India SMART UTILITY Week 2020

March 03 - 07, 2020 | The Lalit Hotel, New Delhi, India

ISGF India Smart Grid Forum

India Smart Utility Week 2020

ORGANISED BY INDIA SMART GRID FORUM

03-07 MARCH 2020, The Lalit Hotel, New Delhi, INDIA

Master Class

Energy Storage Assessment

Roadmap for India 2019-2032

Ravi Seethapathy

Hon. Member, ISGF

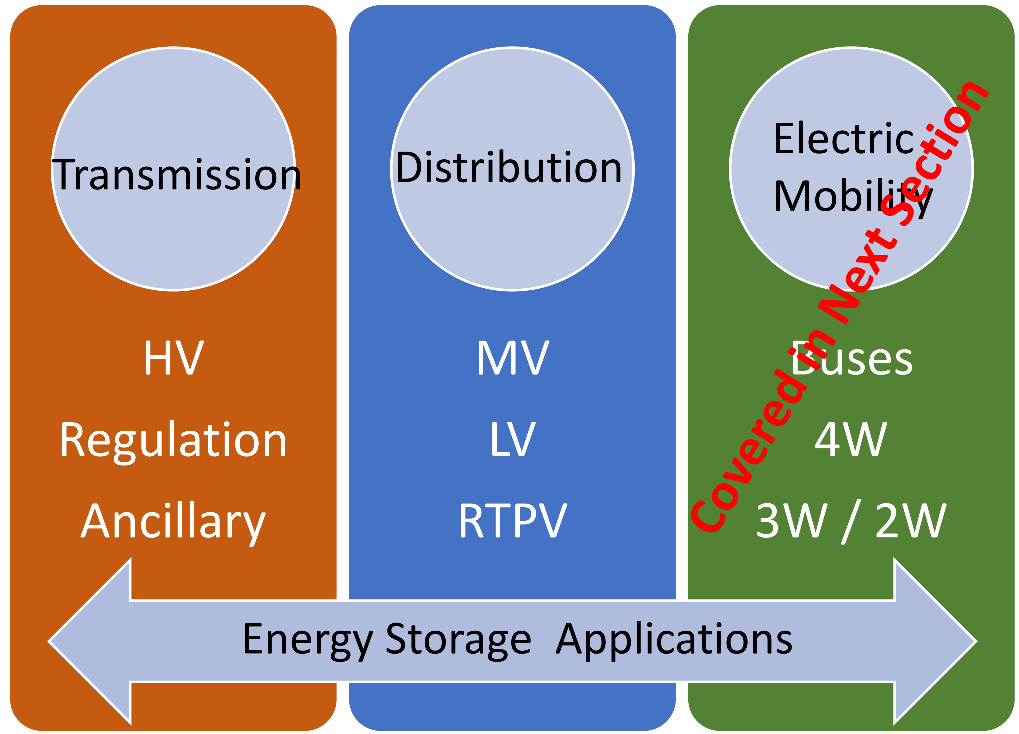
Executive Chairman, Biosirus Inc., Canada

Agenda

1. Typical ESS Applications in Power Systems

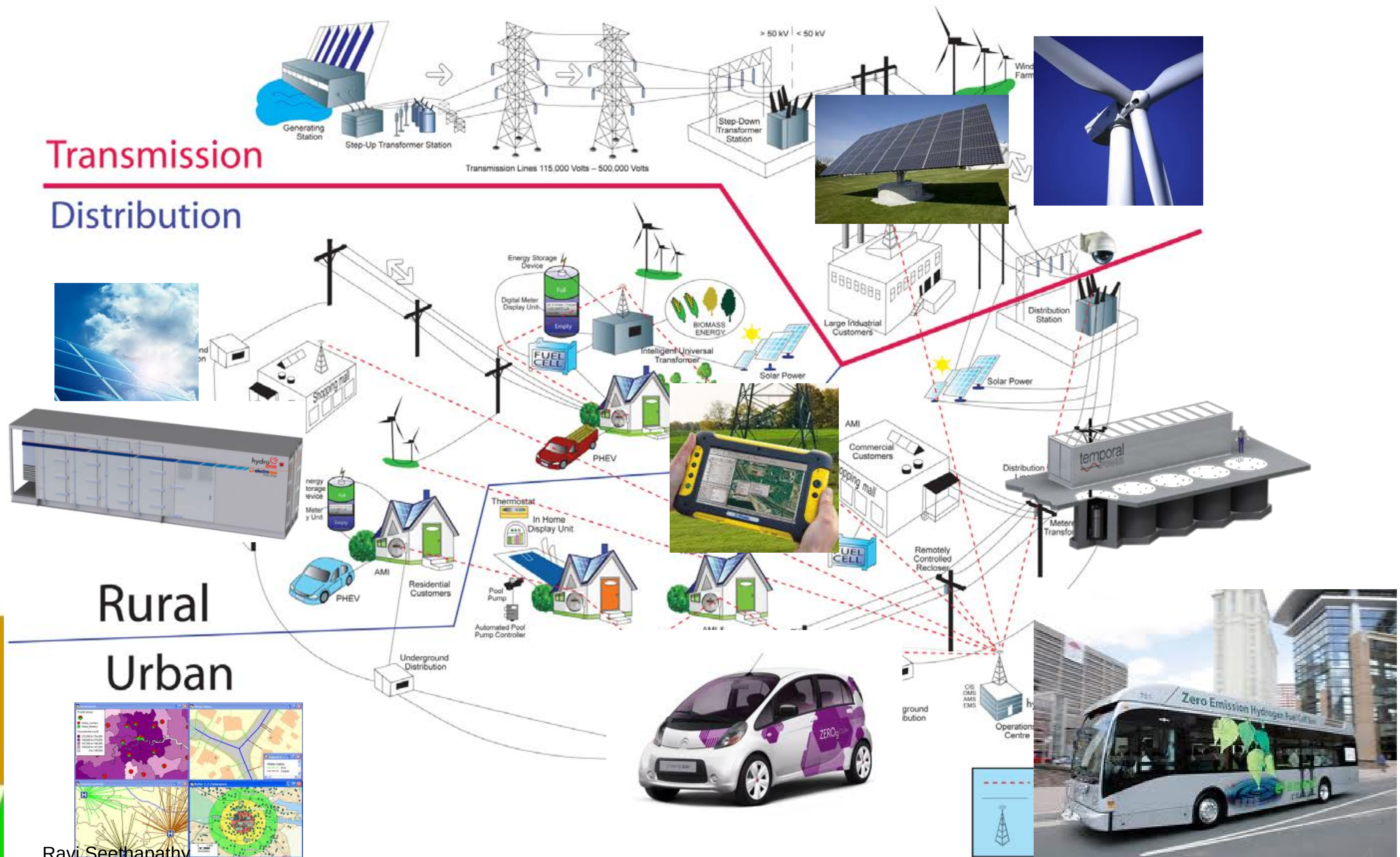
2. India's RE Program
   a) 175 GW RE Target
      i. 60 GW Gr. Mount PV
      ii. 40 GW RTPV

3. India ESS Roadmap 2019-2032
   a) ESS for RTPV
   b) Methodology Overview
   c) Results

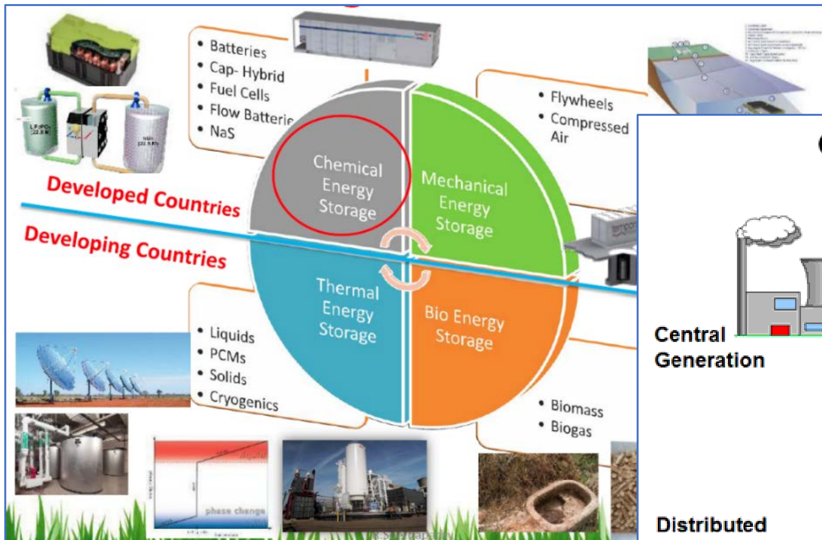


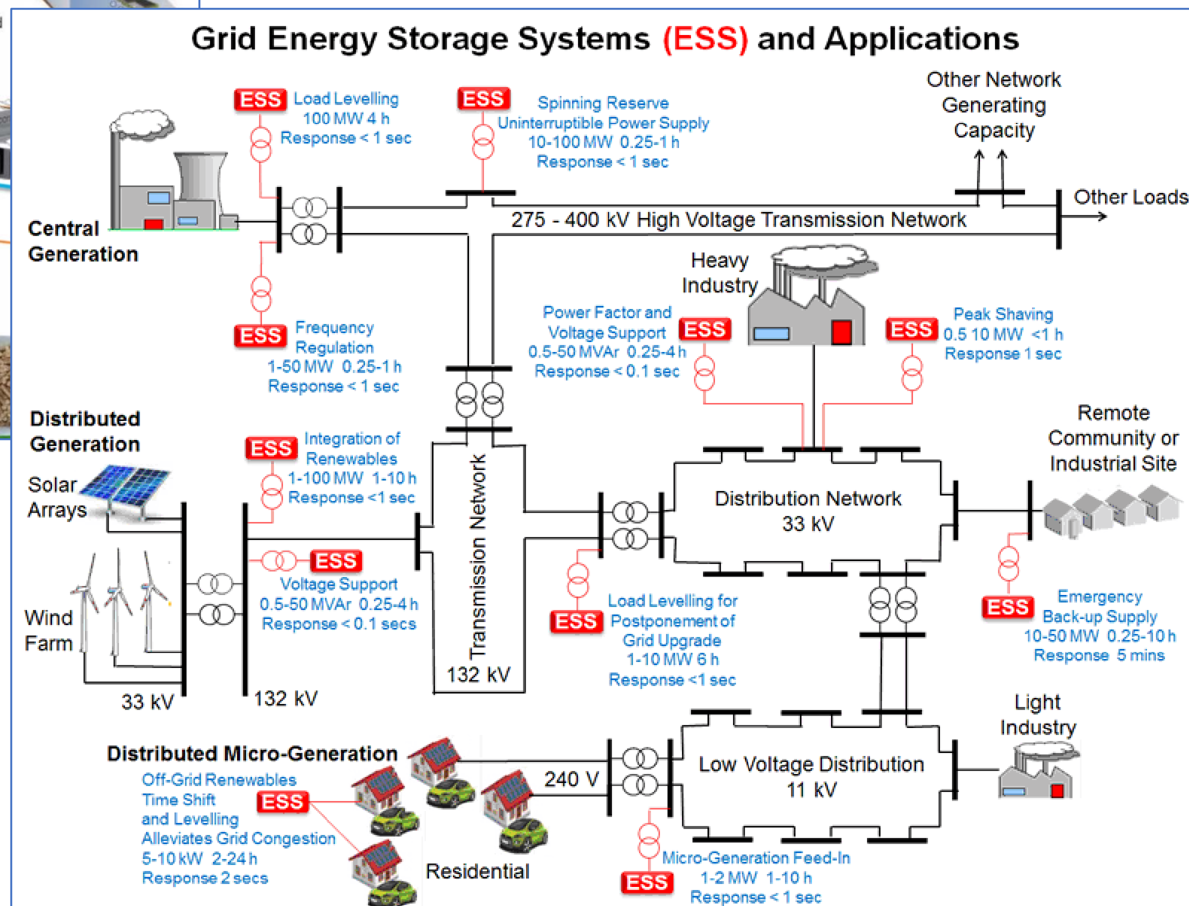
Typical ESS Applications in Power Systems

