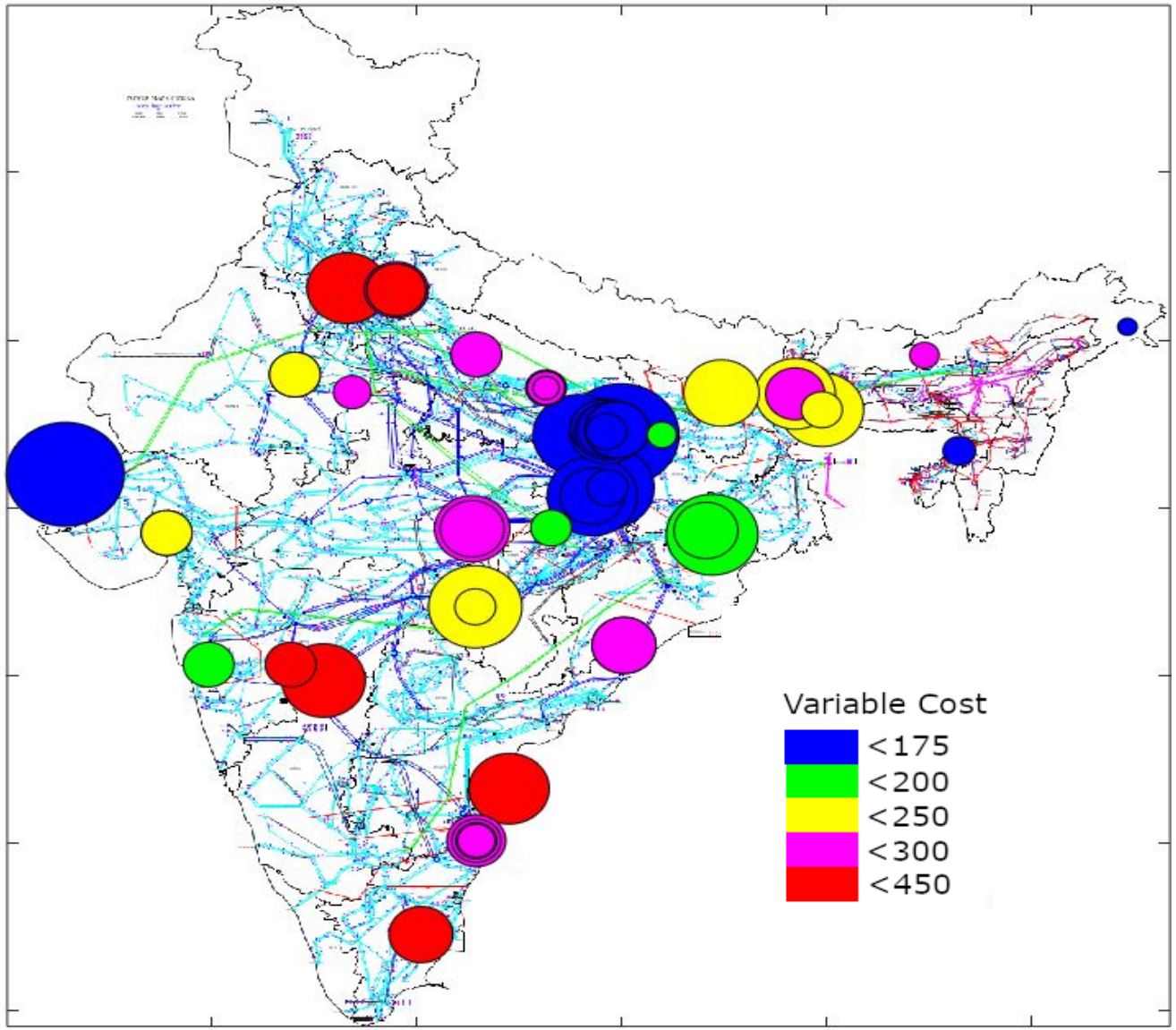
Energy Market Reforms Consultative Workshop
CERC and MERC

13th September, 2019 at Mumbai, Maharashtra

PILOT PROJECT ON

SECURITY CONSTRAINED ECONOMIC DESPATCH IN ISGS PAN-INDIA

SPATIAL DISTRIBUTION OF VARIABLE COST OF GENERATORS



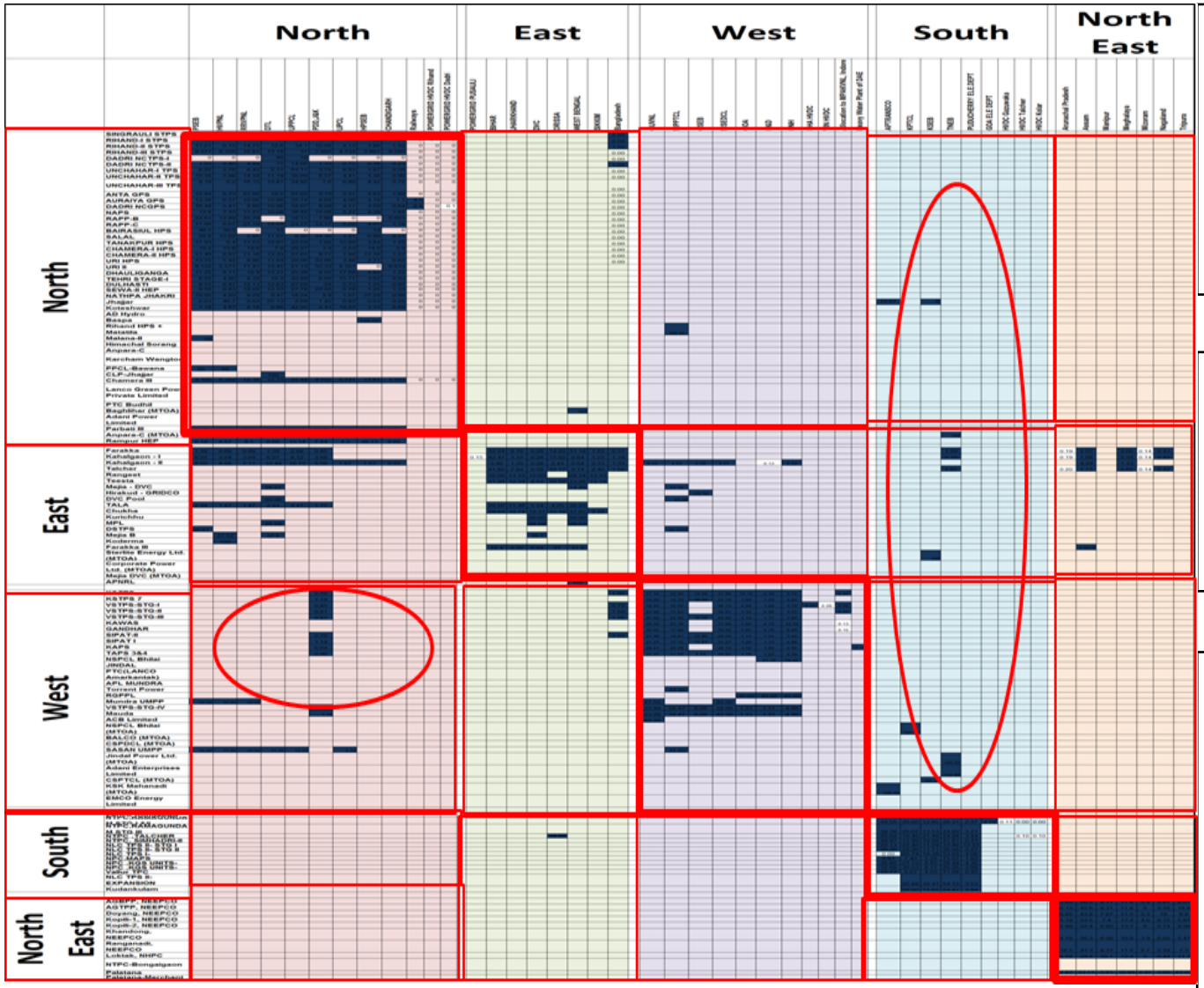
VC(Variable Cost Paisa/kW

VC<175 h
175<=VC<200
200<=VC<250
250<=VC<300
300<=VC<450

Installed Capacity (MW)

200<=MW<300
300<=MW<500
500<=MW<800
800<=MW<1500
1500<=MW<2500
2500<=MW<4500

COMPLEXITY OF ALLOCATIONS TO BENEFICIARIES PORTFOLIO



Composition of Allocation Matrix

- ~150 Plants (Inter-State)
- 36 States/UTs
- Approx. half a Million contracts/day (~ 150x 36 x 96)

