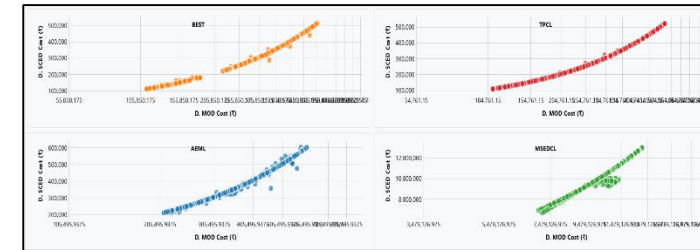
- Large Scale of Maharashtra Power system: ₹200 cr/day energy charge — even ₹0.01/kWh efficiency yields big savings.
- Proven Value: ~₹0.01/kWh efficiency → ~₹100 cr annualized savings realized in Online SCED pilot.

### System Patterns & Decision Insights

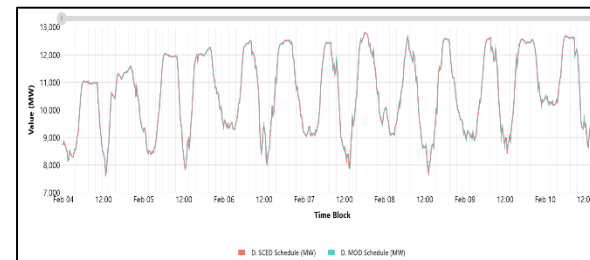
Up Reserve vs Time Block



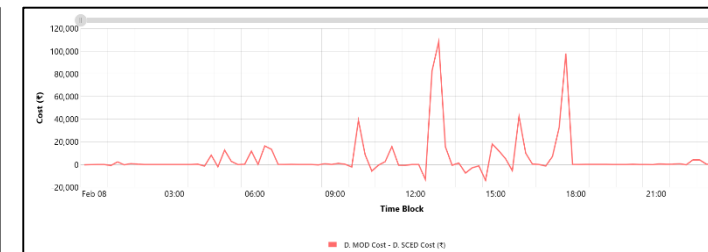
SCED Cost vs MOD Cost



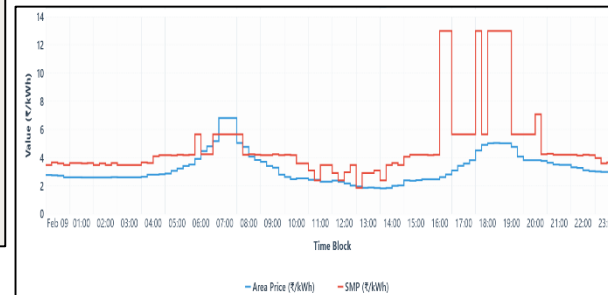
SCED Schedule vs MOD schedule



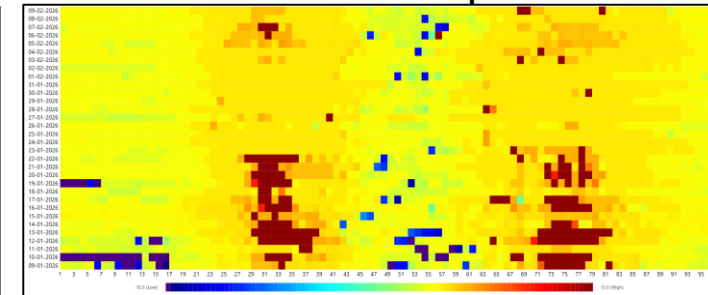
Savings vs Time Block



SMP vs MCP



SMP Heat Map



<b>Reserve</b>	<b>Performance</b>	<b>Infeasibility</b>	<b>SMP</b>	<b>Scatter</b>	<b>Diurnal</b>	<b>Duration</b>
Ramp Reserve Generator	Generator	Infeasibility Overview	SMP	Generator 2D Scatter	Generator-Avg	Generator
Ramp Reserve Discom	Generator All Blocks	Infeasibility Plot	SMP vs MCP	Discom 2D Scatter	Discom-Avg	Discom
Cumulative Ramp Reserve	Discom	Infeasibility Daily Count	Avg SMP	Generator 3D Scatter	Generator-DateWise	Multiple Generator
Spinning Reserve Generator	Discom All Blocks	Surplus/Shortfa II Count	SMP Duration	Discom 3D Scatter	Discom-DateWise	Multiple Discom
Spinning Reserve Discom	Generator Centralized	Surplus/Shortfa II Daily	SMP Heat Map			
Cold Reserve	<b>Diagnostics</b>	<b>VC</b>	<b>Trend</b>	<b>Validation</b>	<b>Monitor</b>	
Cumulative Spinning Reserve	Engine Log	Cumulative Capacity vs VC	Multi-Y Axis Generator	Generator Data Status	Real-Time Display - Generator	
Reserves - Diurnal Pattern	Interruption Log	Variable Charge Upload	Multi-Y Axis Discom	Station Wise Installed Capacity	Real-Time Display - DISCOM	
Reserves - Histogram	Last Processed Log	Variable Charge Details	<b>DUALS</b>	Zero Schedule	Real-Time Display - Centralized	