Smart Grid

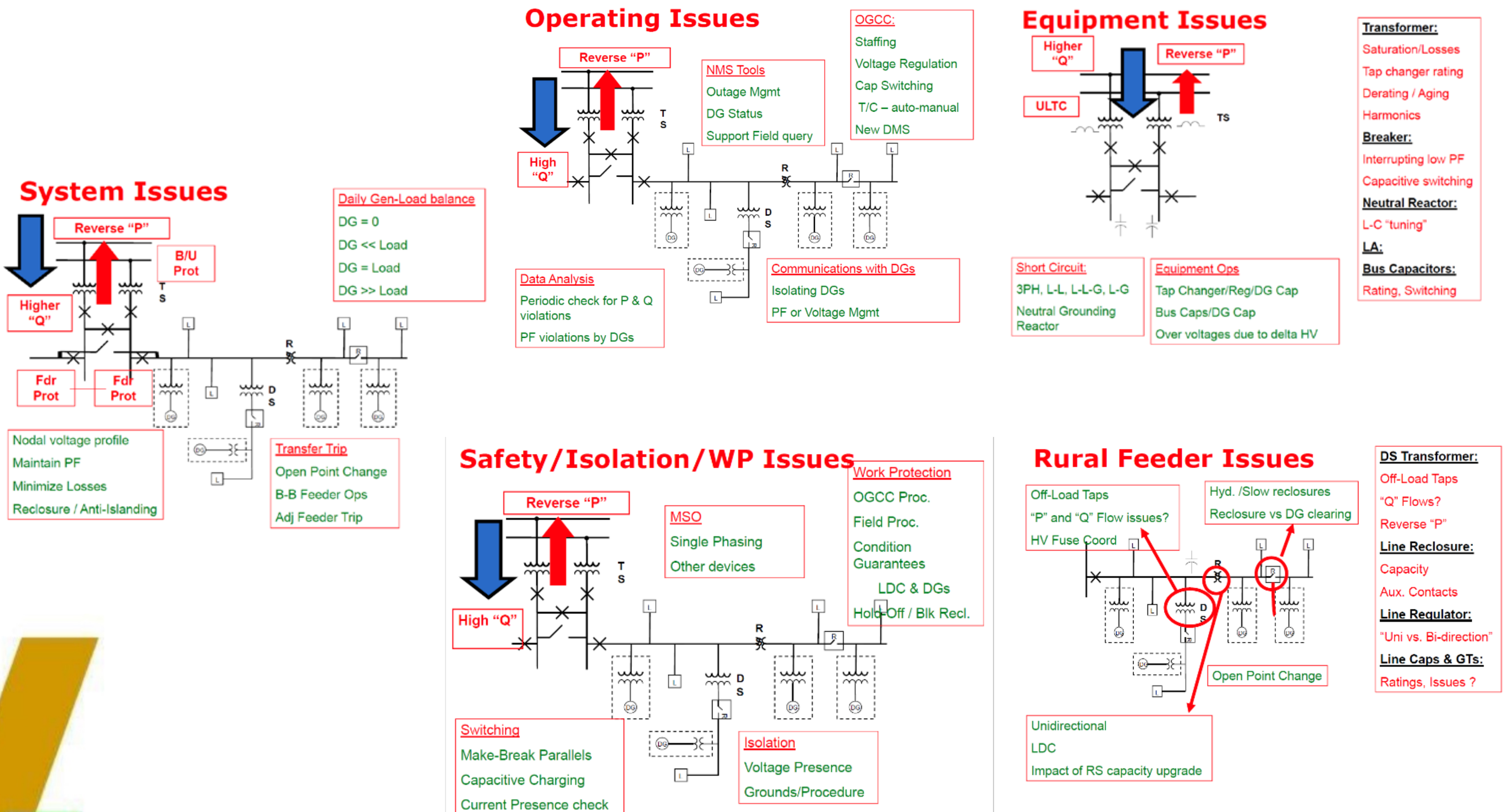

Transmission
Distribution
Rural
Urban
Generating Station
Step-Up Transformer Station
Transmission Lines 115,000 Volts – 500,000 Volts
> 50 kV | < 50 kV
Step-Down Transformer Station
Energy Storage Device
Digital Meter Display Unit
FUEL CELL
BIOMASS ENERGY
Intelligent Universal Transformer
Solar Power
Large Industrial Customers
Distribution Station
PHEV
AMI
Commercial Customers
Thermostat
In Home Display Unit
Residential Customers
Pool Pump
Automated Pool Pump Controller
Underground Distribution
Remotely Controlled Recloser
Operations Centre
temporal
Zero Emission Hydrogen Fuel Cell Bus

Energy Storage Systems Applications

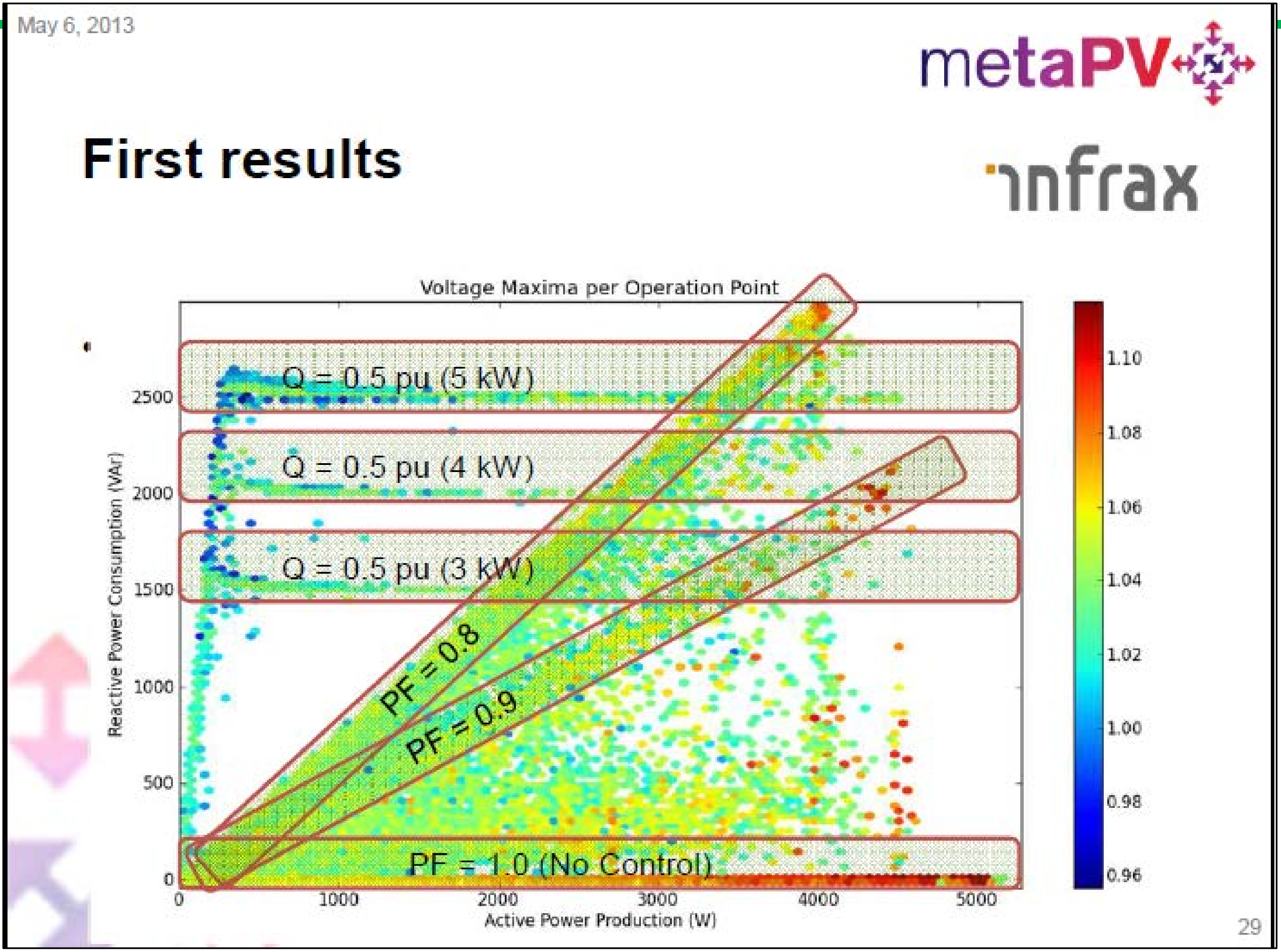




DER Management

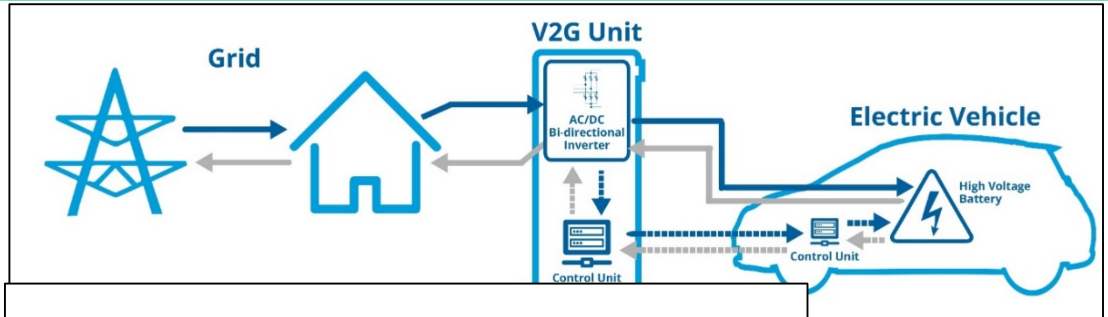


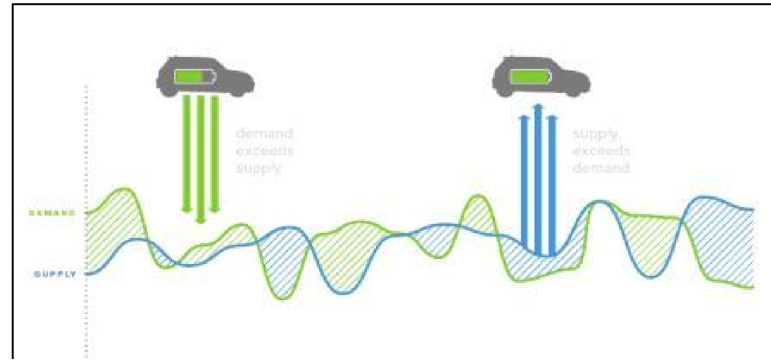
DER PF Control

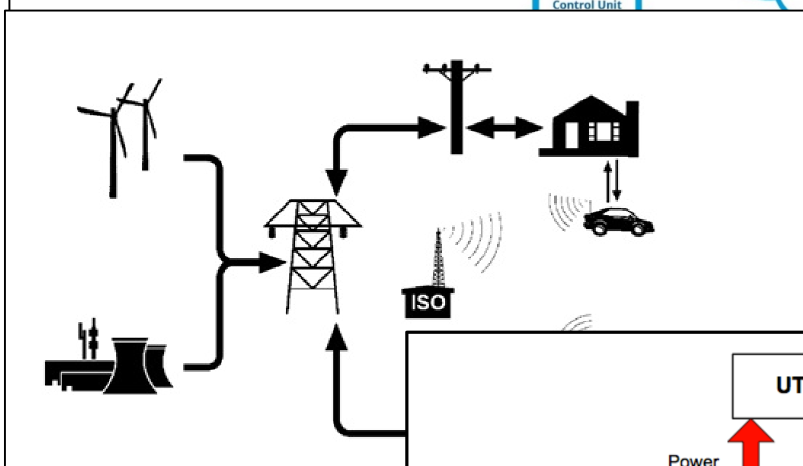


Source: Infrax

EV Charging Power Architecture

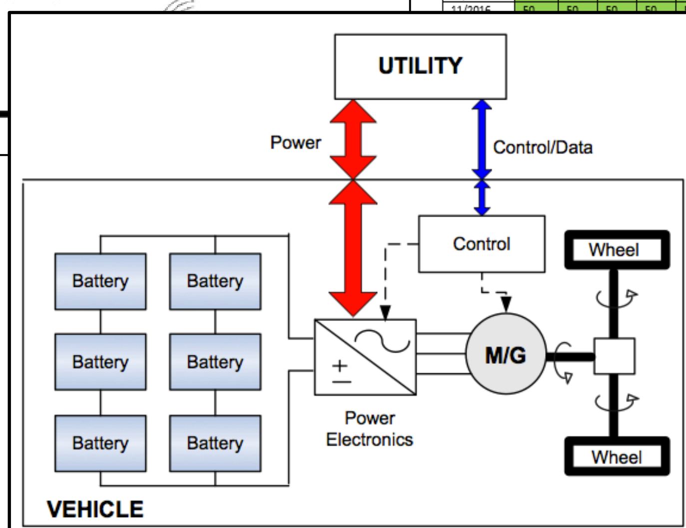






	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
System DTs 2430 MW																								
Weekday	(MW)																							
05/2016	1341	1250	1206	1167	1107	1023	1121	1204	1355	1526	1675	1762	1747	1774	1880	1850	1766	1728	1744	1631	1566	1535	1610	1434
12/2015	623	582	572	566	579	619	785	895	997	1062	1119	1156	1122	1036	1026	1055	1257	1332	1256	1156	1087	971	835	705
Weekend	(MW)																							
05/2016	1245	1188	1136	1116	1063	990	1033	1047	1086	1142	1230	1297	1338	1375	1498	1499	1393	1387	1454	1380	1341	1339	1435	1315
12/2015	605	556	543	543	554	563	717	817	912	957	1001	1049	999	906	870	873	1066	1162	1119	1064	1015	918	793	697
Kasba Ind DT 400KVA	I	N	D	U	S	T	R	I	A	L														
04/2016	60	60	60	60	60	60	90	90	180	310	325	340	300	320	270	270	270	240	150	120	60	60	60	60
11/2016	50	50	50	50	50	75	75	100	200	250	250	225	200	220	220	225	225	225	175	125	75	75	75	60
						R	C	I	A	L		+		R	E	S	I	D	E	N	T	I	A	L
						30	30	30	50	75	125	150	135	125	120	120	175	260	260	275	250	200	75	50
						15	15	15	15	20	60	60	60	45	45	75	135	135	120	120	105	60	15	15
						T	R	I	A	L		+		R	E	S	I	D	E	N	T	I	A	L
						240	270	270	270	270	260	250	270	300	315	315	315	325	325	325	310	270	270	270
						150	160	180	190	200	220	210	180	180	210	220	220	220	210	220	210	220	190	180
						R	C	I	A	L														
						25	25	25	45	100	350	425	425	456	430	430	425	420	175	125	40	25	25	25
						15	15	15	30	60	210	240	240	240	240	247	247	235	75	50	20	15	15	15

ns to show where EV charging is possible - during the day/night, and summer/winter
arying name-plate capacities (KVA)
apacity availability on that specific DT, relative to the load already present at that time
e or no capacity available for EV charging
bout 40-50% DT capacity is availability for EV charging
bout 80% of DT capacity is available for EV charging
te as seen by the system is also noted. However, this is for information only. EV charging will be location specific.