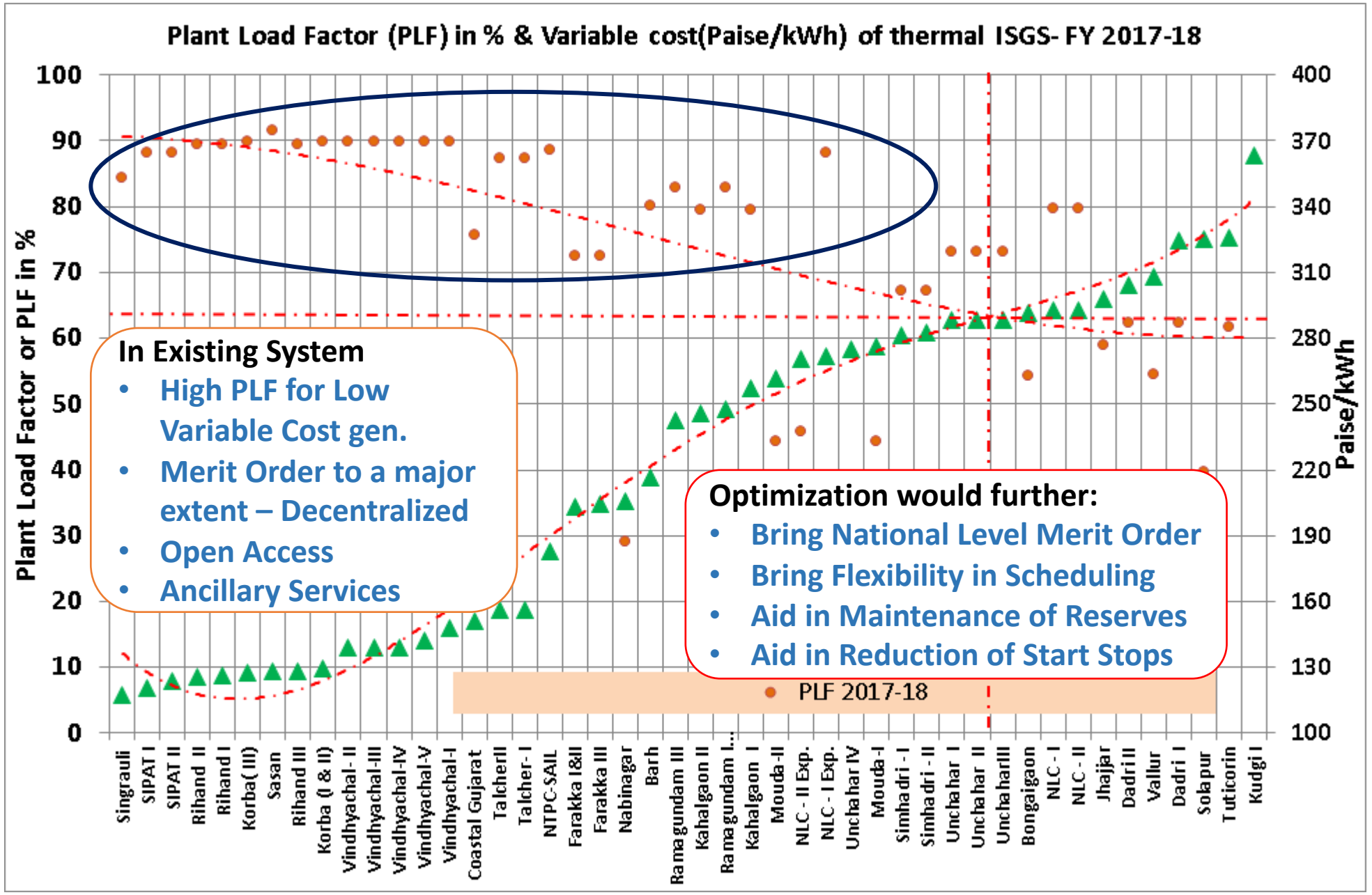
Need for Optimization

- Fragmented allocation
- Savings in Total Production Costs
- Harness Flexibility in scheduling

Scope for Incremental Optimization and Generating Savings

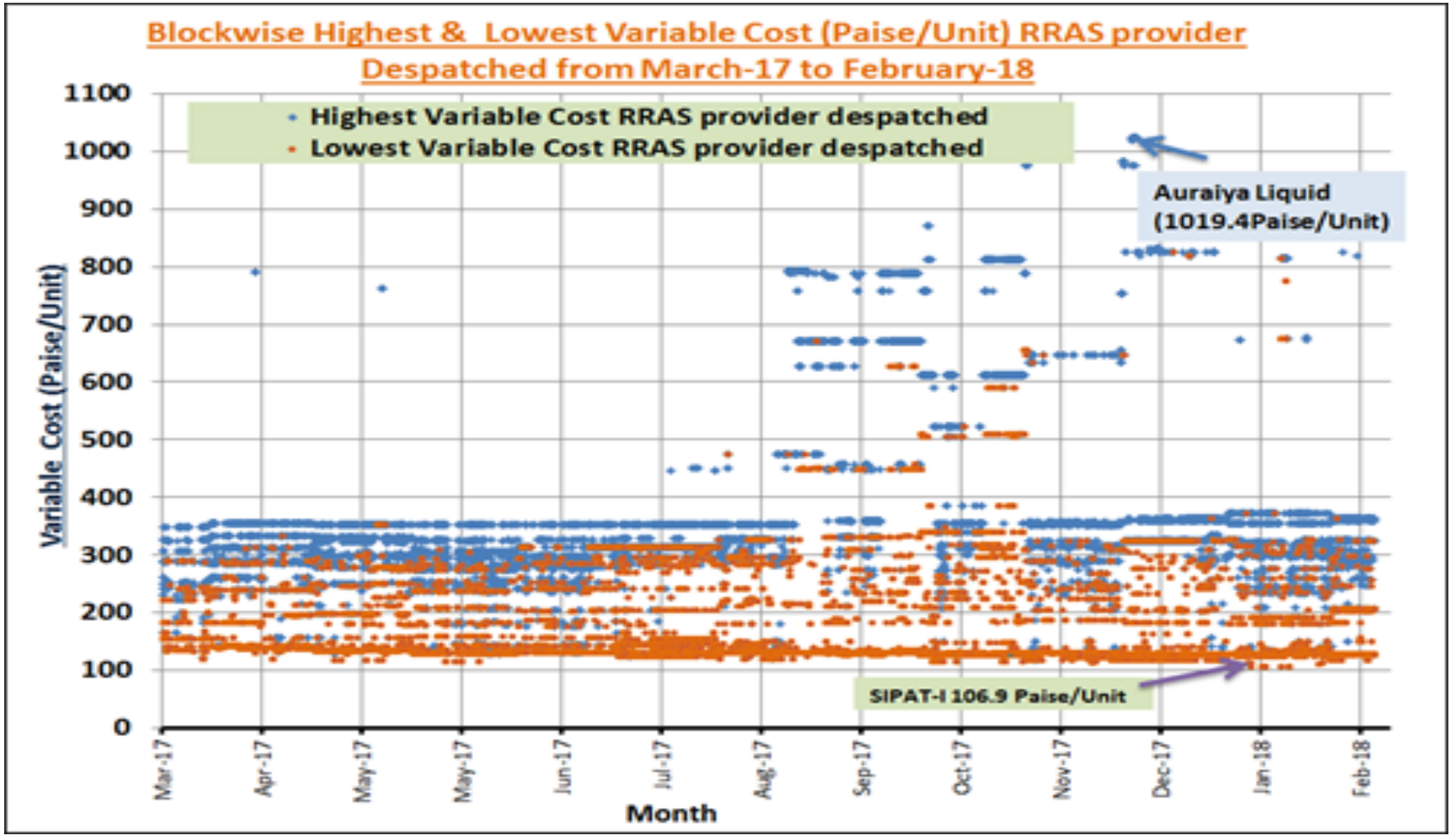
- Diversity
- Decentralized scheduling
- Transaction Cost

PLF & Variable Cost



Variable Cost of RRAS Provider

RRAS: Reserves Regulation Ancillary Service



Example

Thin Centralized Optimization Layer

Present Decentralized Scheduling Process

(IC - 4000 MW)
(₹ 5/kWh)
Gen A 4000 MW
A – 1000 MW
B – 2000 MW
C – 1000 MW
State X TOT- 4000 MW

(IC -5000 MW)
(₹ 6/kWh)
Gen B 4000 MW
A – 1000 MW
B – 1000 MW
C – 2000 MW
State Y TOT- 4000 MW

(IC -6000 MW)
(₹ 7/kWh)
Gen C 4000 MW
A – 2000 MW
B – 1000 MW
C – 1000 MW
State Z TOT- 4000 MW

Total IC 15000 MW

Total State Requisition 12000 MW

Total Production Cost ₹ 720 Lakhs/hour

Optimized Generation Schedule

Gen A 4000 MW

+1000
Gen B 5000 MW

-1000
Gen C 3000 MW

National Pool

Optimized Despatch Schedule

4000 MW — **State X**

4000 MW — **State Y**

4000 MW — **State Z**

= **Total State Requisition 12000 MW**

Total Production Cost ₹ 710 Lakhs/hour

> **Total Potential Savings ₹ 10 Lakhs/hour**

ECONOMIC DESPATCH - MATHEMATICAL FORMULATION

Objective Function

- Minimize Pan India ISGS Variable Cost

Subject to Constraints

- Meeting Total Requisition by States from ISGS
- Transmission Constraints (ATC)
- Technical Minimum of Plants
- Maximum Generation (DC-on-bar)
- Ramp up/down rates

- Improved Optimization algorithm
  - To make it more robust to deal with infeasibility
  - Ride through within the given constraints in real time
- The updated version of the software has been deployed w.e.f 14:45 hours of 18th Apr'19.
- Revised Detailed Procedure uploaded on POSOCO website

Minimise $\sum_{i=1}^{k} C_i P_i + \sum(Violation\ Penalties)$ .....(1)

- k = *total number of Plants*
- *Where* C_i *is the variable per unit cost of the* i^{th} *Plant*
- P_i *is the optimised scheduled power of the* i^{th} *Plant*
- $Violation\ Penalties$ are computed based on constraint violations