<b>Price &amp; Cost</b>	<b>Radar Plot</b>		Time Series	<b>Perturbation</b>		
MOD vs SCED Discom	Cost Difference	<b>3D Surface</b>	Average	Perturbation Plot	<b>Load Factor</b>	
MOD vs SCED Generator	Schedule Difference	Generator 3D Surface	<b>SCUC</b>	Perturbation Daily Count	Generator	
	<b>Savings</b>	Discom 3D Surface	SCUC		Discom	
	Savings	<b>Settlements</b>	<b>Learning</b>	<b>Histogram</b>	<b>Supl - Demd</b>	
		Settlements	Learning Management System	Histogram	Supl - Demd	
<b>Utilization</b>			<b>Feedback</b>			
Utilization			Feedback			

### Complete Dashboard Module Landscape

# MAHARASHTRA SLDC'S RENEWABLE ENERGY INTEGRATION & REAL-TIME MONITORING.

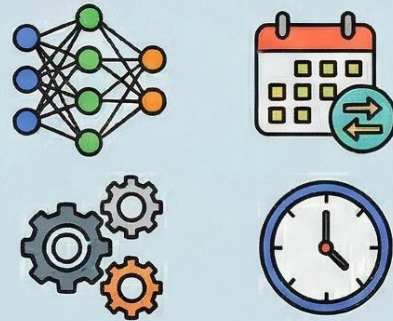
## RE FORECASTING & SCHEDULING TOOL - OPERATIONAL SINCE JULY-2019

### INPUTS & DATA SOURCES



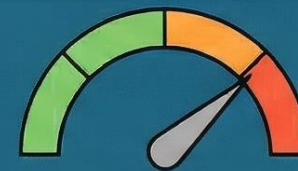
- Real-Time Generation & Weather Data from RE Plants
- NCMRWF Weather Forecasts
- Power Forecast from External Agency

### FORECASTING & SCHEDULING

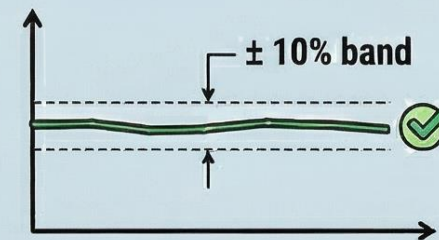


- Schedules from QCAs
- ML-Based Internal Forecasting Tool
- Week-Ahead, Day Ahead, and 16 Intra-Day Revisions

### PERFORMANCE METRICS



NRMSE of Internal Forecasting Tool: 4.6%



QCA SCHEDULE ERROR < 10% for 100% period of the year

### OPERATIONAL MONITORING & COMPLIANCE



- Monitoring Real-Time Generation visibility
- Issue Notices for Large Deviations
- Collect Dynamic Models at FTC
- Field Measurements for Power Quality
- Monitor RE Plant behavior during Grid Events

**PENALTY for Non-Visibility: Rs.5,000/- per day**

# MAHARASHTRA STATE ELECTRICITY TRANSMISSION CO. LTD. (MAHATRANSCO) | OPERATIONAL OVERVIEW & COMMITTEES | (per MEGC Regulations, 2020 & IEGC)