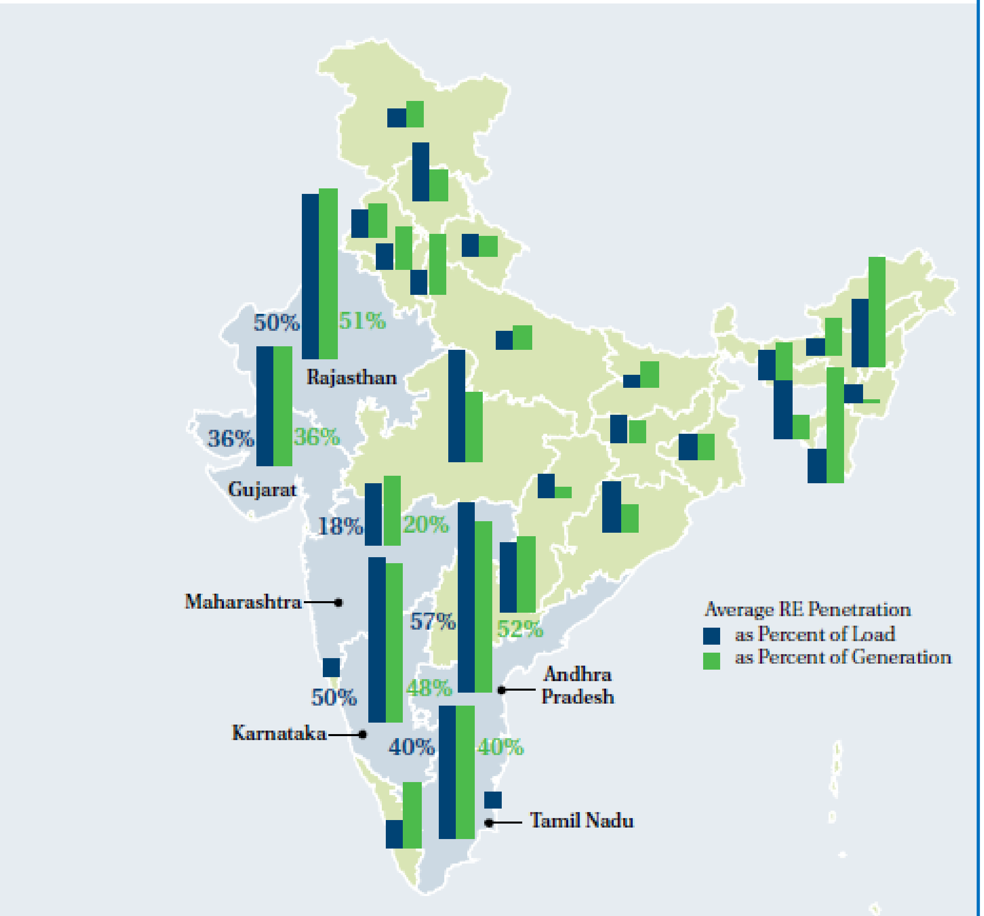


Ravi Seethapathy

India's RE Program Targets and Highlights

India RE Penetration

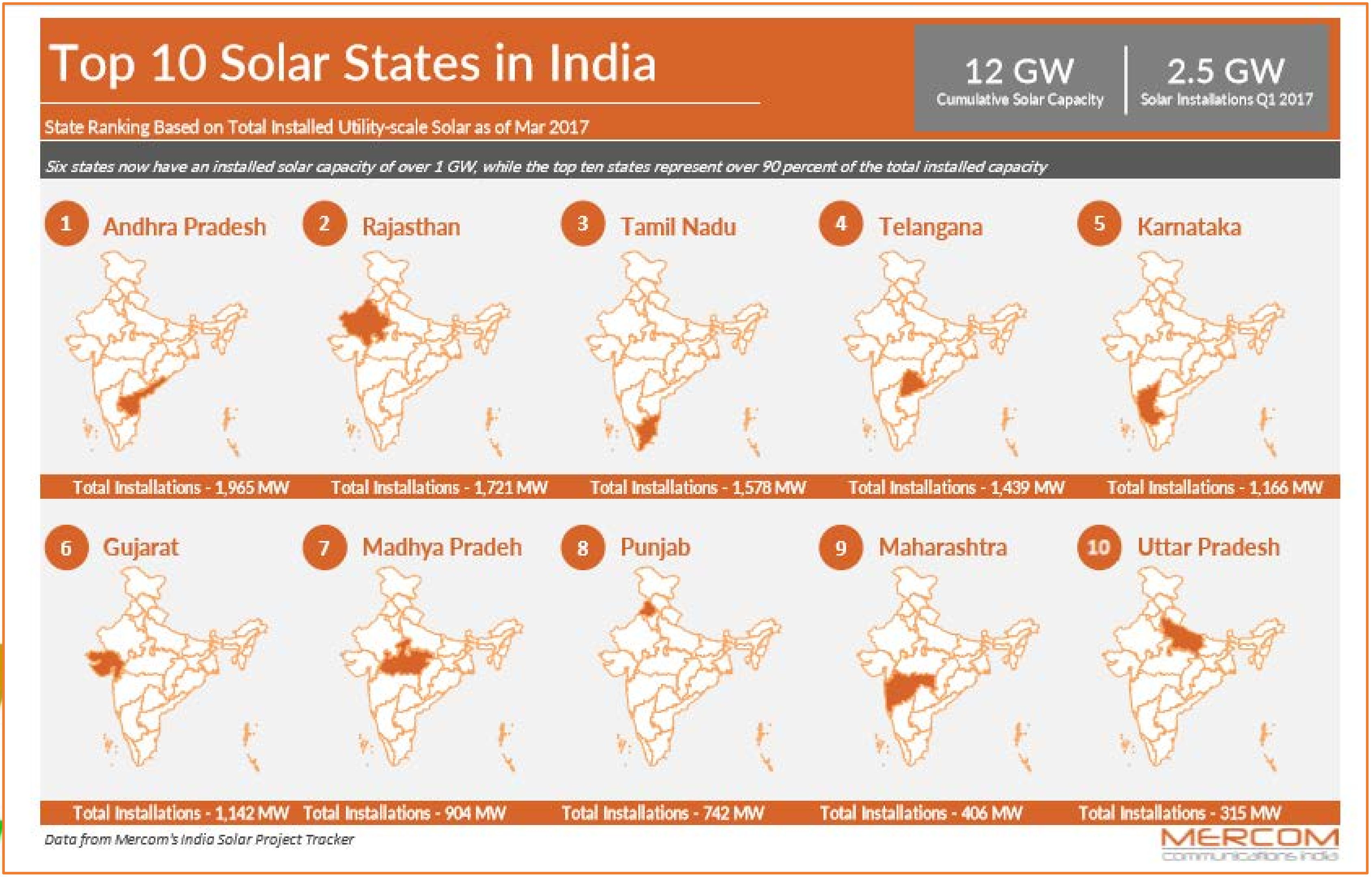
RE penetration as percentage of Generation and Load



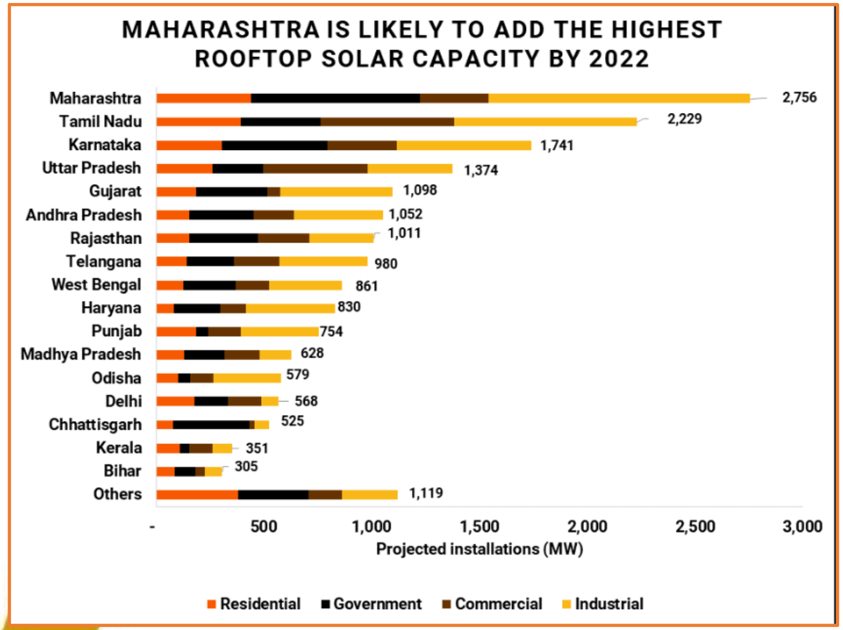
Annual RE penetration exceeds 50% of load in 3 states

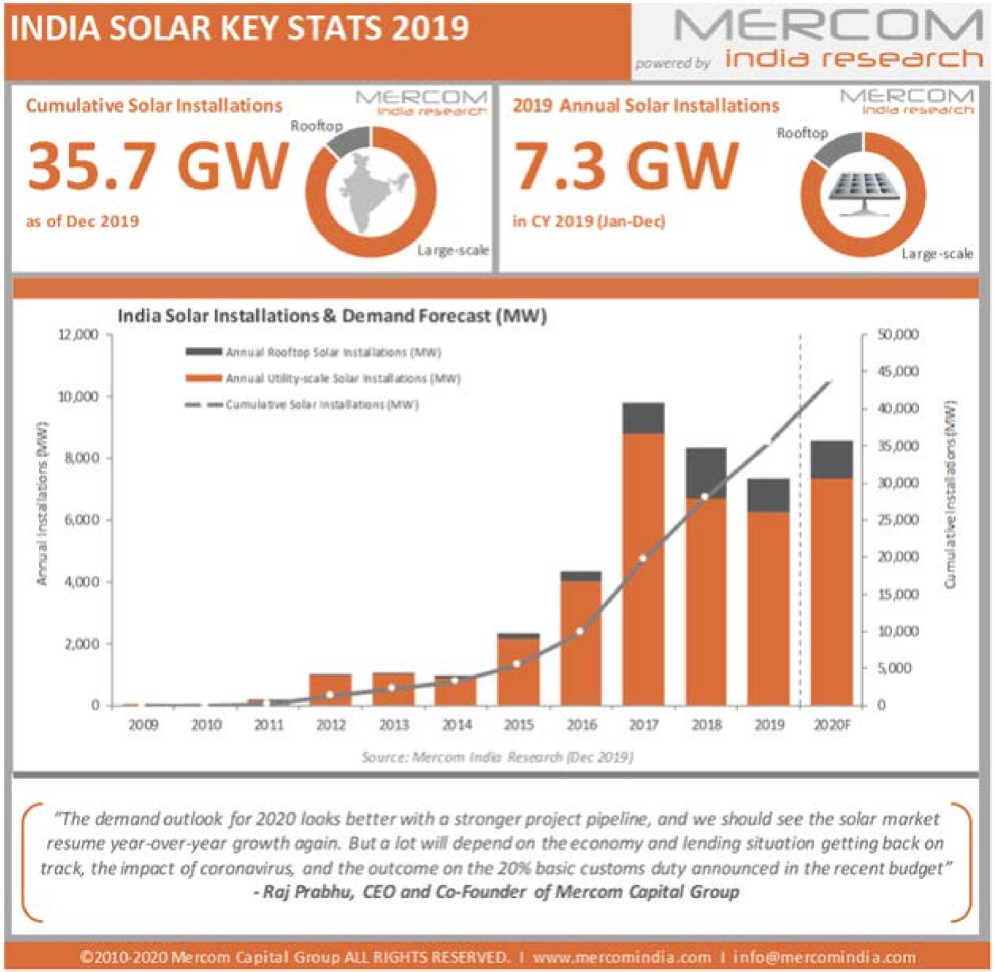
Source: Bridge To India

Top Solar States in India



India Solar Trend





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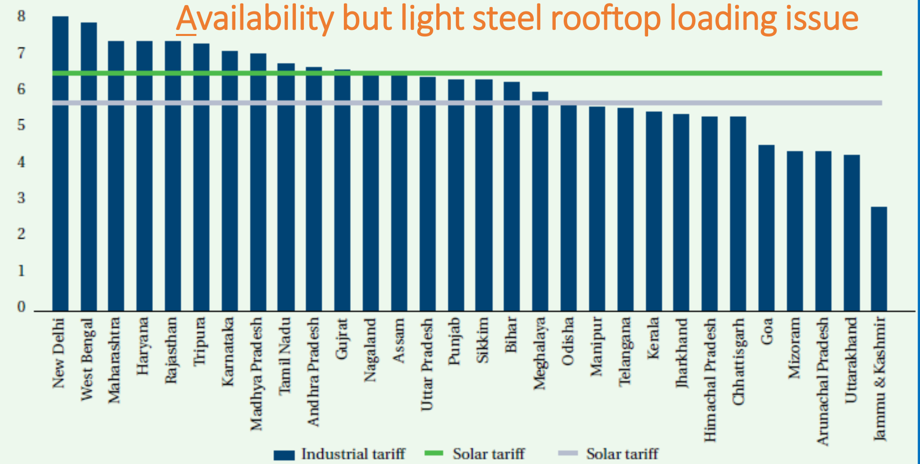
India RTPV Solar Tariffs (I-C-R)

ISGF India Smart Grid Forum

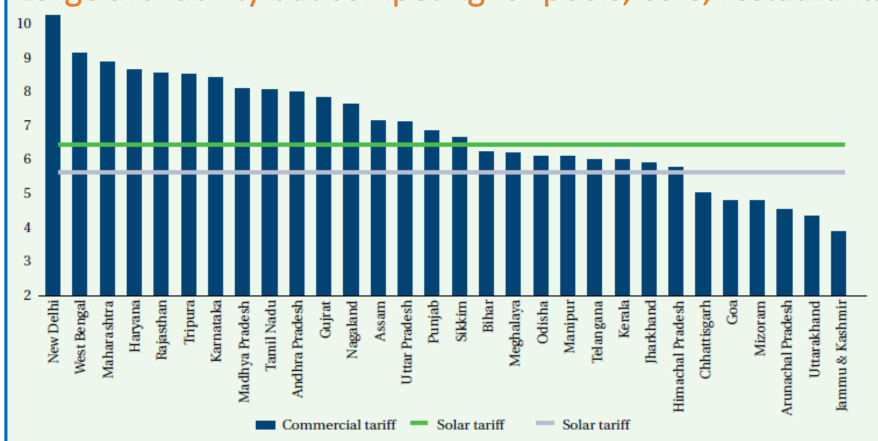
Industrial Consumers-Utility Tariff & Rooftop Solar Energy Tariff

Availability but light steel rooftop loading issue



Commercial Consumers-Utility Tariff & Rooftop Solar Energy Tariff

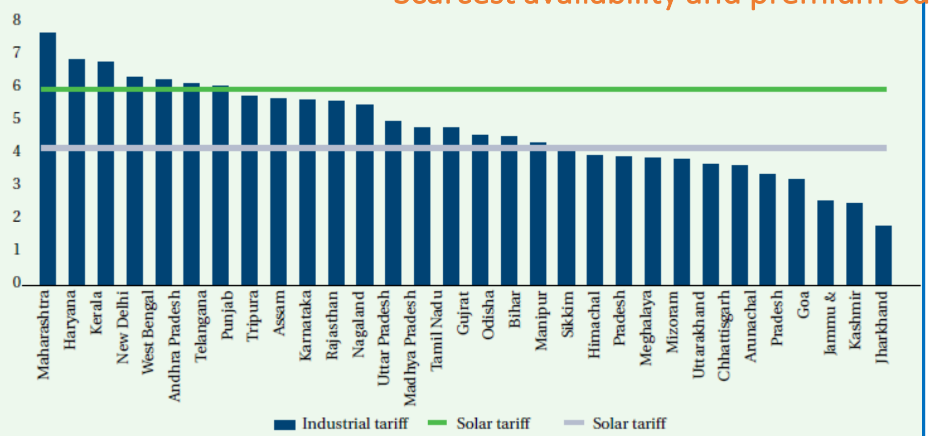
Large availability but competing for pools, bars, restaurants