Subject to

- $\sum_{i=1}^{k} P_i = \sum_{i=1}^{k} S_i - Schedule\ violation$ ..... (2)
- $P_i \leq (DC\ on\ bar)$ .....(3)
- $P_i \geq P_{i,min}$ .....(4)
- $P_{i,t} \leq P_{i,t-1} + Ramp\ up\ rate + Ramp\ up\ violation$ .....(5)
- $P_{i,t} \geq P_{i,t-1} - Ramp\ down\ rate - Ramp\ down\ violation$ .....(6)
- $\forall\, r \in R,\ \sum_r (P_{i,r} - S_{i,r}) \geq \min((SCHIR_r - ATC_r), 0) - ATC\ violation$ .....(7)
  - *S* -is the scheduled power
  - *t* -represents current time of execution
  - *R* -represents each of the regions viz., North, East, West, South and North East
  - *ATC* -is the Available Transmission Capability of each region *R*
  - *SCHIR* -is the Scheduled Net Interchange of the region *R*
  - $P_{i,min}$ is the *technical minimum* for thermal power plants considered at 55% DC on bar or schedule whichever is less

SCED SOFTWARE DEVELOPMENT

Home | Schedule and Optimal | Opt. Sch - Pres. Sch | Opt. Sch - Old Opt. Sch | System Marginal Price | Logout

Security Constrained Economic Dispatch 18/03/2019 03:49:20 pm present time block: 64

SNo	Type	Plant Name	Reg.	State	Inst. Cap.	Total	DC	DC on bar	(A) Sch. for (66)	Pmax	(B) VC (P/U)	(C)Opt. Sch. for (66)	(D) = C x B x 10 / 1Lakh Opt. Cost (Lk/Hr)	Pmin	(E) =A x Bx 10/1Lakh Present Cost (Lk/Hr)	(F) =(C-A) Opt. Sch. minus Pres. Sch.(66)	G=(D-E) Savings (Lk/Hr) (66)	(H) Old Opt. Sch. for (65)	(I) = (C-H) Opt. Sch. minus Old Opt. Sch.	Ramp up rate in MW / 15min	Ramp down rate in MW / 15min
1	T	Sipat STPS Stage 1	2	Chhattisgarh	3x660	1980	1866	1866	1866	1866	119.2	1866	22	1026	22	0	0	1866	0	90	90
2	T	Sipat STPS Stage 2	2	Chhattisgarh	2x500	1000	942	942	942	942	122.9	942	11	518	11	0	0	942	0	70	70
3	T	Korba-Stage-3	2	Chattisgarh	1X500	500	471	471	471	471	124.7	471	5	259	5	0	0	471	0	35	35
4	T	Korba STPS Stage 1 and 2	2	Chhattisgarh	3x200 + 3x500	2100	1959	1959	1959	1959	126.7	1959	24	1077	24	0	0	1959	0	135	135
5	T	Sasan	2	MP	6x660	3960	3700	3700	3700	3700	131.4	3700	48	2035	48	0	0	3700	0	180	180
6	T	Rihand 2	1	UP	2x500	1000	471	471	469	471	134.7	471	6	259	6	1	0	471	0	50	75
7	T	Singrauli TPS	1	UP	5x200 + 2x500	2000	1835	1835	1831	1835	135.3	1835	24	1009	24	3	0	1835	0	135	200
8	T	Rihand 1	1	UP	2x500	1000	922	922	922	922	135.3	922	12	507	12	0	0	922	0	100	150
9	T	Rihand 3	1	UP	2x500	1000	942	942	942	942	137.7	942	12	518	12	0	0	942	0	100	150
10	T	Vindhyachal STPS Stage 2	2	MP	2X500	1000	932	932	932	932	144.1	932	13	512	13	0	0	932	0	70	70
11	T	Vindhyachal STPS Stage 3	2	MP	2X500	1000	942	942	913	942	144.4	942	13	518	13	28	0	942	0	70	70
12	T	Vindhyachal STPS Stage 4	2	MP	2X500	1000	942	942	941	942	144.4	942	13	518	13	0	0	942	0	70	70

	ATC	SCHIR	Reg		No. Of Units	Total Cap.	DC	DC on bar	Sch. for (66)	Pmax	SMP (P/U)	Opt. Sch. for (66)	Opt. Cost (Lk/hr)	Pmin	Present Cost (Lk/hr)	Opt. minus Present Sch.	Savings (Lk/hr)	Old Opt. Sch.	Opt. minus Pres. Sch.	Ramp up rate MW / 15min	Ramp down rate MW / 15min
	13600	8602	NR	UP,Haryana	28	9870	7112	7112	6466	7112	283.1	6078	118	3911	130	-387	-12	6118	-39		
	9999	1000	ER	Bihar,WB,Orissa	21	7650	6641	6641	5811	6641	283.1	6641	145	3652	126	830	18	6641	0		
	9999	1000	WR	MP,Chg,Guj,Mah	43	21930	19579	19579	19285	19579	283.1	19044	301	10768	309	-241	-7	19015	28		
	9750	8557	SR	AP,Tel,TM,Kar	34	13890	10328	10328	8655	10328	283.1	8442	226	5680	235	-212	-9	8378	63		
	855	0	NER	Assam	1	250	455	455	299	455	283.1	310	9	250	9	11	0	340	-30		
			AI		127	53590	44116	44116	40517	44116	283.1	40517	801	24264	811	0	-10	40495	22		

Continuous Internal Review Meetings across RLDCs/NLDC

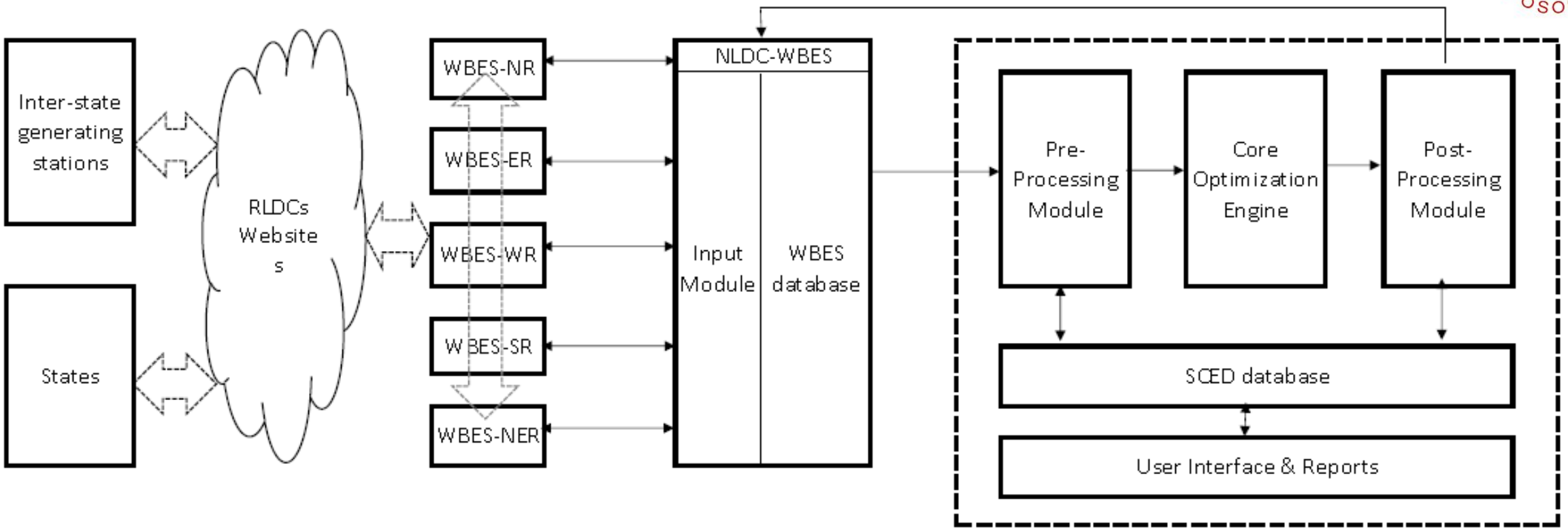
Changes in Web Based Energy Scheduling System (WBES)

Guiding Principles

- Robust enough to run continuously in real time
- Self healing / Ride-through in case of infeasibility
- No manual user intervention

- In-house development of software application
- Team of people pan-India validating the data exchange and information protocols on day to day basis.
- Data interfacing a challenge

INFORMATION FLOW IN SCED



Technologies used:

Internet	Oracle DB .NET	POSOCO WAN Internet	Oracle DB .NET	Python MS Excel	GAMS	Python MS Excel
				Mongo DB PHP, Javascript, node.js		

SCED DASHBOARD – 24X7 MONITORING

Optimal & Present schedule

Reduction in Cost

System Marginal Price

Transfer Capability

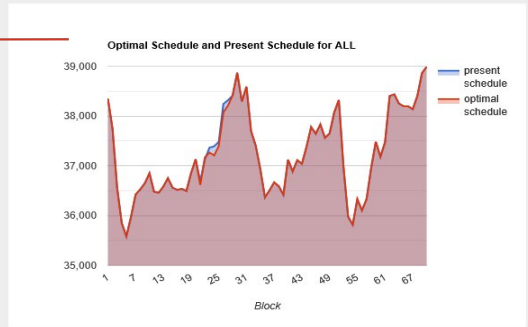
Schedule Data | Output | Application | Core Engine | Start SCED | Stop SCED