## OPERATIONAL COMMITTEES

-  Grid Co-ordination Core Committee (GCC) 
-  Operational Co-ordination Committee (OCC)
-  Maharashtra Transmission Committee (MTC)
-  Protection Co-ordination Committee (PCC)
-  Metering & Communication Co-ordination Committee (MCCC)
-  Mumbai Islanding Group
-  LTS Monitoring Committee

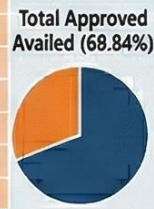
## OUTAGE PLANNING & MANAGEMENT (MSLDC, Kalwa)

'Managing outages of 765 kV, 400 kV & 220 kV via web-based OMS.'

-  State Outage Coordination Meeting (SOCM)
-  Mumbai outage Coordination Committee Meetings (MOCM) (monthly transmission outage feasibility)

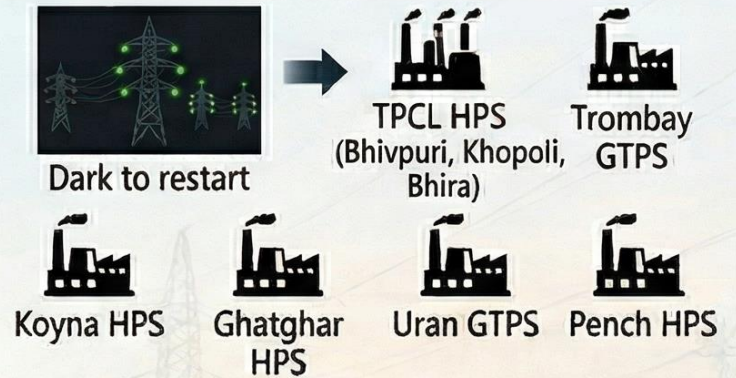
### Outage abstract for Year 2025

Month	Total Proposed (Nos)	Total Deferred by			Total Approved (Nos)	Total Aailed (Nos)	Total Not Aailed (Nos)	Approved Aailed %
		WRLDC (Nos)	from site (Nos)	by SLDC (Nos)				
JAN	1836	108	36	456	1236	822	414	66.50%
FEB	1852	164	371	74	1043	638	405	61.17%
MAR	1723	404	220	16	1083	689	394	63.62%
APR	2050	183	500	13	1434	1163	271	81.18%
MAY	1675	523	16	106	1030	694	336	67.38%
JUN	1233	405	100	29	699	467	232	
JUL	1201	90	414	9	688	472	187	
AUG	1177	354	24	112	707	473	217	
SEP	1339	405	107	13	814	601	216	
OCT	767	102	336	7	322	222	61	
NOV	990	444	78	65	403	318	85	
DEC	941	48	51	403	439	354	85	
<b>TOTAL</b>	<b>16564</b>	<b>3183</b>	<b>51</b>	<b>403</b>	<b>9898</b>	<b>6913</b>	<b>2903</b>	






## DISASTER MANAGEMENT & RELIABILITY

- **Black Start Procedure** (Recovering from partial or total blackout)