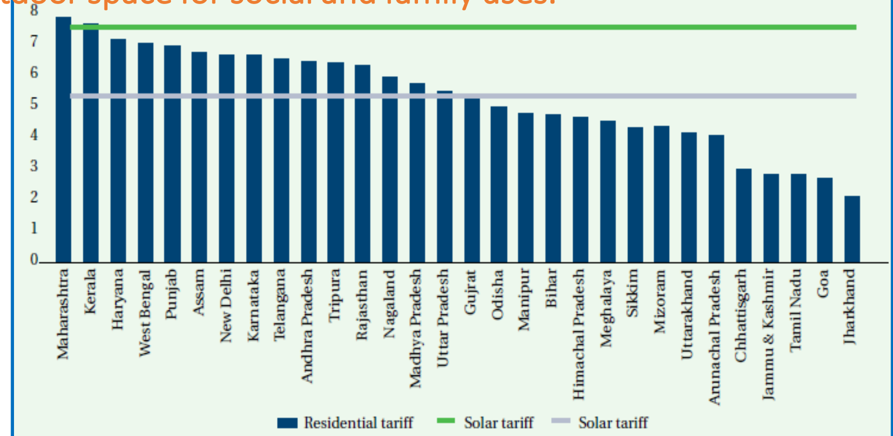


Residential Consumers<1000 units-Utility Tariff & Rooftop Solar Energy Tariff

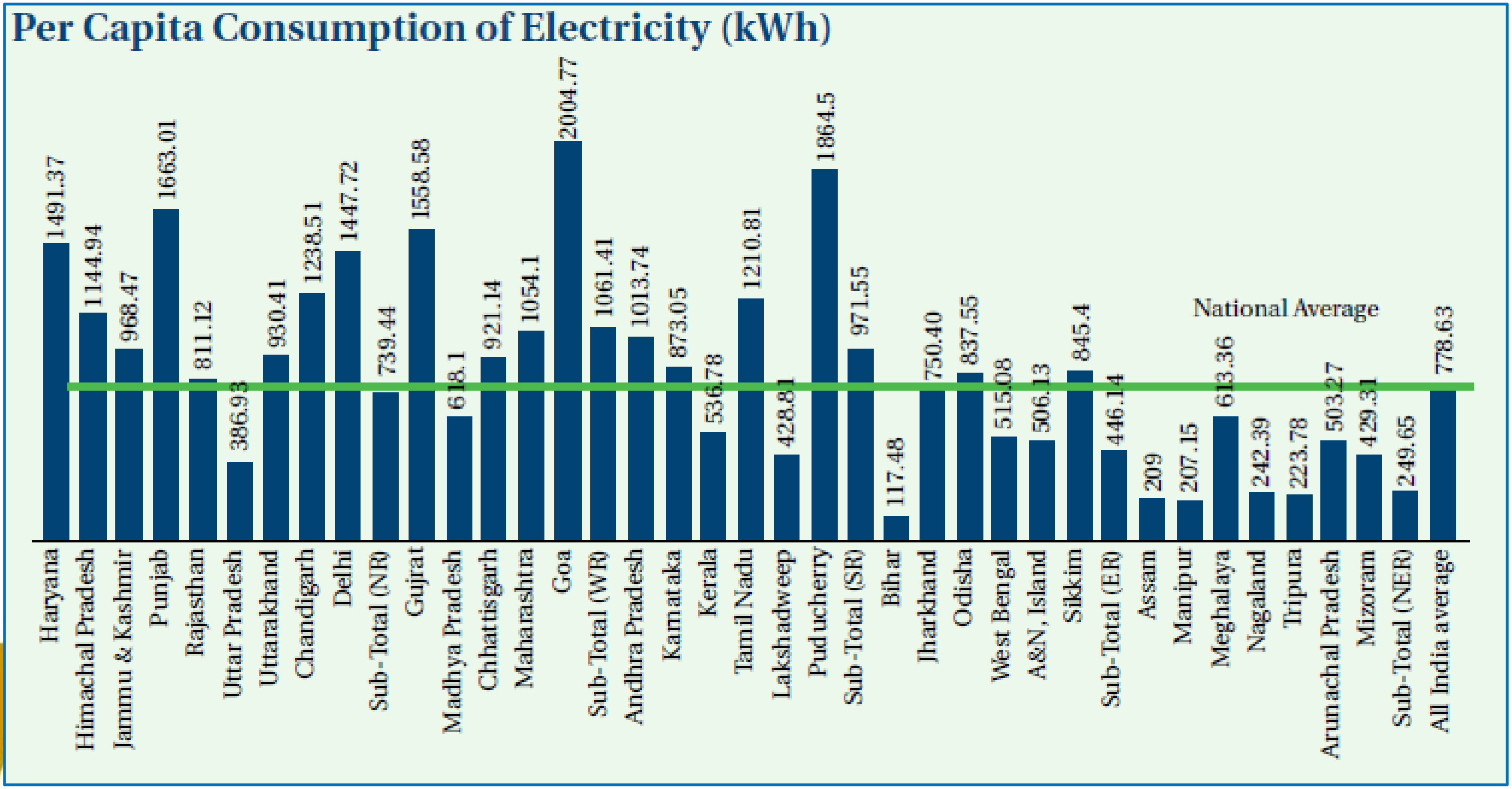
Residential Consumers<500 units-Utility Tariff & Rooftop Solar Energy Tariff

Scarcest availability and premium outdoor space for social and family uses.





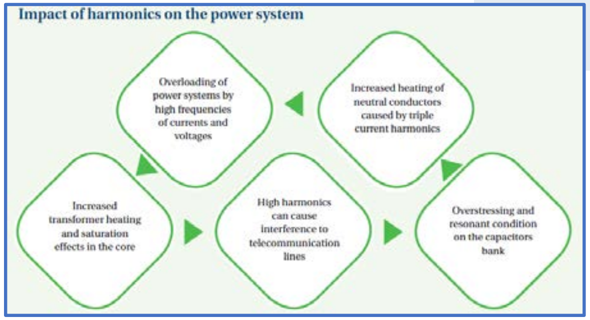
India Per Capita Electricity Consumption



India RTPV Limits & Rules

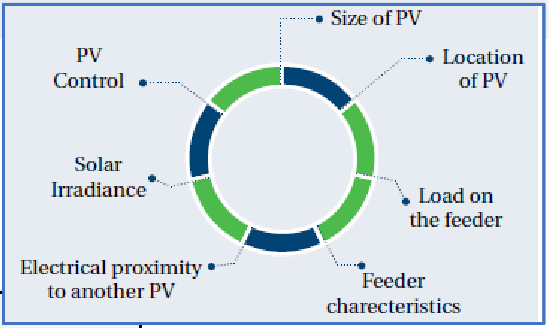
Varying RTPV Limits/Rules across States

State or Union Territory	RTPV Limit for Individual Customers	Installed Capacity Limit as % of DT capacity
Tripura	<100% contracted load	15% of DT capacity, allowed to exceed upon detailed load study
Uttar Pradesh	<100% contracted load	75% of DT capacity
Uttarakhand	<500	15% of DT capacity, issue raised to increase this value
West Bengal	>5 kW, injection shall not be more than 90% of the consumption from the licensee's supply in a year	Not Specified



Issues

Feeder Characteristics, PQ Controllability
Relaying, Power Backfeed



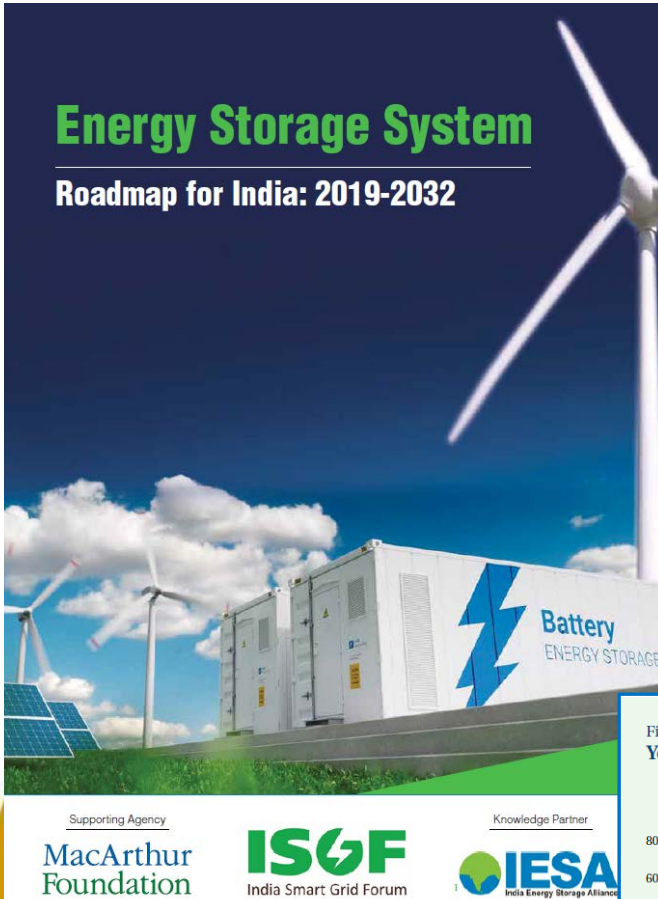
Technical Issues Limiting VRE Hosting Capacity of Feeders

- Thermal Ratings
- Voltage Regulation
- Fault Level
- Reverse Power Flows
- Rapid Voltage Change
- Islanding
- Protection
- Power Quality

- Geographic Diversity of VRE
- Renewable Generation Forecasting
- Generator Flexibility
- Energy Storage
- Curtailment
- Demand Shift through Load Control

The Study

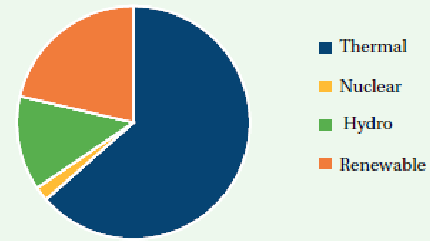
Study: Introduction



175 GW RE Program

- Solar : 100 GW- (60 GW from ground-mount and 40 GW from rooftop)
- Wind : 60 GW
- Small Hydro : 5 GW
- Bioenergy : 10 GW

Figure 1:
Installed Capacity

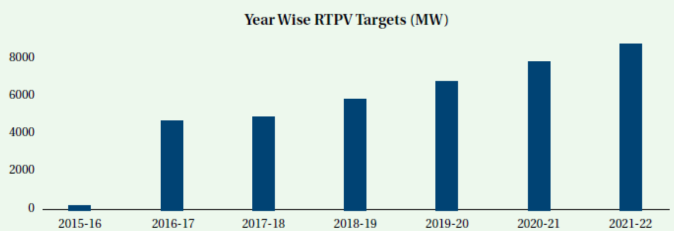


Source: MNRE

Key areas for Energy Storage applications

- Integrating renewable energy with transmission grids and distribution grids
- Setting up rural micro grids with diversified loads or stand-alone systems
- Developing storage component for electric mobility plans

Figure 2:
Year wise Rooftop Solar Targeted Capacity



Source: MNRE

Study: Objective

Purpose of study: Maximum solar connection is allowed at LT side in order to achieve 40 GW targets of RTPV by 2022.

STEP 1 – Load flow study of MV/LV feeder, DT and LT Network

STEP 2 – Conduct load flow with different levels of RTPV connected at LT side without any energy storage device and study the PQ issues (low PF, undesirable fluctuations in voltages), thermal issues (heating of conductor, etc.)

STEP 3 – Estimated the maximum permissible limit for RTPV connected at LT side with energy storage devices without PQ and thermal issues

Run load flow study:

STEP 1 – Identify/select time slots for the load flow study (Four time slots i.e. 8:00 AM -11:00 AM, 11:00 AM - 1:00 PM, 1:00PM - 4:00 PM, 4:00PM - 7:00PM)

STEP 2 – Select any specific time during each time slot for which feeder is lightly or heavily loaded (in this study, ISGF considered both conditions in order to run load flow during severe conditions)

STEP 3 – Run the load flow study of feeder load current during the selected time slot

STEP 4 – Perform load flow analysis for increasing solar RTPV connection at consumer side (LT/HT/agriculture/commercial etc.) in steps w.r.t. percentage of transformer rating

Results of the study:

- Analyze the maximum limit of percentage increase in RTPV up to which there are no PQ issues
- Analyze the maximum increases in RTPV up to which PQ issues can be mitigated with energy storage devices at LT side/at DT/at MV side

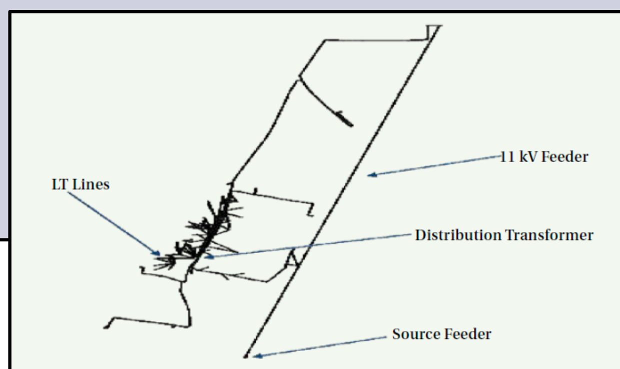
Study: Methodology

Before starting load flow, following data was collected:

Single line diagram
- Conductor rating
- Conductor length
- Voltage rating of DT
- Connected/ Sanctioned Load
- Diagram of LT network

Meter
- Load survey data of Feeder/DT

Solar
- RTPV connected on the feeder
- Solar irradiance curve of the location



01 11 kV Feeder Single Line Diagram (SLD)

02 11 kV Feeder Meter Load Survey Data

03 Feeder Current Carrying Capacity and Load Growth

04 Conductor Data

05 Ratings of Distribution Transformers (DTs)/ Capacity and Voltage Ratio

06 Consumer Details

07 RTPV connected to the Feeder

Study: Participants & Tools

List of DISCOMs that participated in the study

Region	Selected state	Feeder category	DISCOM Name
North	Delhi	Urban lightly loaded	Tata Power Delhi Distribution Ltd. (TPDDL)
	Haryana	Agricultural	Uttar Haryana Bijli Vitran Nigam Ltd. (UHBVN)
South	Karnataka	11 kV	Bangalore Electricity Supply Company Ltd. (BESCOM)
	Andhra Pradesh	Semi urban heavily loaded	Andhra Pradesh Southern Power Distribution Company Ltd. (APSPDCL)
West	Maharashtra	Urban lightly loaded	Adani Energy Mumbai Ltd. (AEML)
East	West Bengal	Urban heavily loaded	CESC, Kolkata