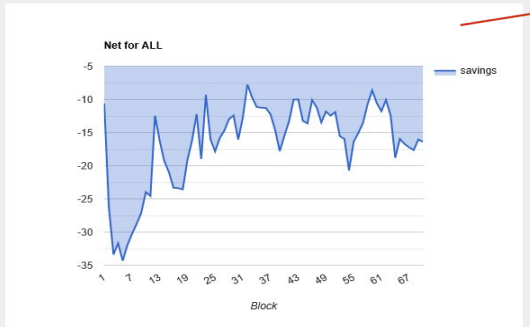
NR | ER | WR | SR | NER

Output

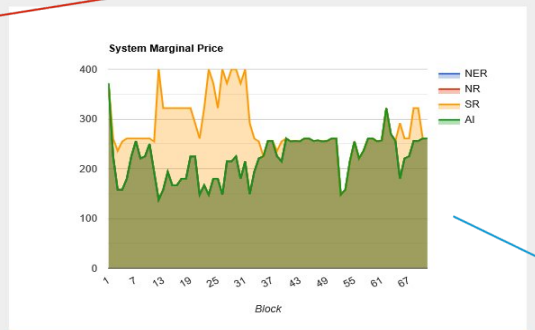
Running

Working

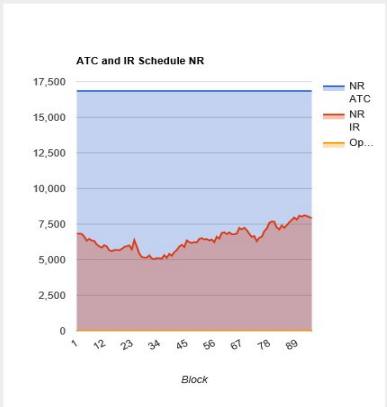


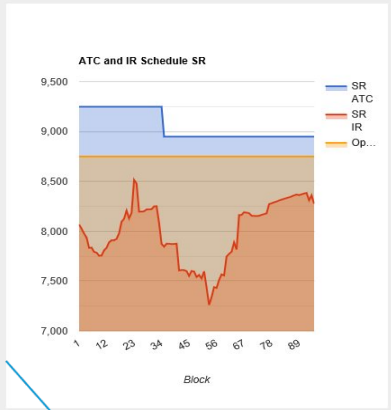


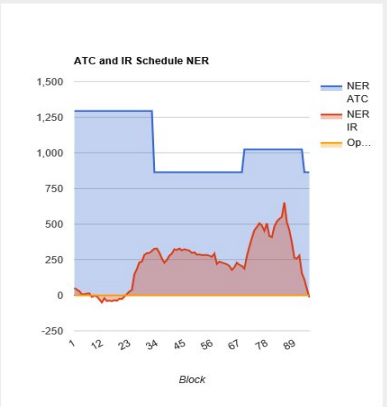
Cumulative Net :-289.63 (in Lakhs)



Average SMP NER	Average SMP NR	Average SMP SR	Average SMP ALL India
224.71	224.71	287.69	224.71







ATC and IR Schedule for Current Optimization

Region	Fetched Values(ATC)	SCH IR	Operator Filled ATC
NR	16857	6671	0
SR	8950	8153	8750
NeR	1025	403	0

HIGHLIGHTS OF PILOT ON SCED

Number of Participant Generators

49 Nos.
(Coal & Lignite based)

Number of Generating Units

132 Nos.

Total Installed Capacity

55,940 MW

Average System Marginal Price (SMP)

298.27 Paisa/Unit

Decrease in Number of Revisions in Plants

43 %

Percentage Decrease in Quantum of Revisions (in MW) in Plants

34 %

Daily Average Perturbation

1276 MW

Charges to be paid to SCED Generator

₹ 759 Crore

(Avg. approx. ₹ 6.3 Cr./day)

Charges to be refunded by SCED Generator

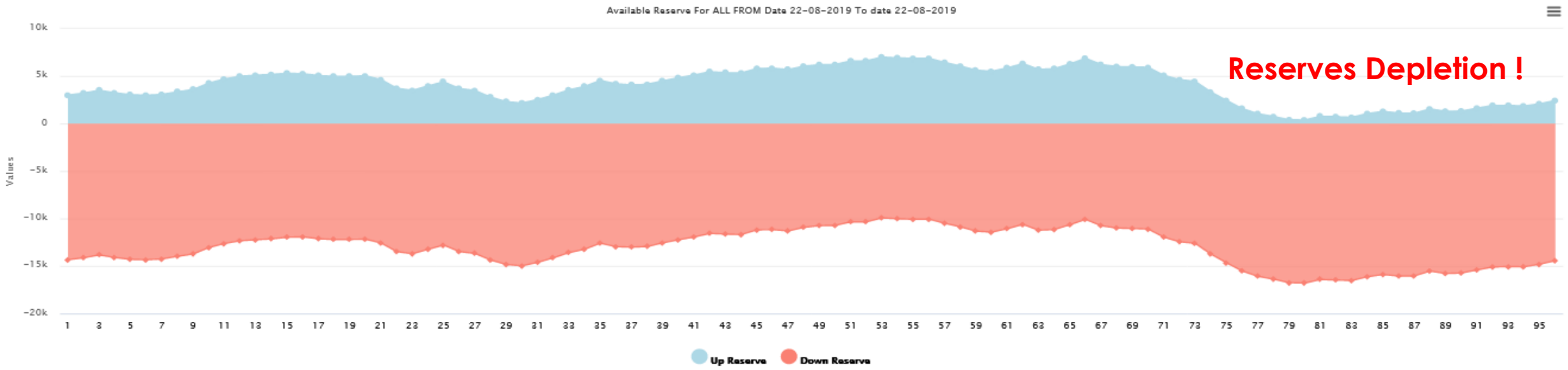
₹ 1149 Crore (Avg. approx.₹ 9.6 Cr./day)

Net Variable Charges Payable(+)/(-)Receivable Reduction in fuel cost

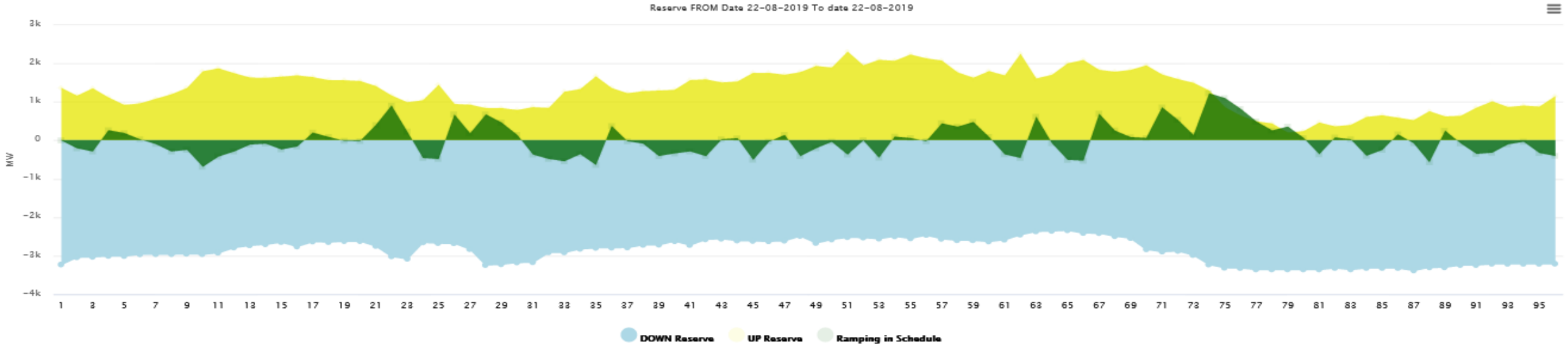
(-) ₹ 389 Crore (Avg. approx. ₹ 3.3 Cr./day)

Note: RPCs Accounts released upto 28th July, 2019

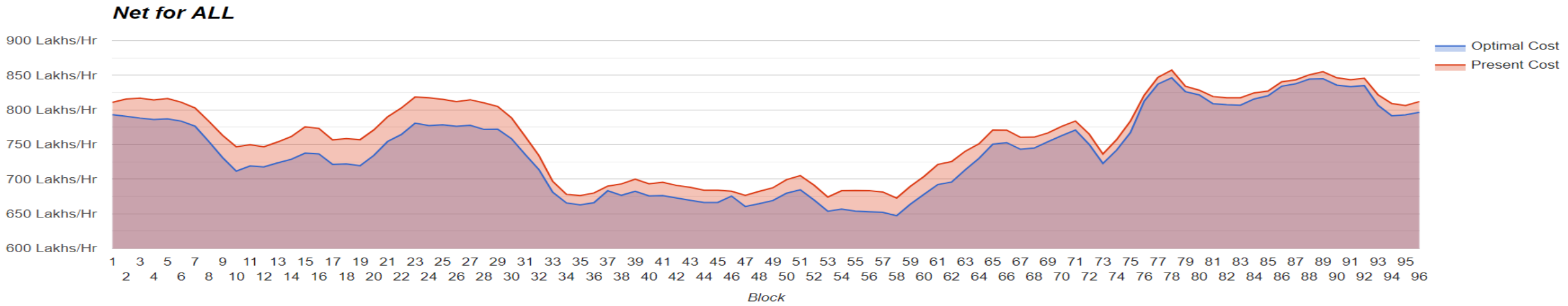
SPINNING RESERVES - SAMPLE DAY



Reserves Depletion !