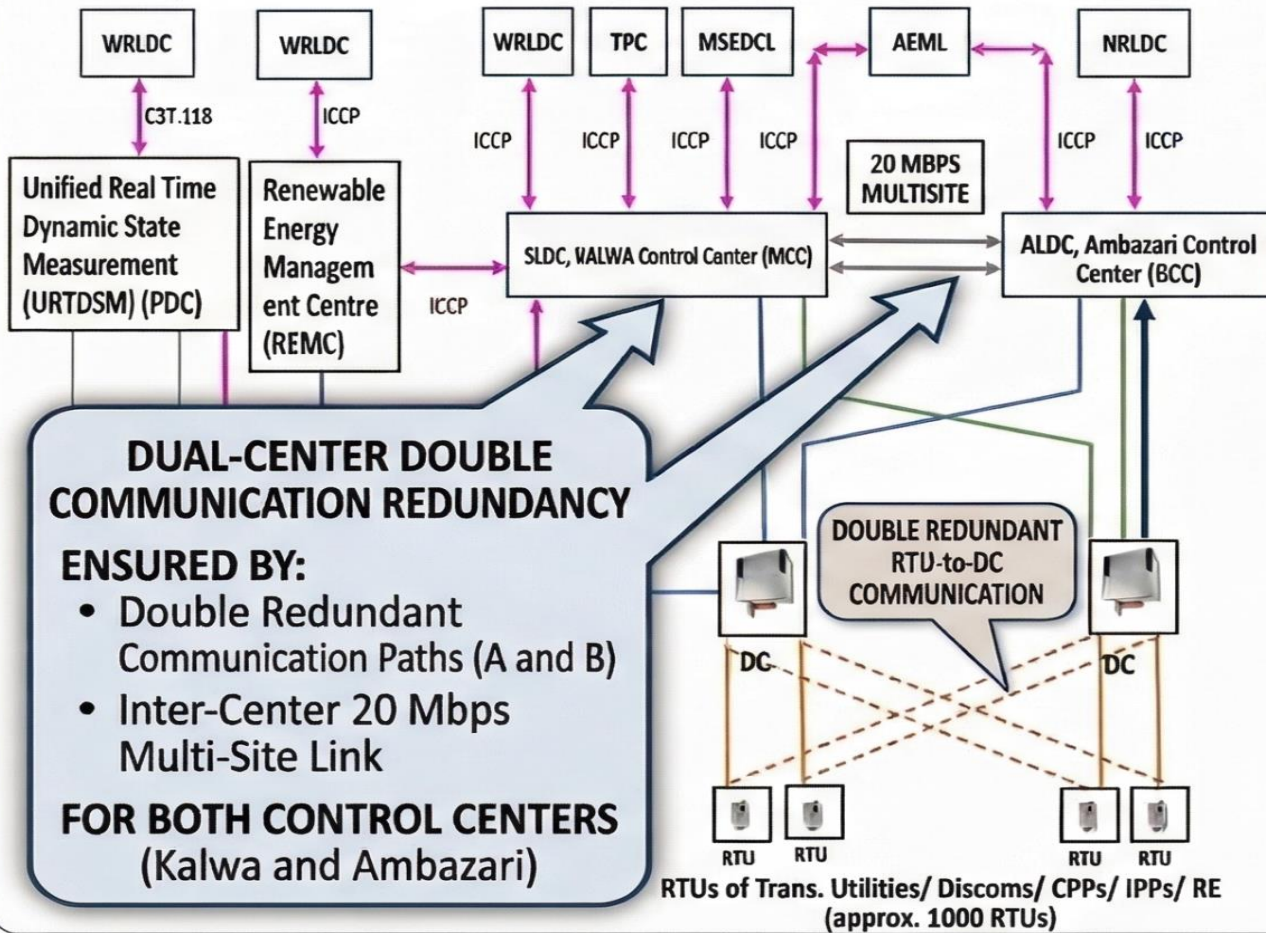


### Back-up Control Operation through ALDC

-  Main-I / Main-II planned rather than Main & Back-up (as per MOP & CABIL)
-  LDC functions from Main I & II at periodic intervals
-  BCC Mock Drill (ensuring smooth contingency function, last 3 years)

# MAHARASHTRA POWER SYSTEM OVERVIEW: KEY ARCHITECTURES & METRICS

## SCADA/REMC/URTDISM COMMUNICATION ARCHITECTURE



### DUAL-CENTER DOUBLE COMMUNICATION REDUNDANCY

#### ENSURED BY:

- Double Redundant Communication Paths (A and B)
- Inter-Center 20 Mbps Multi-Site Link

FOR BOTH CONTROL CENTERS (Kalwa and Ambazari)

## SAMAST IMPLEMENTATION & OPERATIONAL METRICS

### Foundation:

- Post-MERC Case 42 (2006)
- Intra-State ABT adopted Aug 2011
- Unified Pool Membership