Preparation of network in CYMDIST for load flow study[28]:

1. Draw complete network diagram upto LT consumer end specifying conductor size, span length, rating, transformer voltage rating
2. Draw load point end consumer mentioning connected/ sanctioned load on LT side of transformer
3. Connect RTPV generation capacity (existing if any) on LT side of network
4. Validate the network diagram and (remove errors, if any)
5. Upload solar irradiance curve data on RTPV connections

Study: Modelling

Time Slots

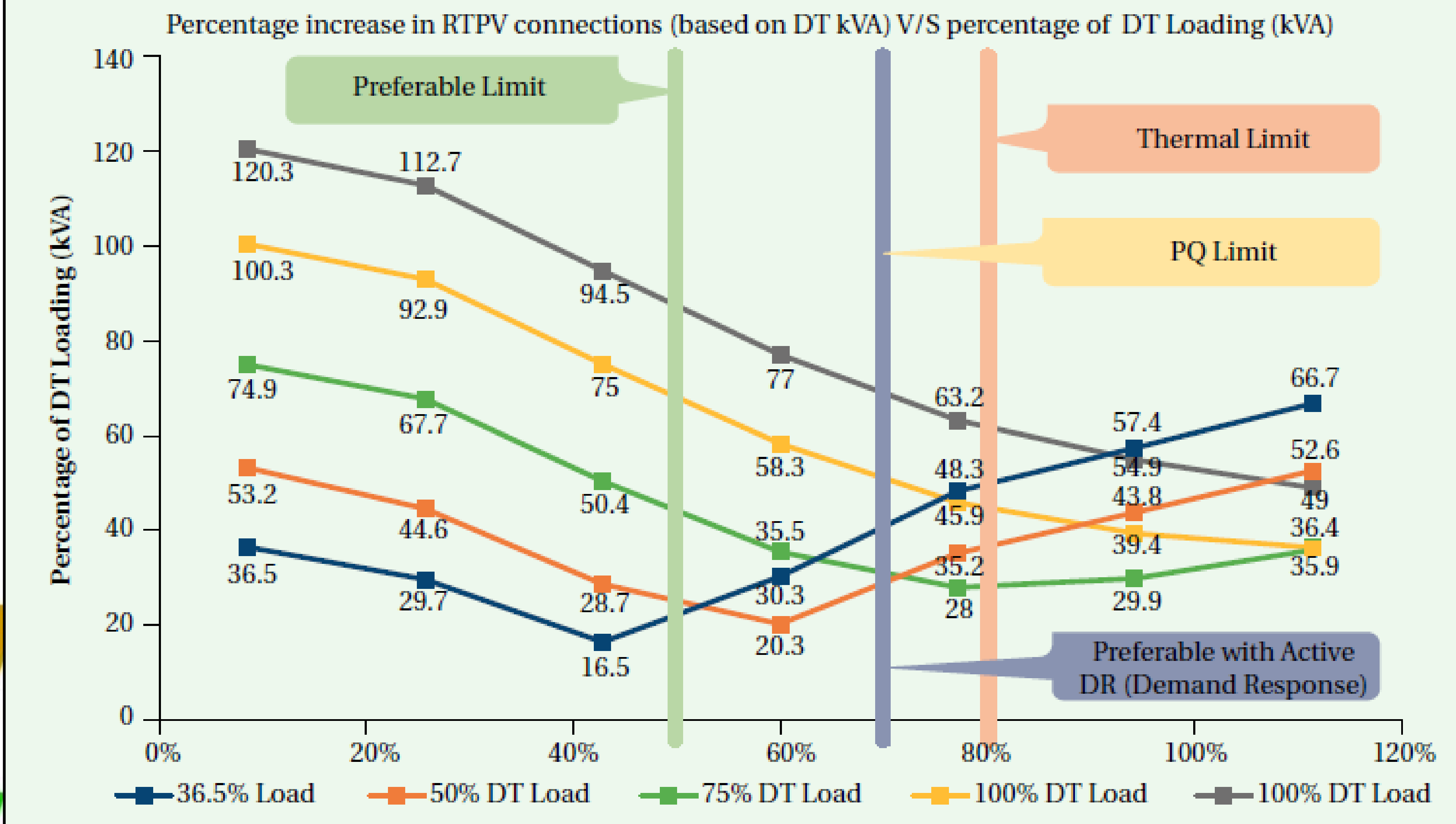
Already connected

Solar RTPV Capacity	Scenario 1 Time 8-11 AM	Scenario 2 Time 11-1 PM	Scenario 3 Time 1-4 PM	Scenario 4 Time 4-7 PM
11% of DT Capacity	70 kWP	70 kWP	70 kWP	70 kWP
20% of DT Capacity	120 kWP	120 kWP	120 kWP	120 kWP
40% of DT Capacity	240 kWP	240 kWP	240 kWP	240 kWP
60% of DT Capacity	360 kWP	360 kWP	360 kWP	360 kWP
80% of DT Capacity	480 kWP	480 kWP	480 kWP	480 kWP
90% of DT Capacity	540 kWP	540 kWP	540 kWP	540 kWP
100% of DT Capacity	600 kWP	600 kWP	600 kWP	600 kWP

Results Overview

Lightly Loaded Urban LV Feeder

TPDDL Feeder - Load Flow Analysis[29,30]



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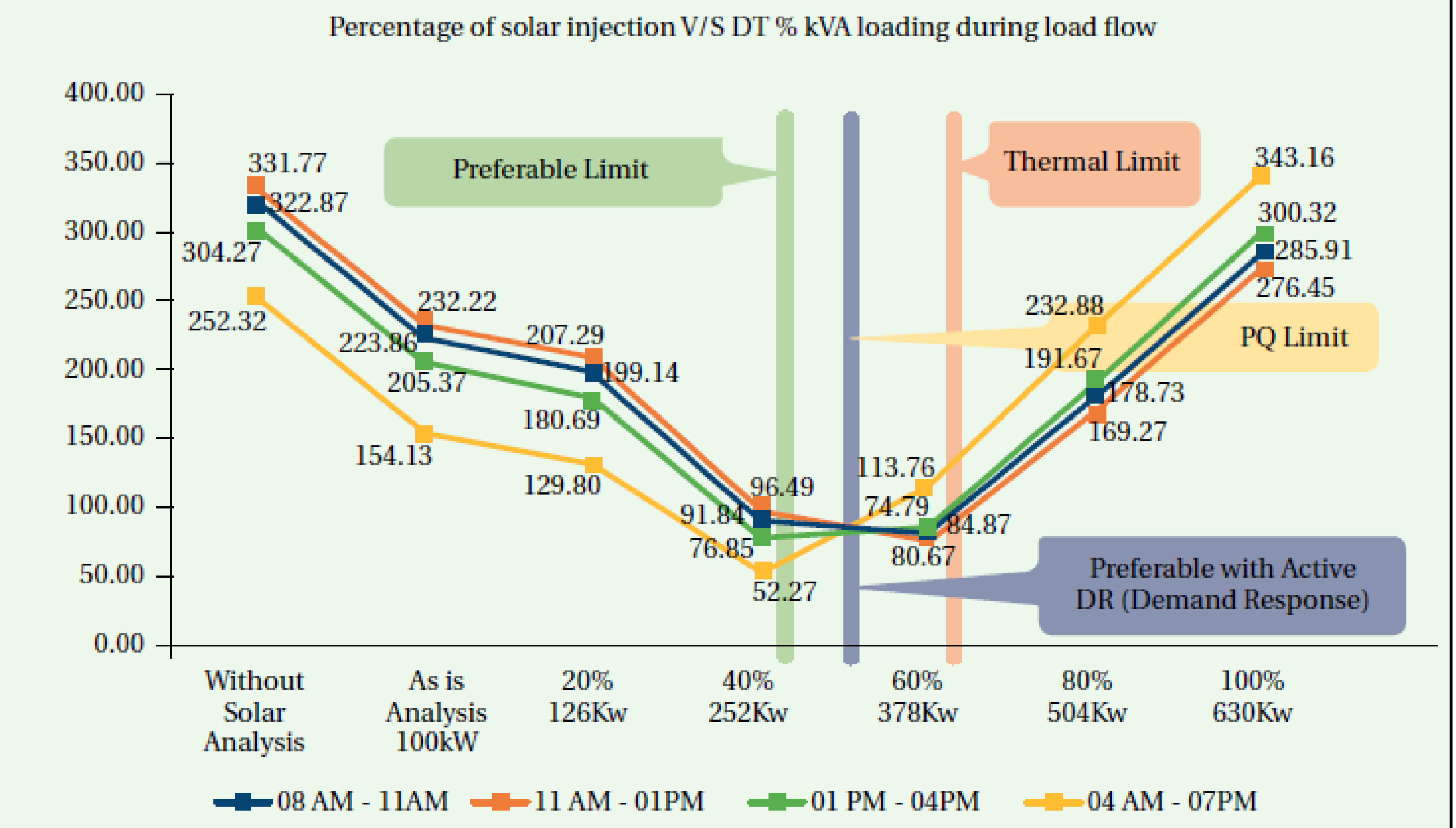
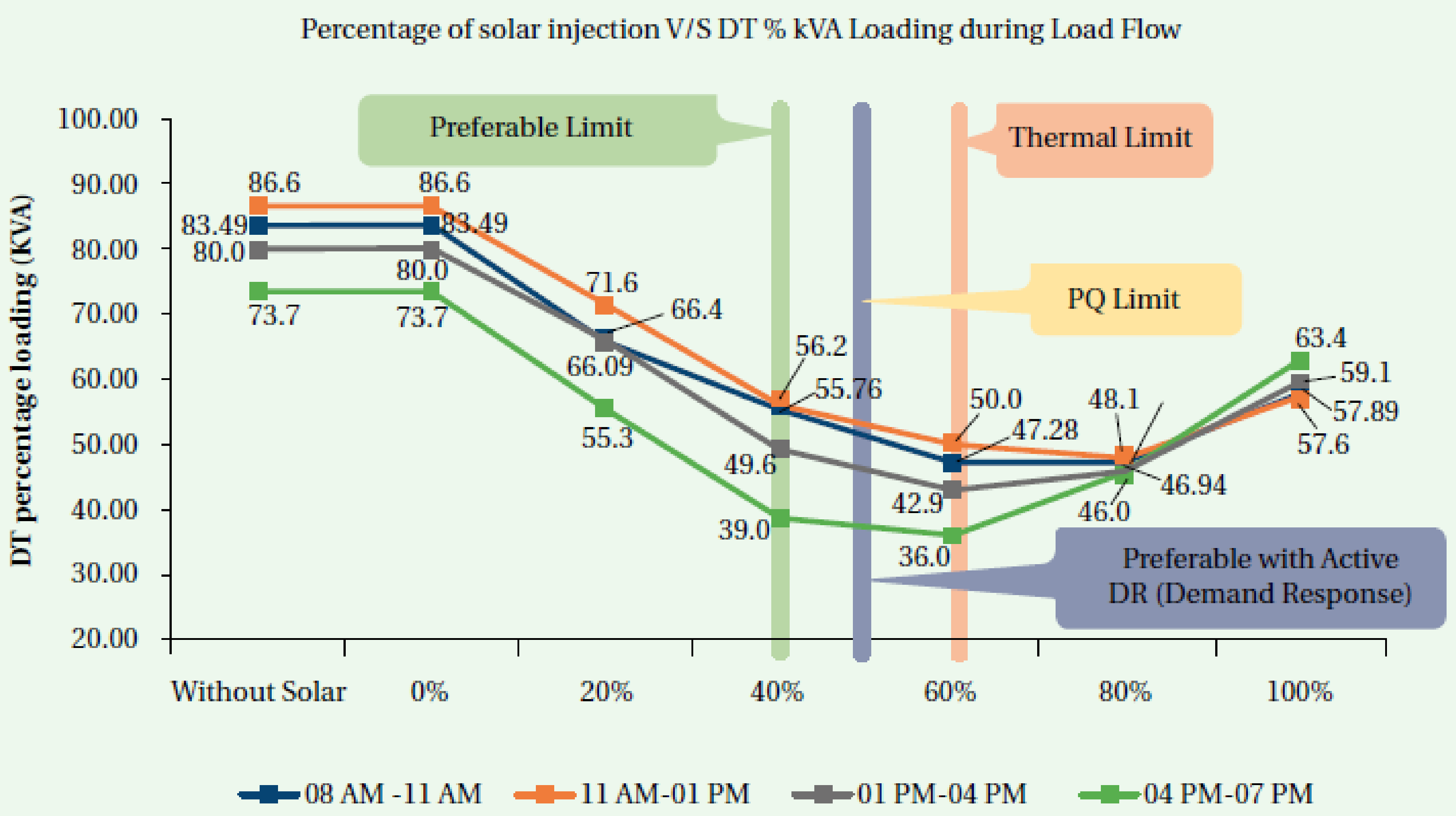
Lightly Loaded Urban LV Feeder