Variable Cost of Generation – Before & After SCED



- (+) means payable from the 'National Pool Account (SCED)' to SCED Generator
- (-) means receivable by the 'National Pool Account (SCED)' from SCED Generator

Region	Up energy (MU)	Down Energy(MU)	Charges to be paid to SCED Generator (Rs Cr)	Charges to be refunded by SCED Generator (Rs Cr)	Net Charges* (Rs Cr)
SR	176	988	46	328	-281
WR	541	323	103	86	17
NR	513	308	92	104	-13
ER	532	169	121	39	82
NER	42	50	13	15	-2
All India	1805	1837	375	572	**-196**

Reduced Average Variable cost of generation (Apr-May 19)

210 Paise/unit → 207 Paise/unit

₹ 196 Crores reduction in fuel cost for April-May19 on a base of approx.
(without considering heat rate compensation)

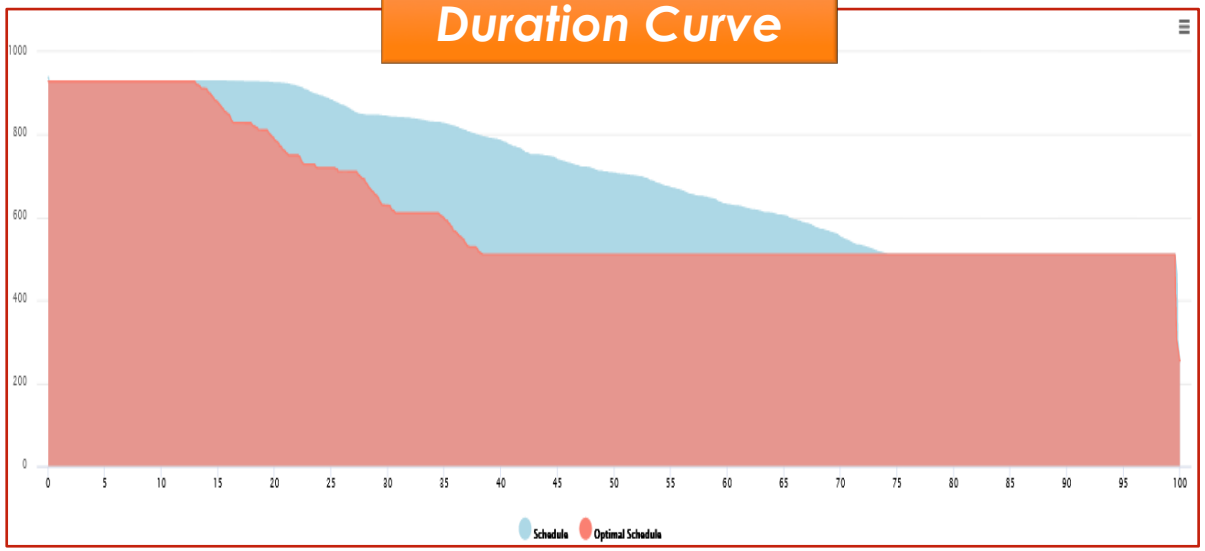