### KEY METRICS (SAMAST SCOPE):

<b>SUBSTATIONS:</b>	<b>1039</b>
<b>INTERFACE ENERGY METERS:</b>	<b>7024</b>
<b>TOTAL INSTS ENTITIES:</b>	<b>180</b>
• Buyers:	19
• Sellers:	161

## SAMAST OPERATIONAL WORKFLOW & GOVERNANCE

### SCHEDULING & METERING:

- Ex-ante scheduling per State Grid Code
- ABT-compliant Main/Check meters with AMR across generators, IPPs, and open access customers for real-time data

### GOVERNANCE & TRANSPARENCY:

- Reconciliation & payment security
- Weekly/monthly data published on SLDC

### ACCOUNTING & SETTLEMENT:

- Uniform energy accounting
- DSM-based settlement
- Monthly transmission losses via DSM-integrated ERP

INTERFACE POINTS METERING DATA (MAHARASHTRA ZONE):	Main Meters	Check Meters	Total
Interface points:	3512	3512	3512
Main Meters:	3512	3512	3512
Check Meters:	3512	3512	3512

## CORE SYSTEM FUNCTIONS (DETAILED OVERVIEW)



**SCADA SYSTEM FUNCTIONING:**  
Monitors grid in real-time.  
MCC at Airoli, BCC at Ambazari.

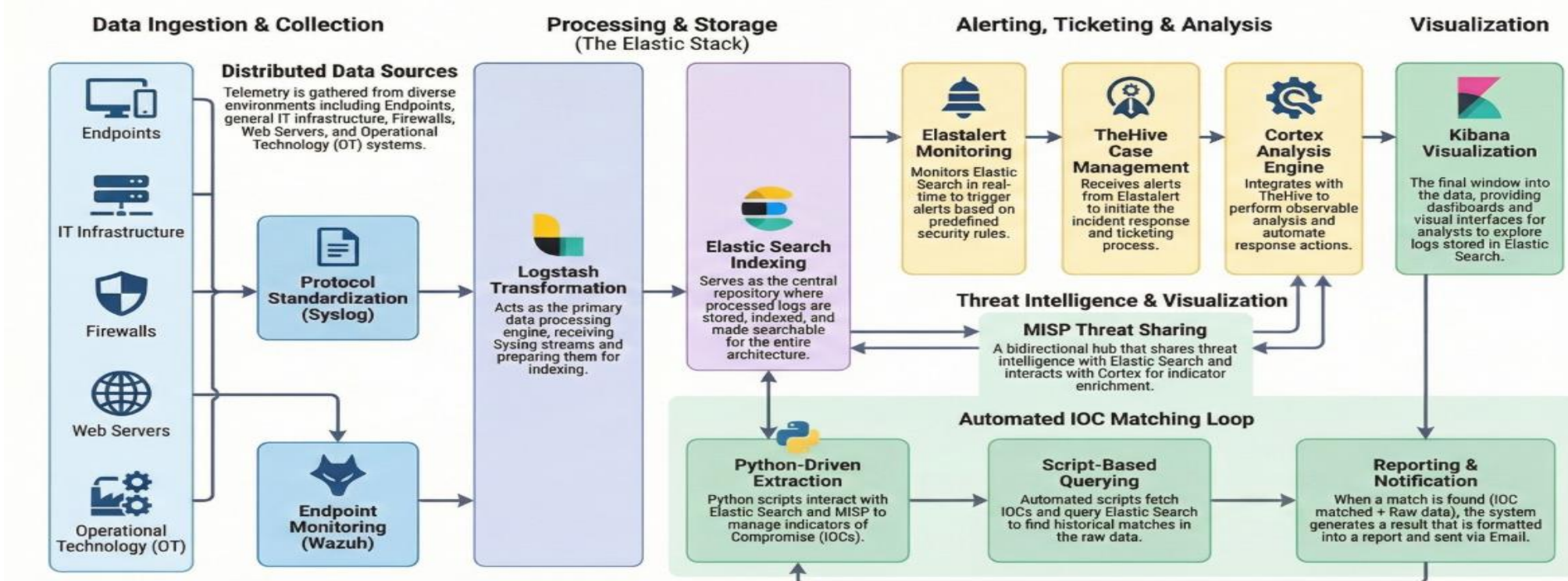


**REMC SCADA SYSTEM FUNCTIONING:**  
Part of Green Energy Corridors infrastructure. Comprises forecasting/scheduling tools, ICCP. Facilitates RE forecasting using real-time solar/wind data.