AEML Feeder Load Flow Analysis



Heavily Loaded Urban LV Feeder

CESC Feeder Load Flow Analysis



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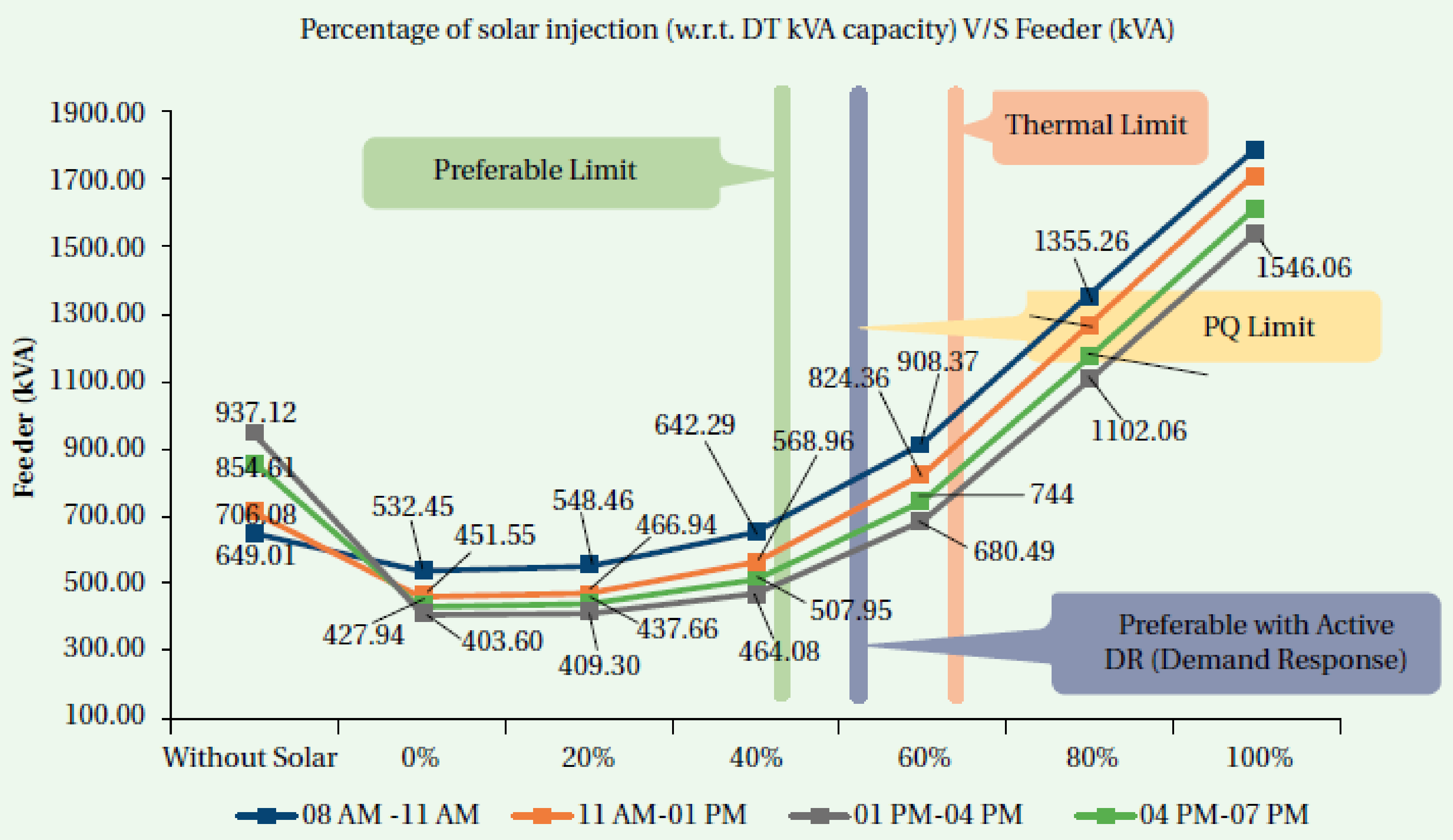
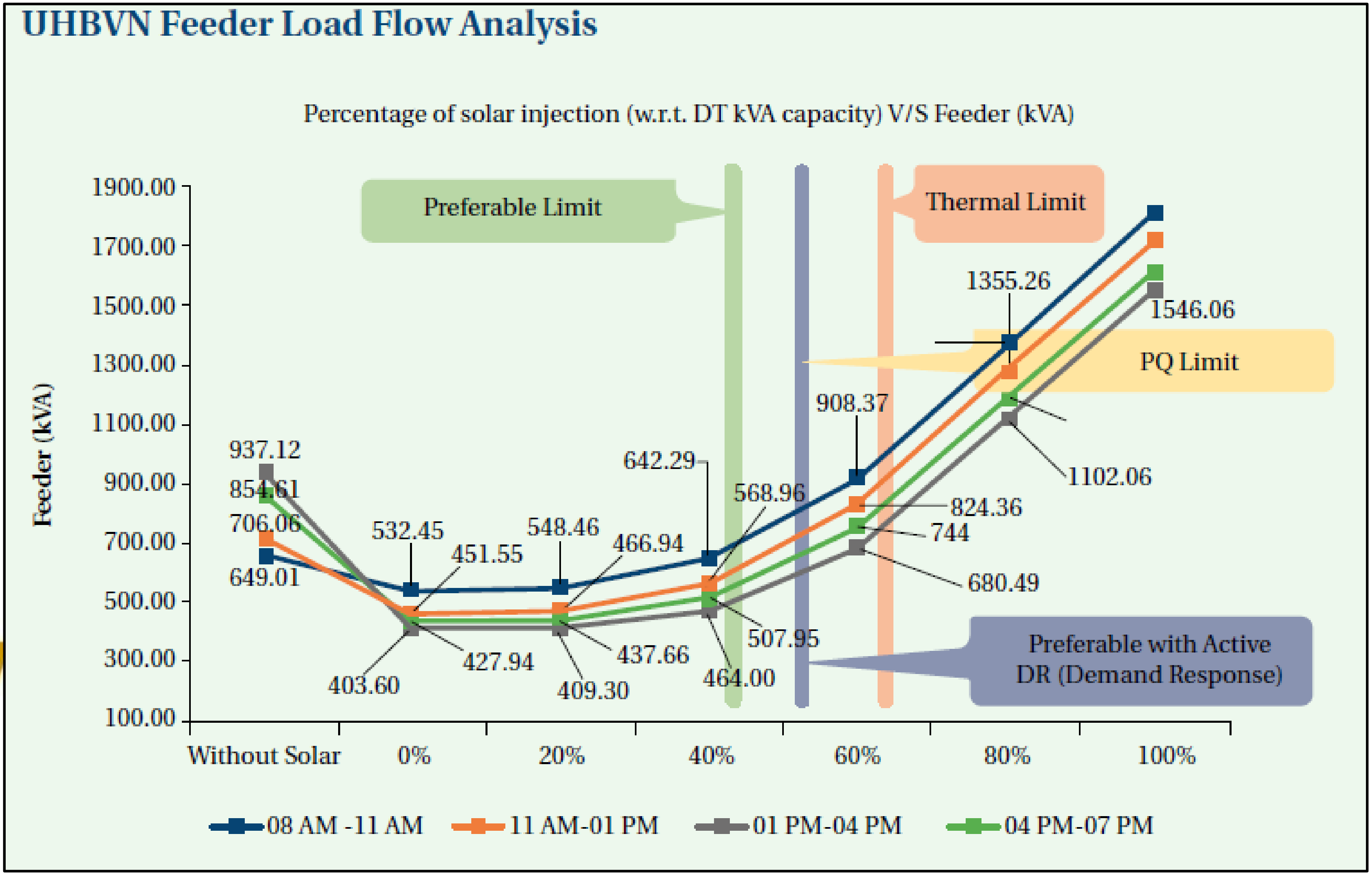
Heavily Loaded Semi-Urban LV Feeder

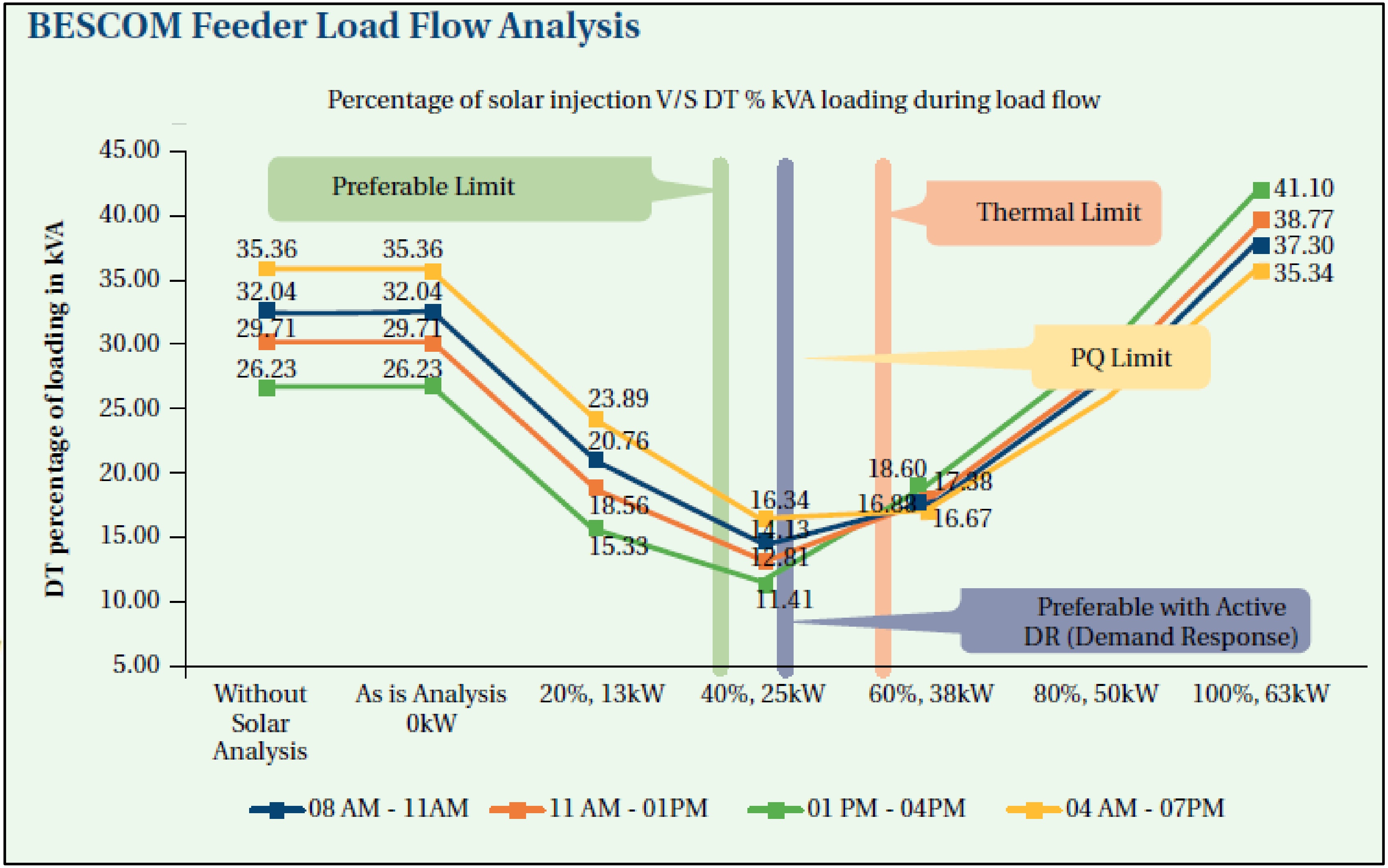
APSPDCL Feeder Load Flow Analysis



Agricultural Rural LV Feeder



11KV Feeder


BESCOM Feeder Load Flow Analysis
Percentage of solar injection V/S DT % kVA loading during load flow
DT percentage of loading in kVA
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
Preferable Limit
Thermal Limit
PQ Limit
Preferable with Active DR (Demand Response)
35.36
32.04
29.71
26.23
23.89
20.76
18.56
15.33
16.34
14.13
12.81
11.41
18.60
17.38
16.88
16.67
41.10
38.77
37.30
35.34
Without Solar Analysis
As is Analysis 0kW
20%, 13kW
40%, 25kW
60%, 38kW
80%, 50kW
100%, 63kW
08 AM - 11AM
11 AM - 01PM
01 PM - 04PM
04 AM - 07PM

Results: Overview

Split of Distribution Network and Solar PV Penetration into Different Categories

Category	Network Expansion Costs	Feeder/ DT Loading	Load Growth	ToD Tariff	Power Cuts (hours/year)	Connected at	Estimated PV Penetration
Metros-Saturated Residential	High	80%	3-5%	No	< 100	415 V	20%-50%
Metros-Saturated Commercial	High	80%	3-5%	Yes	< 100	11 kV	20%-50%
Metros-Saturated Industrial	High	80%	3-5%	Yes	< 100	11 kV	20%-90%
Metros-Growing -Residential	High	50%	5-7%	No	< 100	415 V	20%-50%
Metros-Growing -Commercial	High	80%	5-7%	Yes	< 100	400 V	20%-70%
Metros-Growing-industrial	High	80%	5-7%	Yes	< 100	11 kV	20%-90%
Rural Residential	Low	80%	7-9%	No	< 1000	415 V	20%-70%
Rural Commercial	Low	80%	7-9%	No	< 1000	415 V	20%-70%
Rural 11 kV	Low	80%	7-9%	No	< 1000	11 kV	20%-90%
Peri-Urban/Tier2 Centres R*	Medium	50%	5-7%	Yes	< 300	415 V	20%-70%
Peri-Urban/Tier2 Centres C*	Medium	50%	5-7%	Yes	< 300	415 V	20%-70%
Peri-Urban/Tier2 Centres I*	Medium	50%	5-7%	Yes	< 300	11 kV	20%-90%

(* R-Residential, C-Commercial, I-Industrial; ~Distribution Transformer)

Source: IESA Analysis

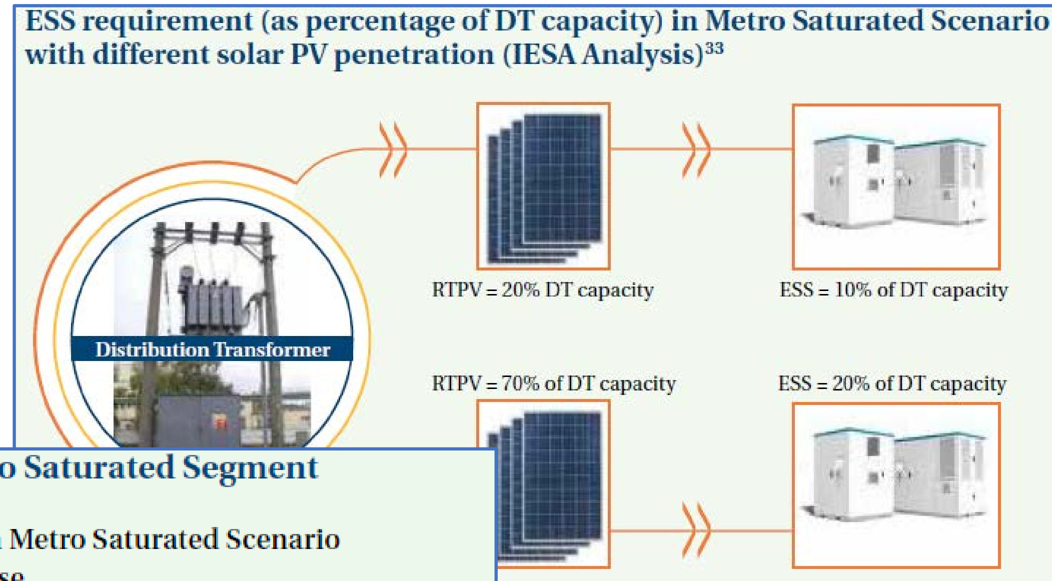
Analysis of PQ issues:

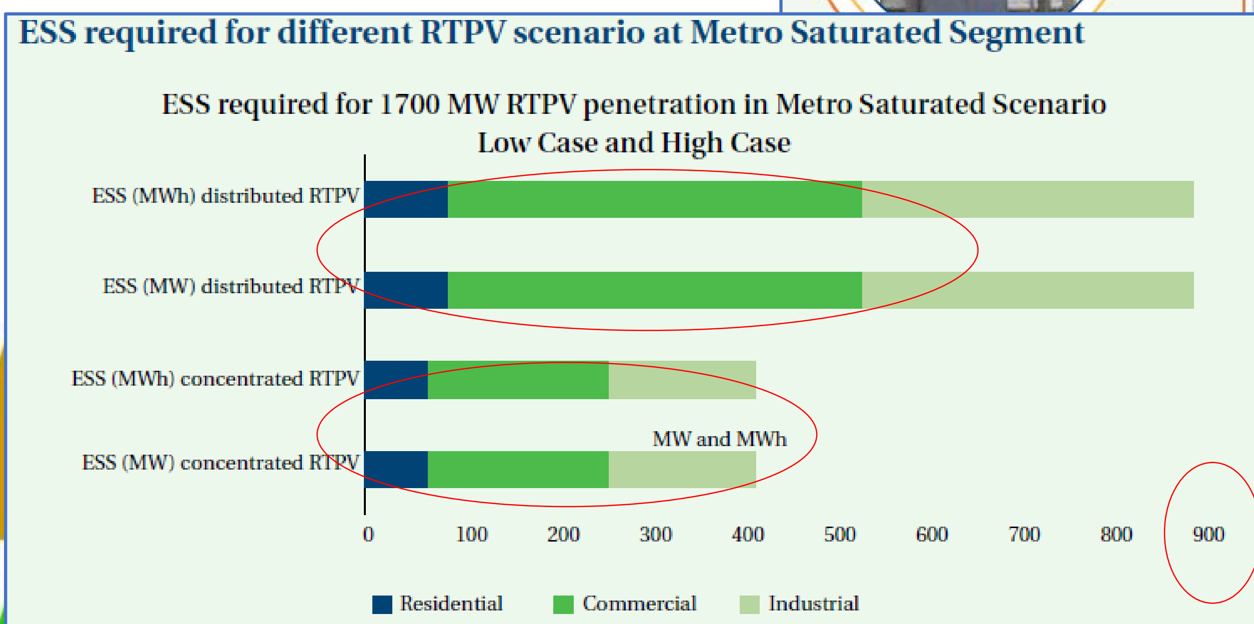
- With increase in RTPV when DT is lightly loaded, Undervoltage is found in some of sections of DT, LT side is removed. So, RTPV improves the health of system
- When DT is more than 75% loaded i.e. heavily loaded and RTPV is increased more than 50% of DT capacity overvoltage is found in some of LT sections near to inverter end. This may increase the voltage at inverter end. This overvoltage is observed randomly across different sections of LT depending upon the solar irradiance level, inverter and load present on sections of conductor

40 GW Rooftop Target Split for Different Types of States

RTPV Split - Categories	Commercial (MW)	Industrial (MW)	Residential (MW)	Total (MW)
Metros-Saturated	850	680	170[32]	1,700
Metros-Growing	1,720	2,150	430	4,300
Rural Residential	3,400	4,250	850	8,500
Peri-Urban/Tier2 Centres	7,650	15,300	2,550	25,500
TOTAL	**13,620**	**22,380**	**4,000**	**40,000**

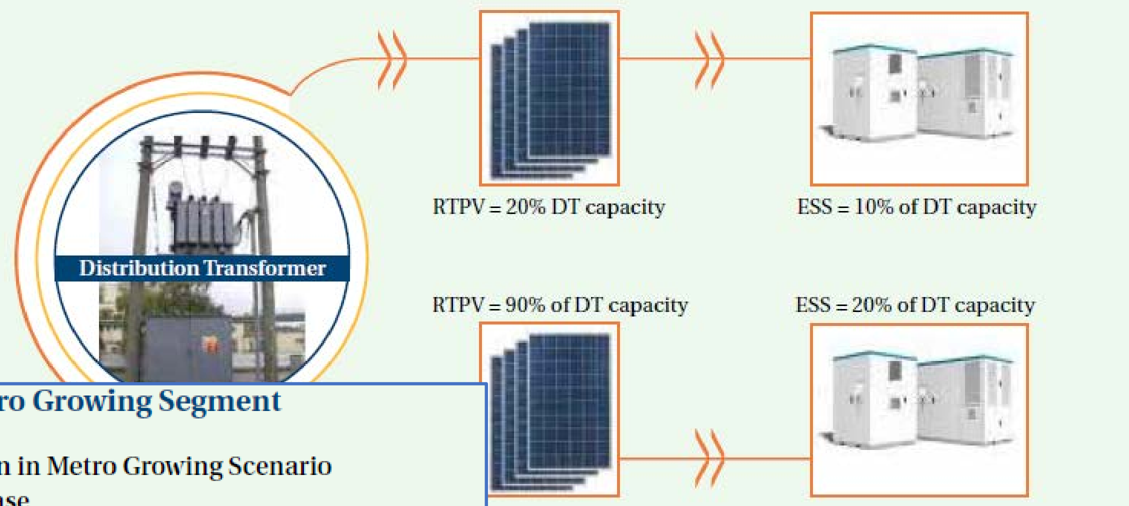
ESS: Metro Saturated RTPV



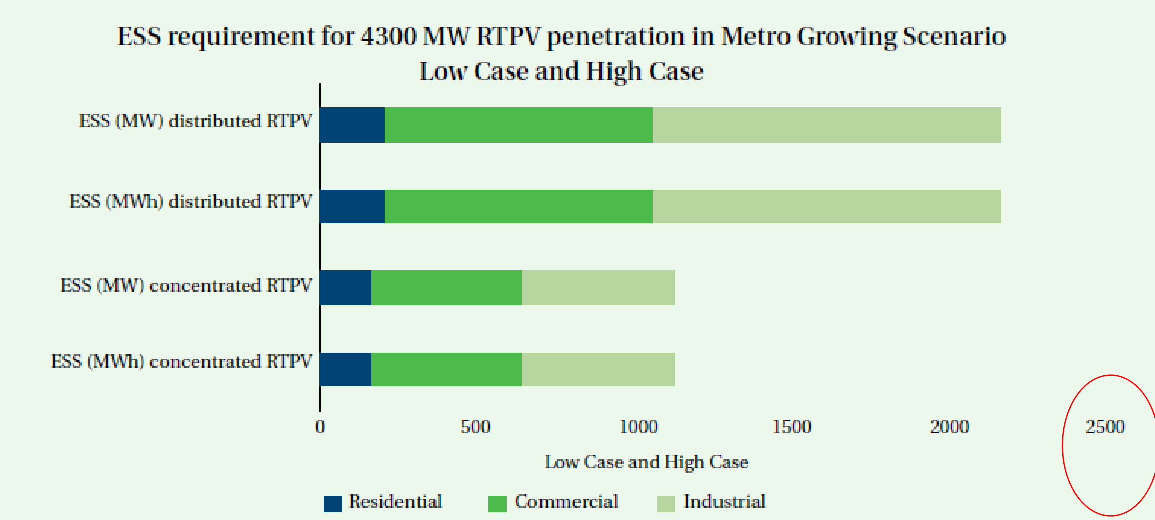


ESS: Metro Growing RTPV

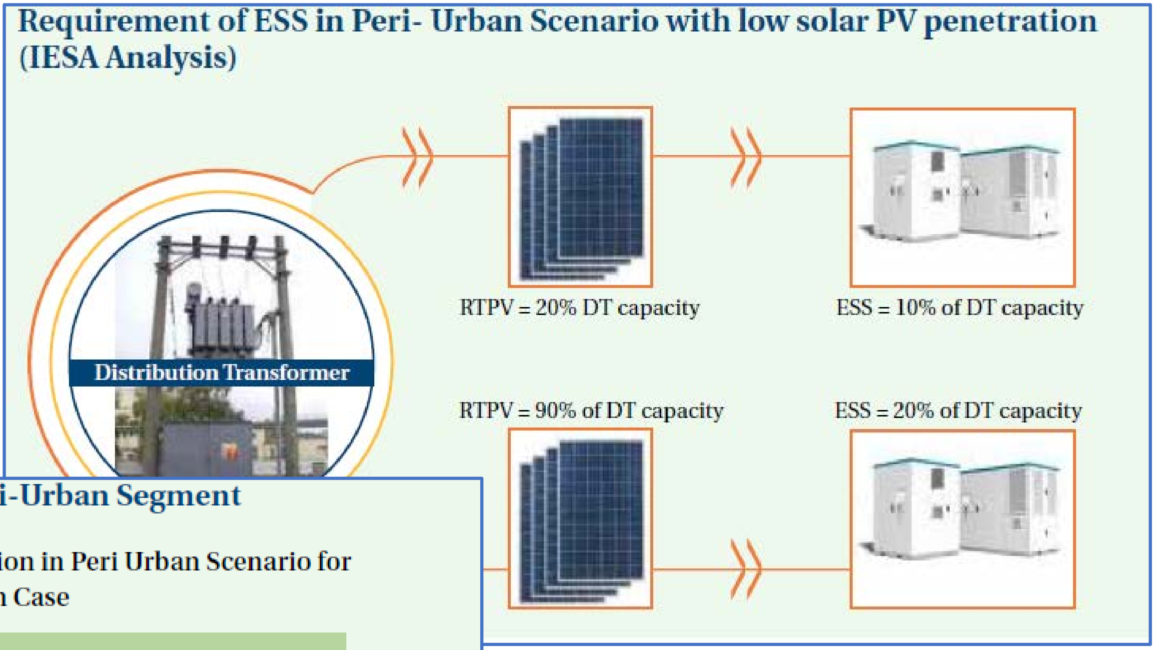
ESS requirement (as percentage of DT capacity) in Metro Growing Scenario with different solar PV penetration (IESA Analysis)