BEHAVIOUR OF GENERATION POST-SCED

Period: 15th Jun to 15th Jul'19

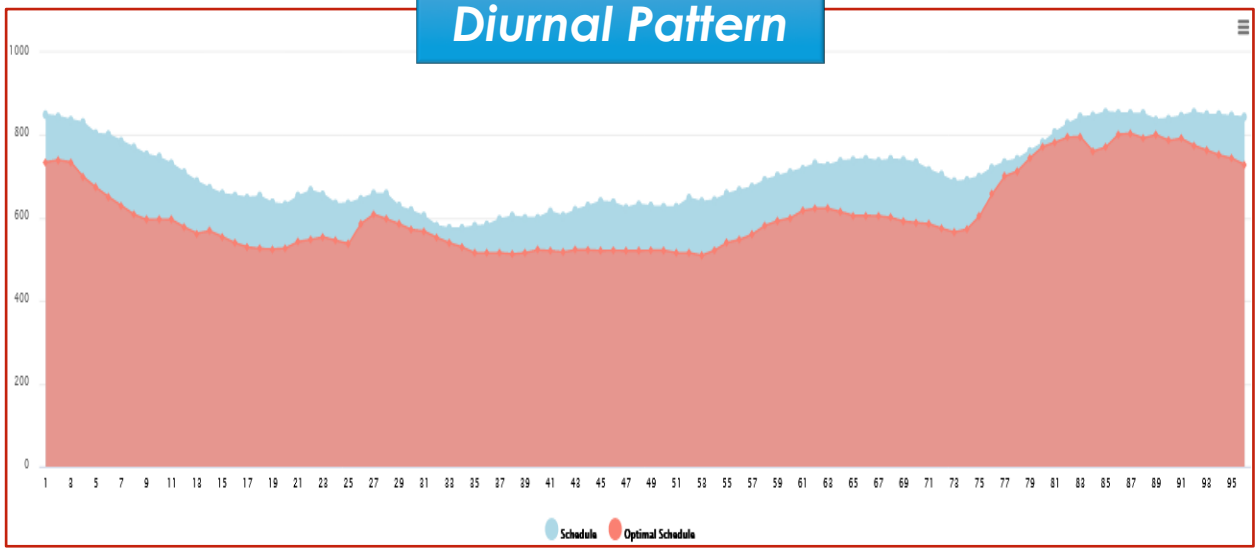
Sample Case: Dadri Stage – II TPS

Optimal Schedule & Actual Meter Reading

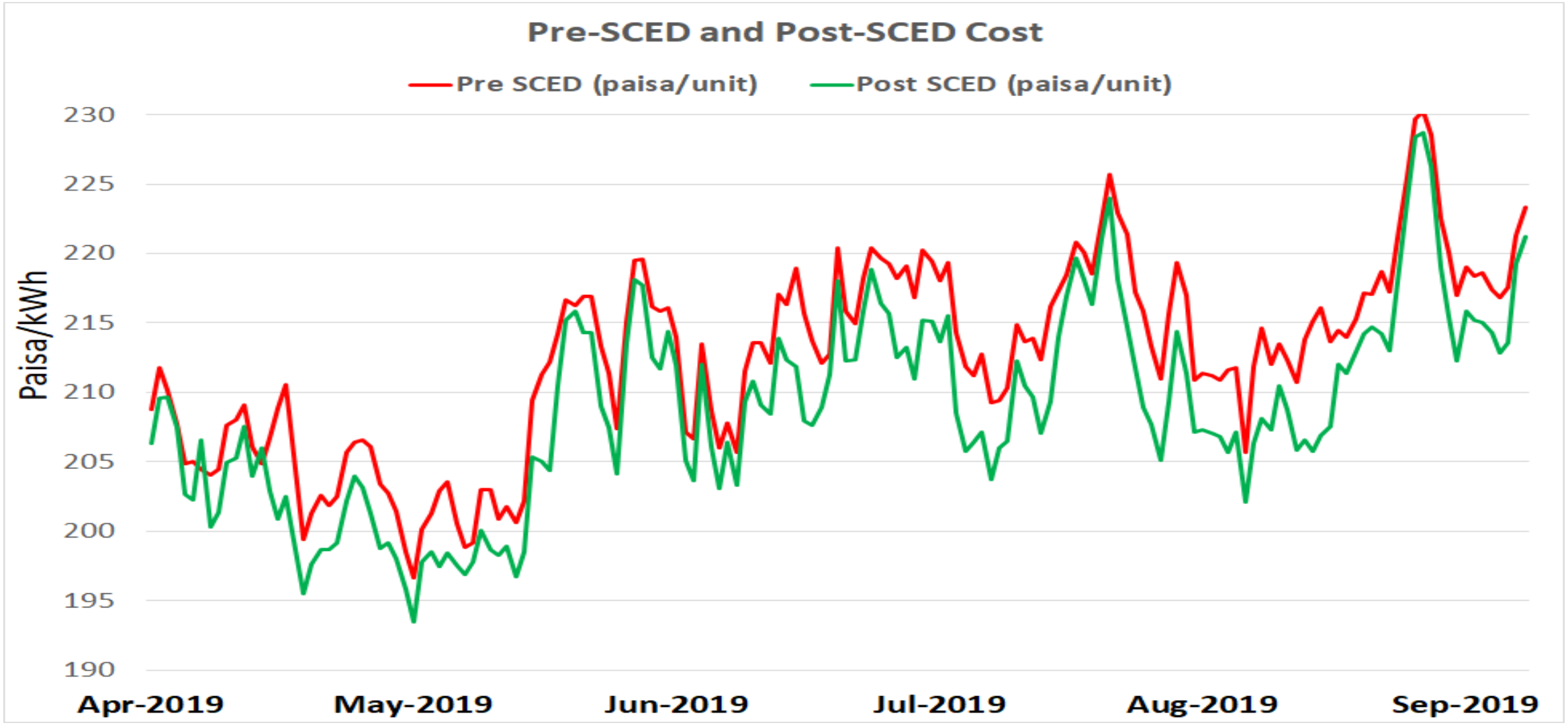
Duration Curve



Diurnal Pattern



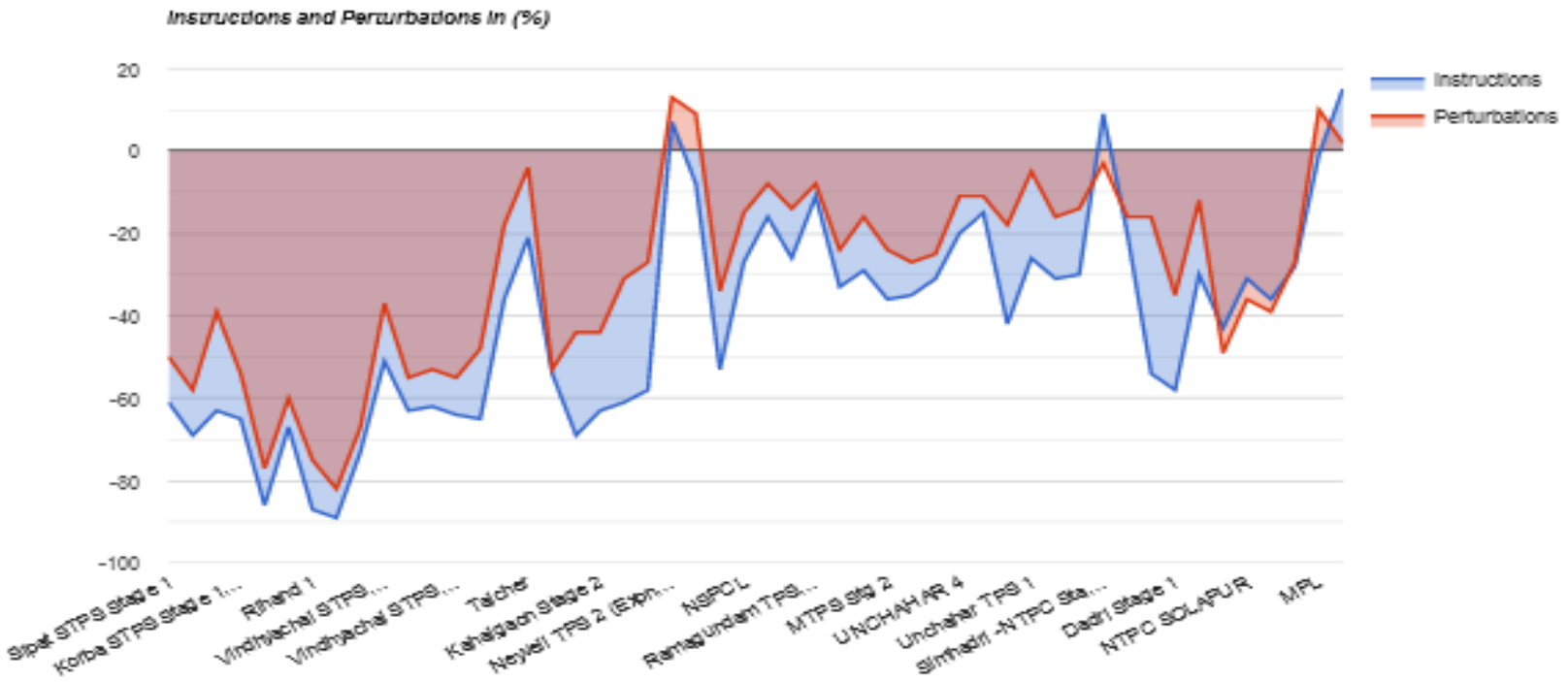
COST OF GENERATION BEFORE AND AFTER SCED



EASE OF POWER PLANT OPERATION POST-SCED

For Apr – Sep' 2019 # after SCED

- # 43% reduction in number of schedule changes
- # 33% reduction in Schedule MW changes
- Increased PLF in cheaper power stations & vice versa

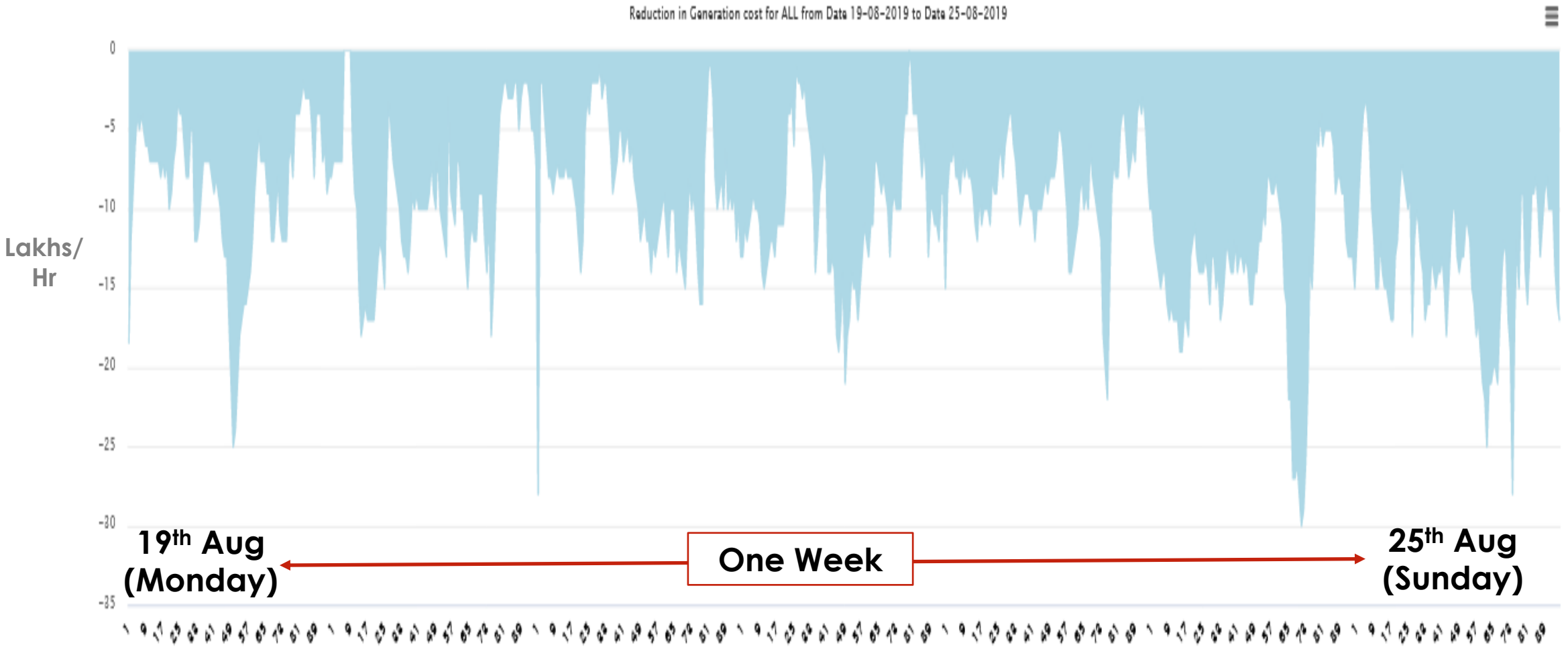


#data till 10th September, 2019

#No. of Instructions (count)		
Post SCED	Pre SCED	% Change
163293	290957	**- 43 %**