**URTDISM SYSTEM FUNCTIONING:**  
Uses Phasor Measurement Units (PMUs) to monitor grid stability via GPS-Synchronized high-resolution data (voltage/current phasors, ROCOF, active/reactive power, frequency).

# Cyber Security BEST practices and SOC at MSLDC



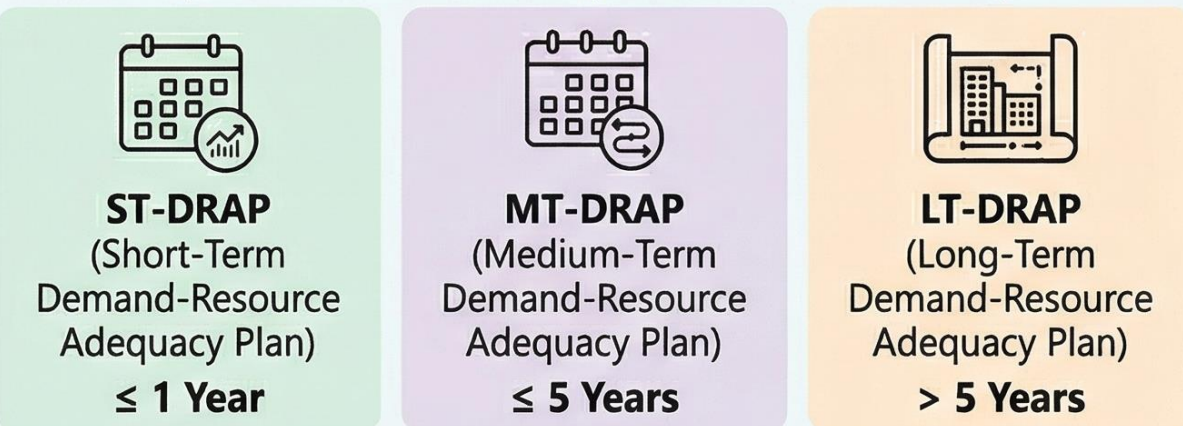
- 24 x 7 round the clock traffic monitoring (IT & OT)
- Immediate action on advisory (C-SOC, CERT-IN, NCIIPC)
- Regular Patch updates & AV definitions update
- Enabling Geo Fencing on all Public facing Sites
- Hardening of IT-OT connectivity
- Air-gapping among OT subsystems
- Restricted VPN connectivity
- Regular Cyber Security Audit
- Annual mock drill for Crisis Management
- CII notification as Protected System
- Periodic review of the Firewall/AD Policies
- Periodic review of OT System through OEM for potential cyber vulnerabilities
- Access Control Implementation

# RESOURCE ADEQUACY PRACTICES IN MAHARASHTRA

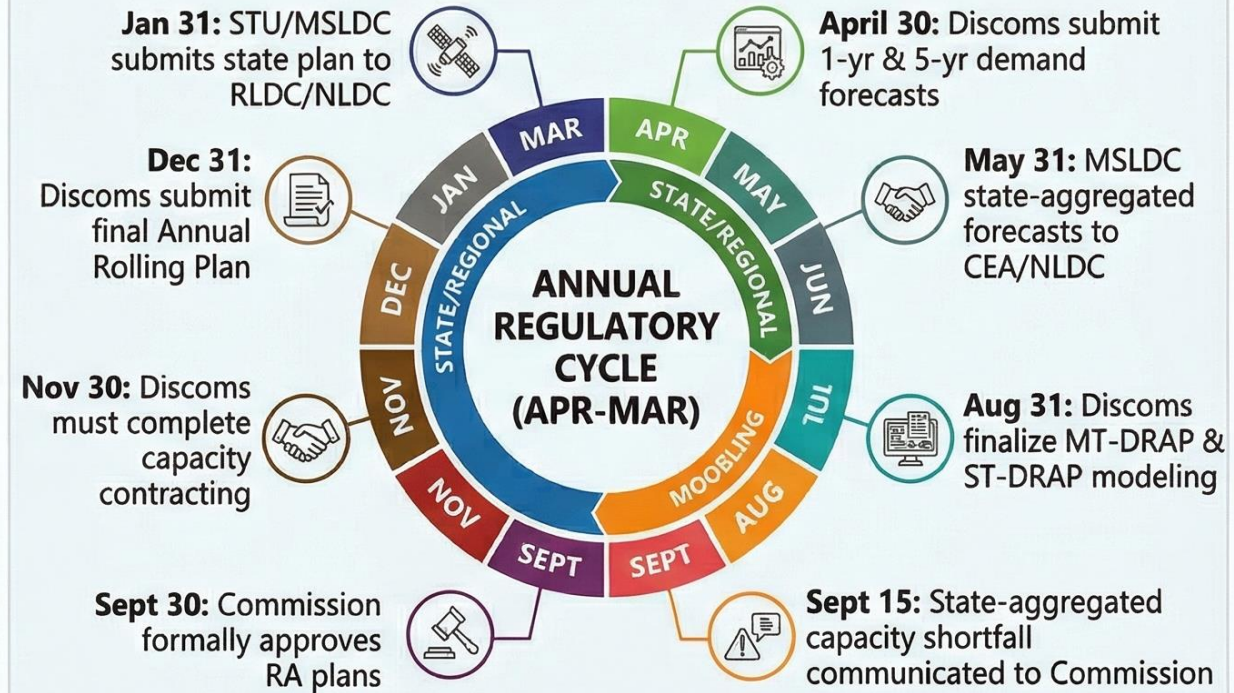
## RESOURCE ADEQUACY FRAMEWORK: KEY PHASES & OUTCOMES



### OUTCOMES (MERC REGULATIONS 2024)



## KEY REGULATORY TIMELINES FOR RESOURCE ADEQUACY



## GENERAL DEMAND ESTIMATION TIMELINES (CERC 2023)

<b>Daily</b>	10:00 hours of Previous day
<b>Weekly</b>	First Working day of previous week
<b>Monthly</b>	Fifth day of Previous month
<b>Yearly</b>	30 <sup>th</sup> September of previous year

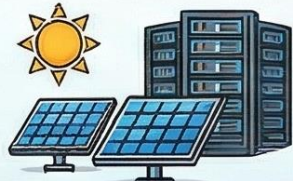
# MSLDC's Transformational Journey: Building a Resilient, Sustainable & Secure Grid



## RESEARCH & INNOVATION FOCUS

### Ongoing Studies (Selected)

- Renewable Energy
- Data Center Load Pattern
- Ancillary Services
- Inertia Monitoring
- Reactive Power Management
- Security Constrained Economic Despatch (SCED)
- MSKVY and Rooftop Solar
- Special Protection Schemes (SPS)



## KNOWLEDGE SHARING & COLLABORATION

### MoU with IIT Bombay (03.09.2025)

- Grid Security & Resilience
- Paper Selected for IEEE ICPS 2025
- Intrastate SCED at IIT Hyderabad



### Reports

- Annual Operational & Performance Report
- Black Start Preparedness
- Decadal Assessment of Electricity Demand & Rooftop Solar
- Compendium of Grid Disturbances 2025



## ACHIEVING EXCELLENCE & AWARDS



Gold Medal - Skoch Award 2024

LDC Excellence Award 2023



Diamond Level – ISGF Innovation Award 2026 (for Advanced Grid Resilience)

Best SLDC - IPPAI Power Awards (2024 & 2025)



Easiest Access for Open Access - IPPAI Power Award



## CAPABILITY BUILDING & TRAINING



### Summary of Employees Trained up to Mar-25

CYBER SECURITY	55
TECHNICAL (SCADA/PSSE/SCED/BCC)	38
REGULATORY/COMMERCIAL/ACCOUNT	34
TEAM BUILDING/HR/LEADERSHIP	89
Others...	--
<b>Over All Total:</b>	<b>720 Man days</b>



**Thank You**