#Changes in Schedule (GW)		
Post SCED	Pre SCED	% Change
8544	12839	**-33 %**

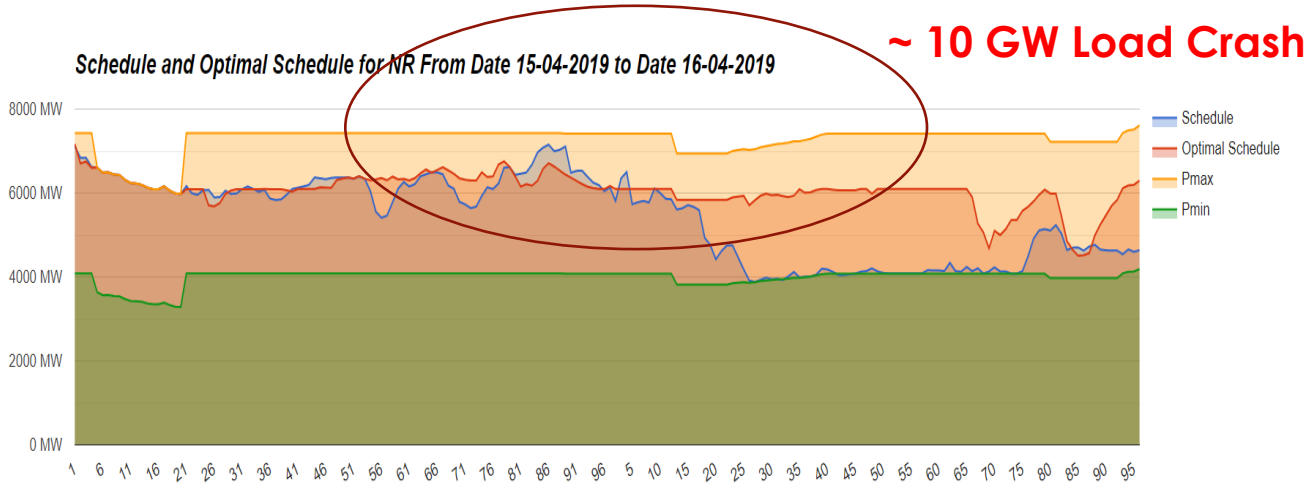
TREND OF REDUCTION IN COST OF GENERATION

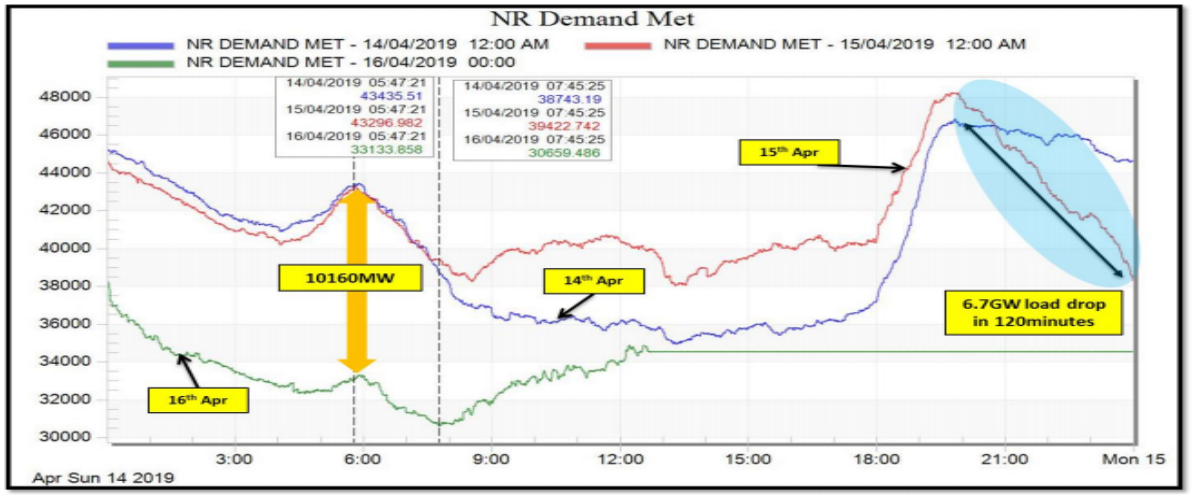


- Holidays / weekends exhibit typically higher savings
- During load crash schedule gets revised to technical minimum within the region; diversity harnessed
- Depends on system demand conditions

SCED PERFORMANCE DURING EXTREME EVENTS

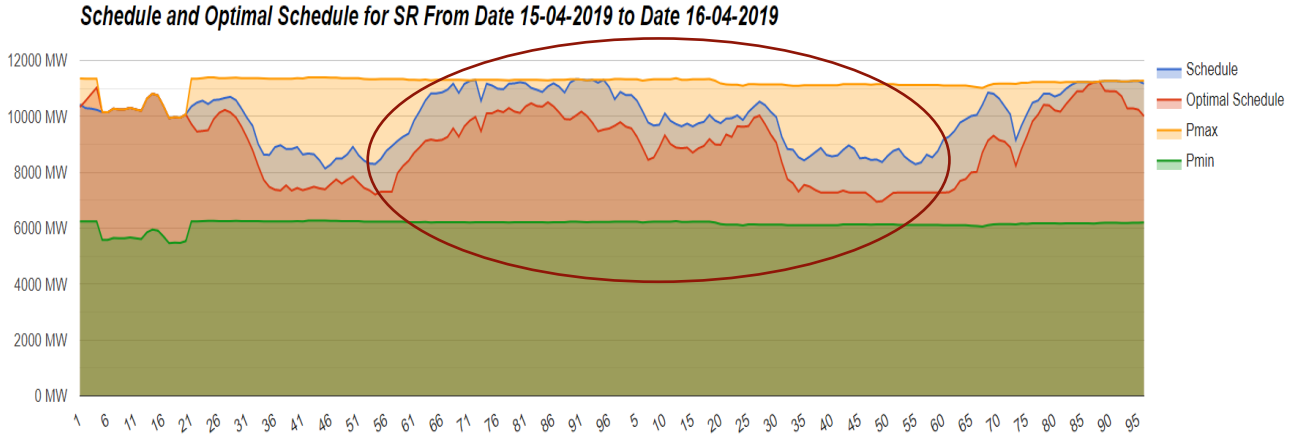
~ 10 GW Load Crash

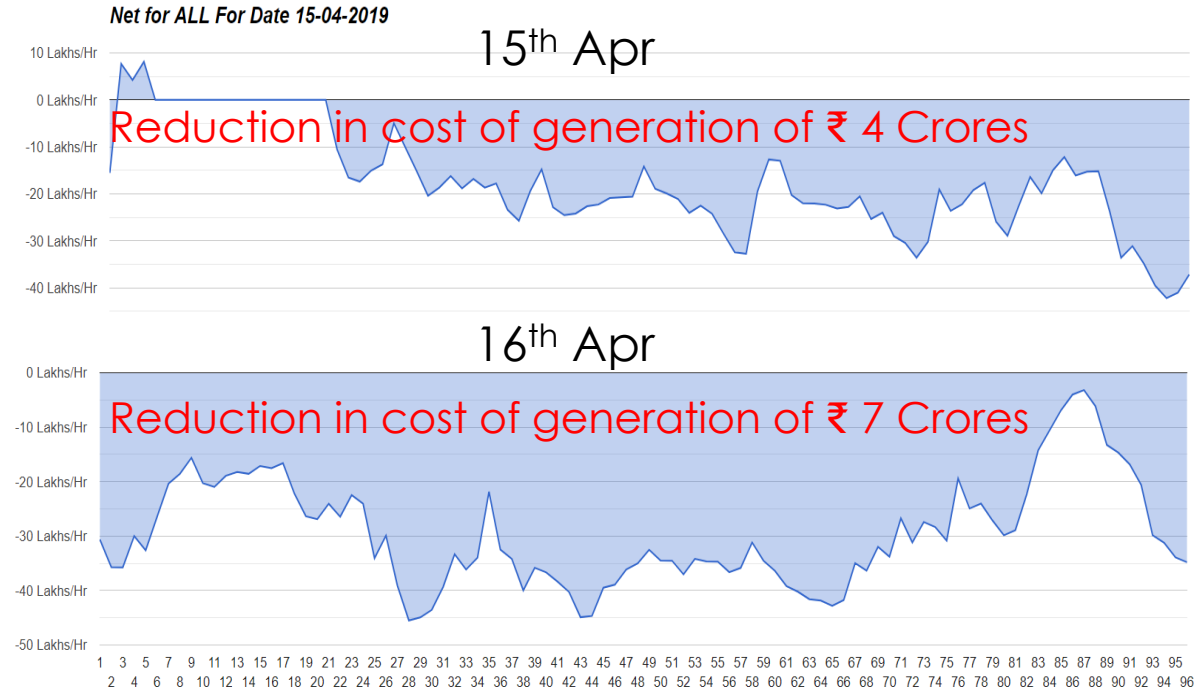




- NR generation scheduled to Technical Minimum including cheaper generation

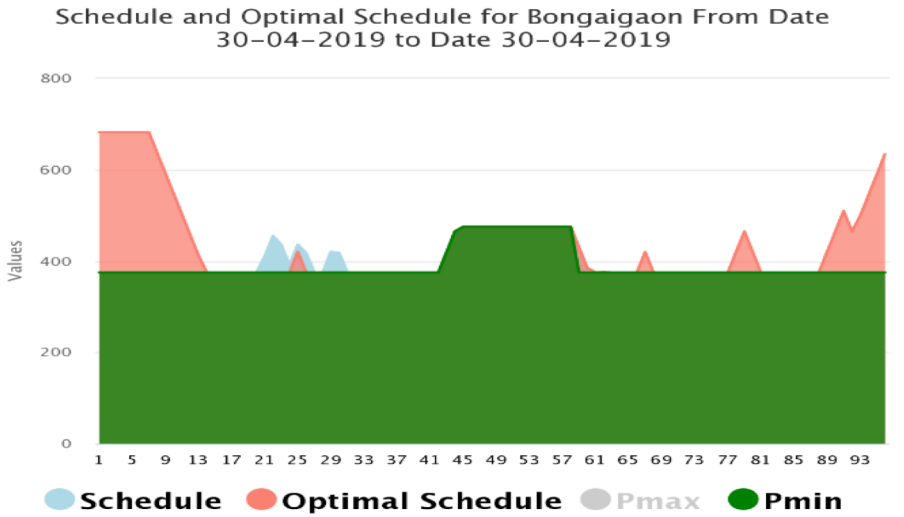
- SCED increased cheaper generation in NR and decreased costly generation in SR, subject to transmission constraints

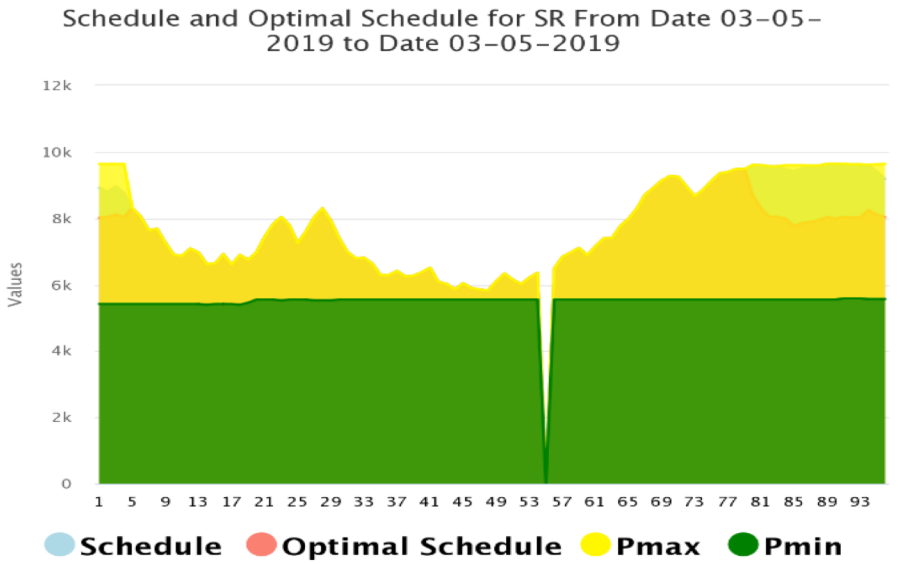




OPERATIONAL FLEXIBILITY PROVISIONS IN SCED

- All SR Generators excluded from SCED application w.e.f. 23:00 hrs on 2nd May 2019 till 1930 hrs of 3rd May 2019
  - In anticipation of forced outages of major links in ER-SR Corridor due to Cyclone " FANI"
- Performance guarantee tests facilitated by increasing technical minimum in SCED at
  - BRBCL (18 Apr 2019)
  - Kudgi (4-10 Apr 2019)
  - Bongaigaon (29 Apr – 1 May 2019)
- Technical Minimum increased at Dadri-II for facilitating boiler modification works (24-26 Apr 2019)
- Technical Minimum increased at MPL for facilitating PSS tuning (19 Jun 2019)
- Facilitated implementation of CERC Order on increased technical minimum for NLC units

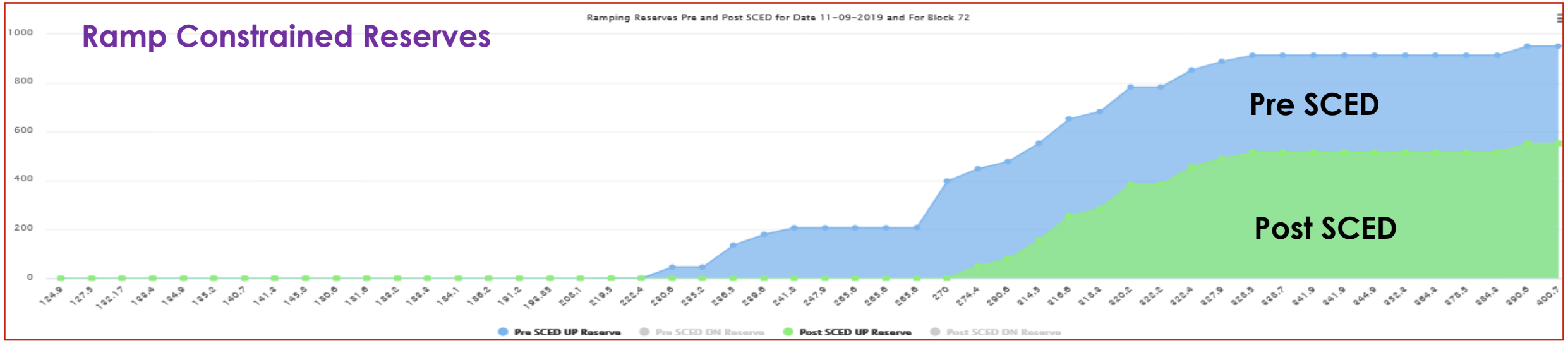




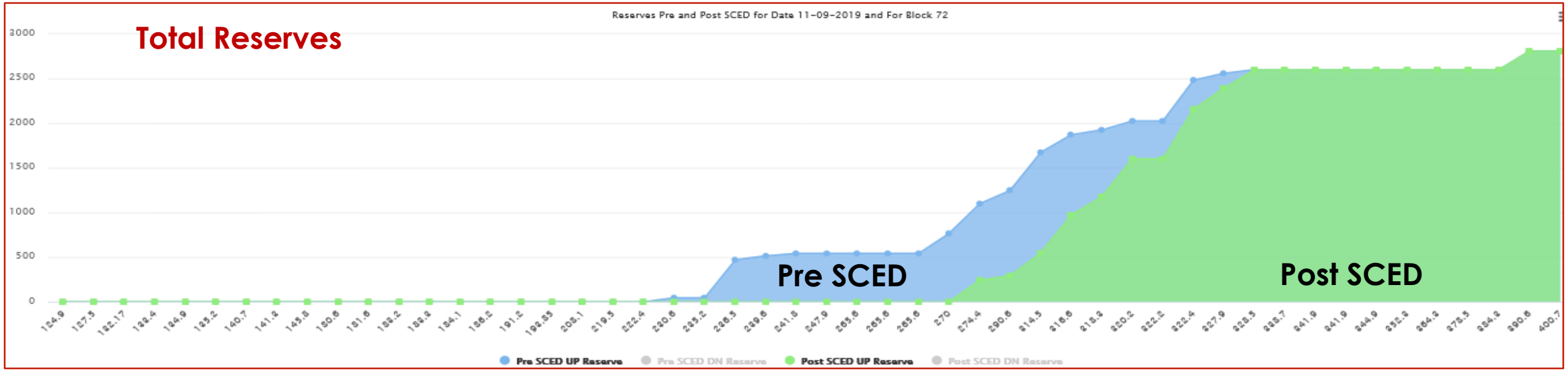
EFFECT OF SCED ON RESERVES

Single Time Block (15 Min.)

Ramp Constrained Reserves



Total Reserves



WAY FORWARD FOR SCED AT INTER-STATE LEVEL

➢ Expanding the ambit of SCED

➢ Co-optimization

- Add-on over SCED software for using available reserves
- Compliance to existing regulatory framework

➢ Spinning Reserves

- Agreed by the Commission in principle
- Regulatory Mandate Needed

CERC Order on Extension of Pilot on Security Constrained Economic Dispatch (SCED) of Inter-State Generating Stations(ISGS) Pan India dtd. 11th September, 2019

http://cercind.gov.in/2019/orders/08-SM-2019.pdf

➢ CERC Staff Papers

- Re-Designing Real Time Electricity Market in India
- Re-Designing Ancillary Services Mechanism in India
- Market Based Economic Dispatch of Electricity: Re-designing of Day-Ahead Market (DAM) in India

RESERVES & ANCILLARY AT STATE LEVEL

- FOR Standing Technical Committee: 22nd Meeting
  - 01st November 2018, New Delhi
  - Need for Reserves and Ancillary Services at intra-state level

- Constitution of Sub-Group on Reserves and Ancillary Services at intra-state level with the following TOR
  - *To disseminate the learning from the experience of implementing the reserve regulation ancillary services and fast response ancillary services at the interstate level and recommend the roadmap for implementing similar mechanisms at the state level.*
  - *To recommend the model regulations for harnessing the flexibility attributes, maintaining the mandated reserves and deploying them under normal and contingent scenario through intra-state reserve regulation ancillary services.*
  - *Any other recommendation as deemed fit in the context.*

- Members from SERC & SLDCs of Maharashtra, MP, Gujarat & Telangana; NLDC, WRLDC, SRLDC, CERC

INTRA-STATE LEVEL - REQUIREMENTS

Tariff of Intra-state Generation Plants (Single-part/Multi-part)	Mechanism for Declaring Capability, Ramp Rates, Technical Minimum	Scheduling and Despatch
Imbalances and Settlement thereof	Computation of Reserves Quantum	Compensation Mechanism for Reserve
Incentive/ Mark-up	Settlement Systems	Recovery for Sustainable Mechanism

BASIC DATA REQUIREMENT (BLOCK WISE)

Basic Parameters

1. Declared capability in MW
2. Declared capability on-bar (in MW)
3. Schedule in MW
4. Pmax = On bar installed capacity – Normative Auxiliary Consumption (MW)
5. Pmin = Technical Minimum generation (MW)
6. Variable charge (VC) in Rs/Kwh
7. Ramp-Up rate in (%age of on-bar Capacity) per minute
8. Ramp-down rate in (%age of on-bar Capacity) per minute

Derivable Parameters

1. Up-reserve
   - On bar installed capacity – Schedule (fig. in MW)
2. Down-reserve
   - Schedule – Technical Minimum (fig. in MW)
3. Cold reserve
   - DC – DC on bar …. (in MW)
4. Hot spinning reserve
   - DC on bar – Schedule ….(in MW)
5. Despatchable reserve =
   - Minimum (Hot spinning reserve & Regulation Up Reserve)

CO-OPTIMIZATION OF ENERGY & ANCILLARY BY MAHARASHTRA

Cases	Production cost before Optimization (Lakhs)	Production cost After Optimization (Lakhs)	Total Reduction in Cost (Lakhs)	Average Cost before Optimization (Rs/Unit)	Average Cost After Optimization (Rs/Unit)	SMP rate (Rs/Unit)
Case 1: Maximum Demand	515	484	31	2.54	2.49	3.29
Case 2: Minimum Demand	366	320	46	2.45	2.27	2.81
Case 3: Maximum Wind	375	350	25	2.47	2.31	2.96
Case 4: Minimum Wind	361	349	12	2.3	2.26	3.69
Case 5: Maximum Surrender	284	276	8	2.54	2.51	2.52
Case 6: Minimum Surrender	507	483	24	2.59	2.41	2.81

(NOTE- It shows that after optimization System is having maximum benefits in terms of Average Cost)

FURTHER ACTIONS OF SUB-GROUP

- **Online Survey** for all states

  https://docs.google.com/forms/d/e/1FAIpQLSfSUgcGh6e76USjtqWD2BePWqjUxX_ys3gh7WqoQR0r3ZHZ5Q/viewform

- **Special Training Program** (Tutorial form) being organised for the members of the Sub-Group from **19th to 21st September 2019**
  - Faculty from IIT Delhi
  - Young enthusiasts from SLDCs to participate

- Expected outcome
  - Readiness to implement a pilot in one of the states as per the orders/directive by respective SERC

THANK YOU !

DISCUSSIONS

“The urge for good design is the same as the urge to go on living. The assumption is that somewhere, hidden, is a better way of doing things.”

Harry Bertoia, Artist and Designer
As quoted in 1000 Chairs, Carlotte and Peter Fiell (2005) p. 66