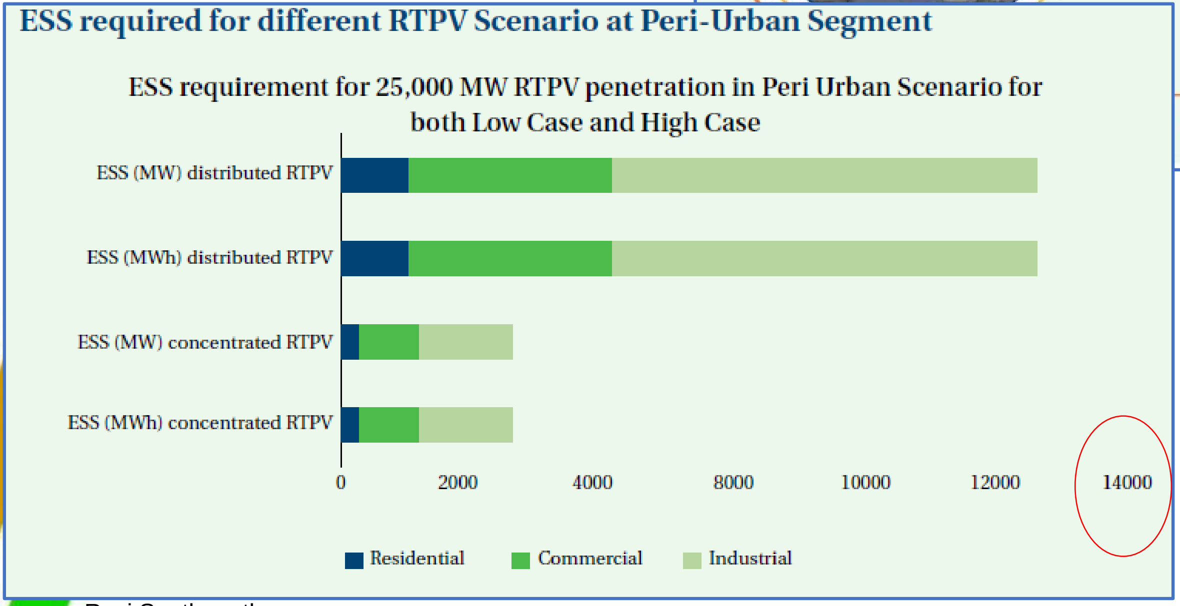


ESS required for different RTPV Scenario at Metro Growing Segment

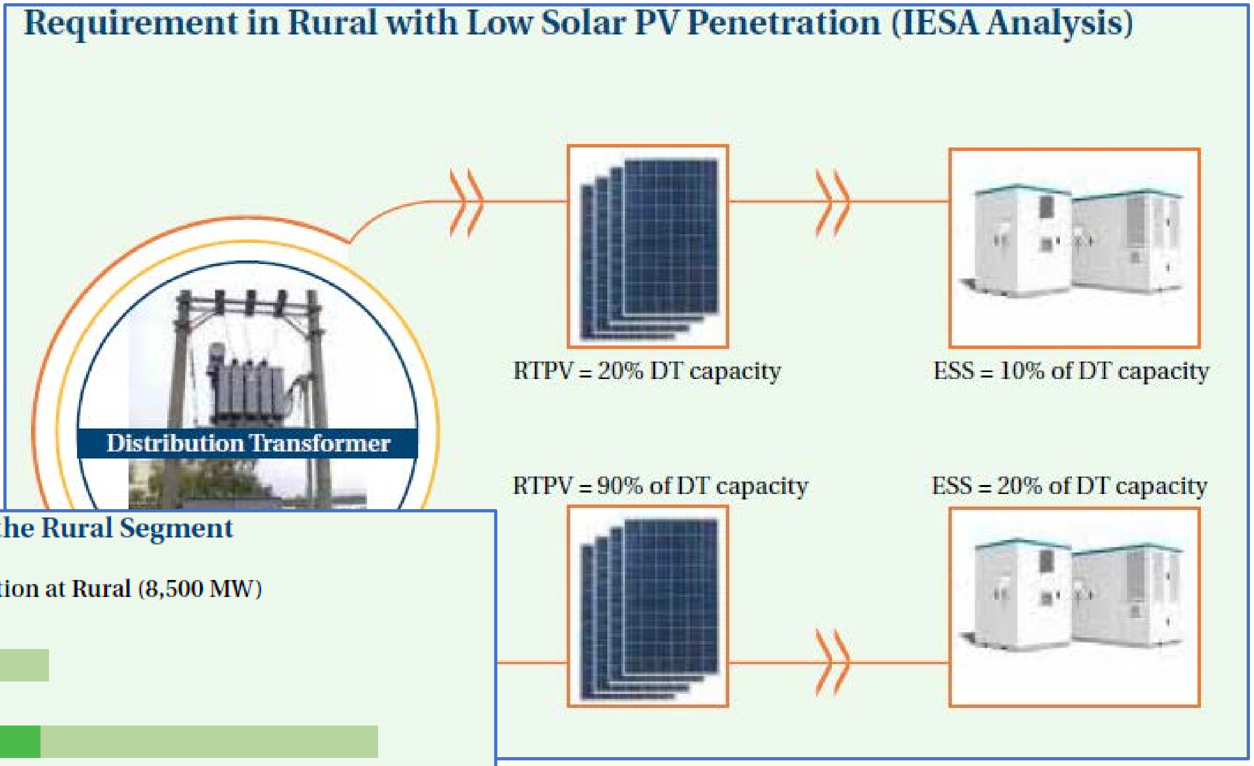


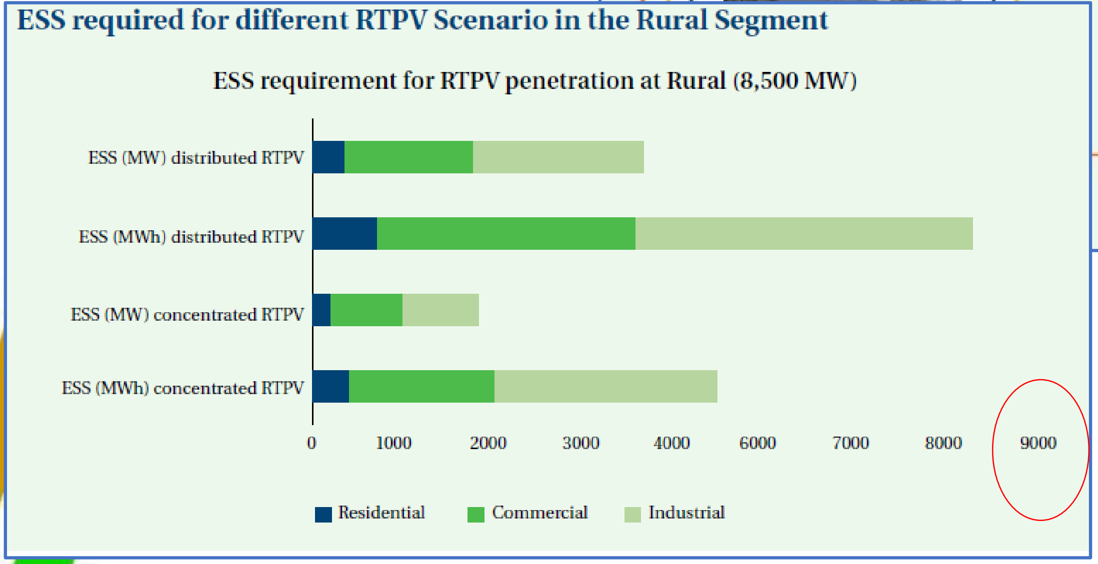
ESS: Semi-Urban RTPV





ESS: Rural RTPV





ESS Estimation MV/LV RTPV

Energy Storage Estimations for MV/LV Grid

Estimations	2019	2022	2027	2032
Generation (GW)				
Thermal	209	NA	NA	NA
Hydro	43	NA	NA	NA
Nuclear	6	NA	NA	NA
Solar	26	107	244	349
Ground Mounted Solar	24	68	148	206
RTPV	1.5	40	98	144
Connected to EHV	14	34	66	94
Connected to MV	11	35	84	112
Connected to LV	2	40	98	144
Wind	35	NA	NA	NA
Small Hydro	4.5	NA	NA	NA
Biomass & Biopower	10	NA	NA	NA
Peak Load (GW)	192	333	479	658
Energy (BUs)				
Annual Energy	1192	1905	2710	3710
Storage Recommended (MWh)				
Battery (LV)	241	5908	14617	21484
Battery (MV)	1054	3482	8393	11191
Total (MWh)	**1295**	**9390**	**23010**	**32675**
Approximate (GWh)	**1 GWh**	**10 GWh**	**24 GWh**	**33 GWh**

Note: In congruence with the RE target of 175 GW by 2022, the calculations were done on the basis of 100 GW Solar, out of which 40 GW is RTPV, 20 GW is medium size installations and 40 GW is from large solar parks. Similarly, for 2027 and 2032, the ratio of RTPV was taken in accordance with the 2022 targets constituting of 40% RTPV of the total solar installed capacity. All the values for 2027 and 2032 have been forecasted using the best available data in public domain.

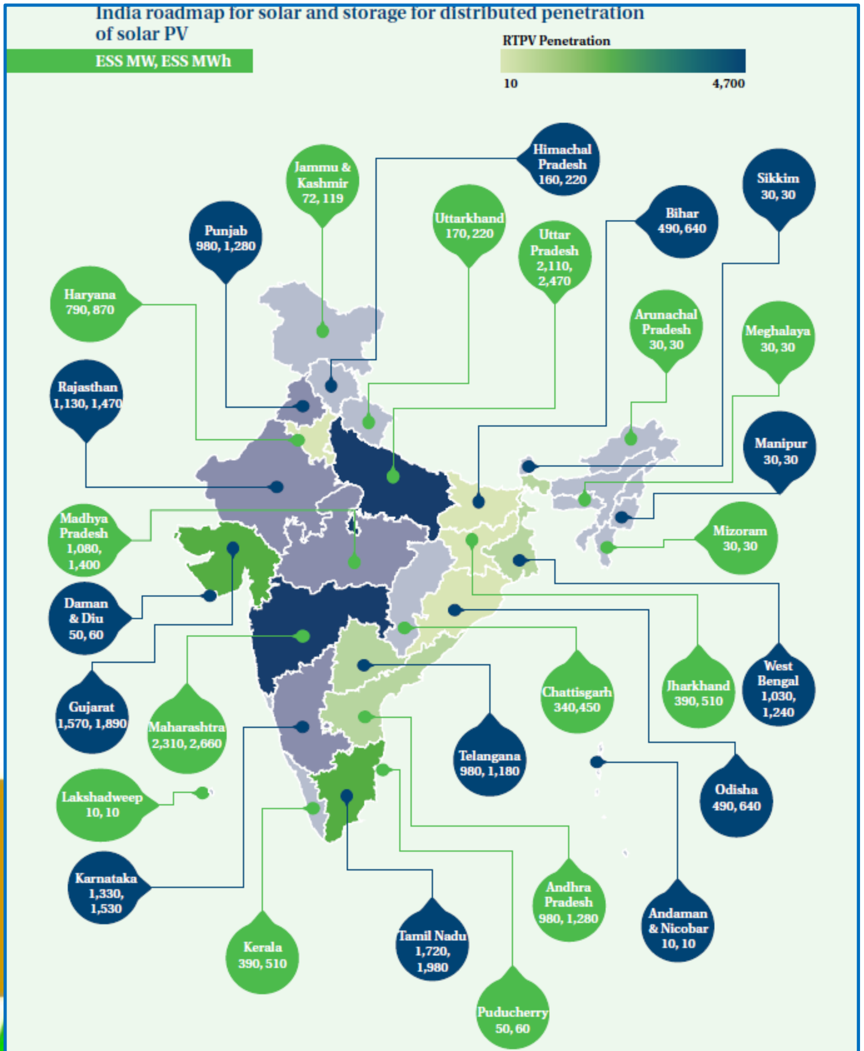
ESS: Consolidated Roadmap

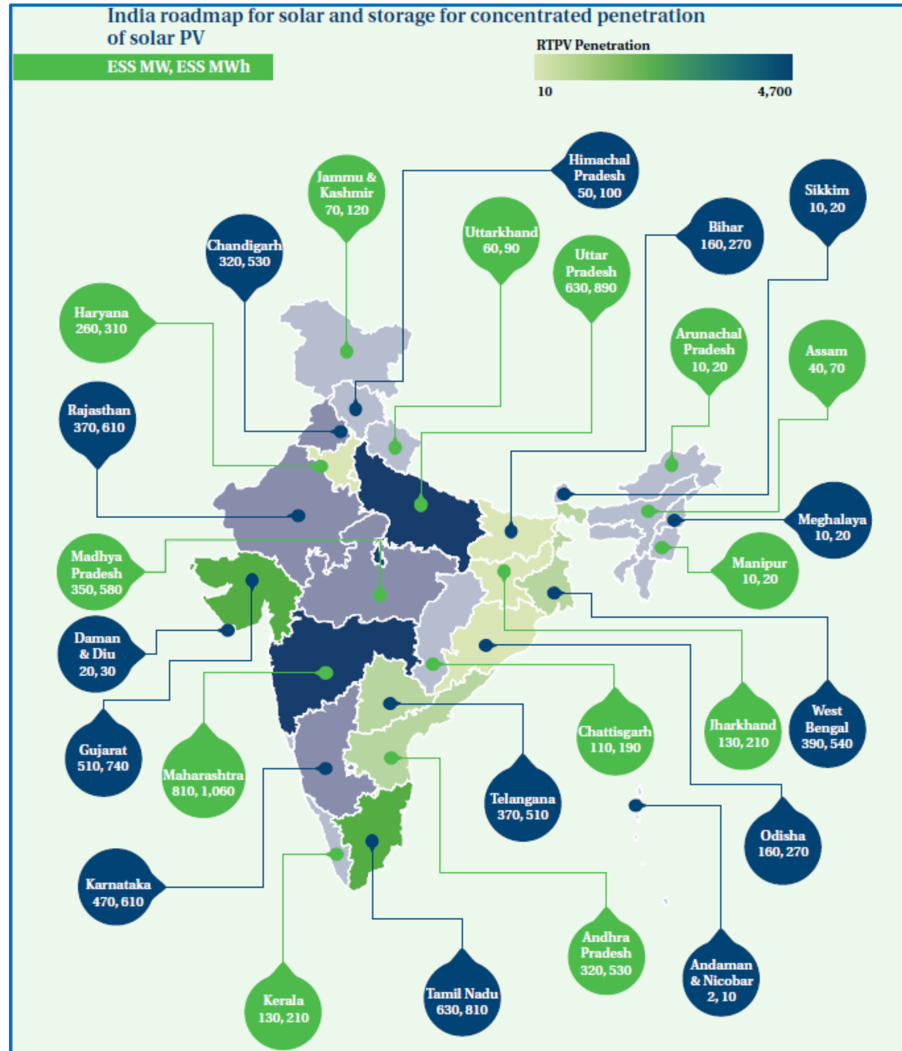
Consolidated Energy Storage Roadmap

	Consolidated Energy Storage Roadmap						
	Applications 2019-2022		Energy Storage (GWh)			
			2019-2022	2022-2027	2027-2032	Total by 2032
Stationary Storage	Grid Support	MV/LV	10	24	33	67
		EHV	7	38	97	142
	Telecom Towers		25	51	78	154
	Data Centres, UPS and inverters		80	160	234	474
	Miscellaneous Applications (Railways, rural electrification, HVAC application)		16	45	90	151
	DG Usage Minimization		-	4	11	14
	Total Stationary (GWh)		138	322	543	1,002
Electric Vehicles	E2W		4	51	441	496
	E3W		26	43	67	136
	E4W		8	102	615	725
	Electric Bus		2	11	44	57
	Total Electric Vehicles (GWh)		40	207	1,167	1,414
Total Energy Storage Demand (GWh)			178	529	1710	2416

Covered in Next Section

ESS: Conc. & Distr. PV Penetration





Thank You

Brief CV of Ravi Seethapathy

Fellow, Canadian Academy of Engineering
Life Senior Member, IEEE
Professional Engineer, Ontario
B.Tech (Hons), M.Eng, MBA
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Ravi Seethapathy, serves as the Executive Chairman of Biosirus Inc., Canada and sits as a Corporate Director on the Board of Power Transmission & Distribution Division (IC) of Larsen & Toubro, India. He also serves as the “Ambassador for the Americas”, for the Global Smart Grid Federation, USA, and an Advisor to the India Smart Grid Forum and the India Energy Storage Alliance. He is an Expert Advisor to the Utilities/Industry in the Energy and Power Systems area with over 35+ years of experience.

His former contributions in the Canadian utility sector includes Systems Innovation & Advanced Grid Development at Hydro One Networks prior to his retirement in April 2014. At Hydro One Networks, he led the power systems technical architecture of its Advanced Grid (Smart Grid) Pilot Project from 2009-2011, the Corporate Smart Grid Strategy Taskforce in 2008 and from 2006 the initial efforts in the integration of DER in the Hydro One Distribution System. His 29+ years of experience at Hydro One/Ontario Hydro has been in almost all fields of electric utility business and he has progressively held leading positions in Protection & Control, Field Operations, Hydraulic Generation and Transmission Operations, Generation Performance, Distribution Strategy/Planning, Mergers & Acquisition, Corporate Audit, Asset Management and Asset Strategies Divisions and most recently in Corporate Research.

His current international technical activities include (1) Canada Expert Member, IEC SEG 11 “Future Sustainable Transportation”; (2) CSA/IEC TC 120 - Energy Storage; (3) CSA SysC LVDC Committee; (4) WG Chair, “Flexible Grid Towards Customer Enablement”, Global Smart Grid Federation; and (5) Chair, India Smart Grid Forum WG 5 (Renewables & Microgrid). He is an invited speaker in the international Smart Grid area having co-authored over 50 technical papers. He/ family have endowed an IEEE Award in "Rural Electrification Excellence". His prior professional engagements include Advisory Council of EPRI’s Power Delivery and Utilization Division (2010-2014); Governing Council, Energy Research Initiative, Semi-Conductor Research Corporation (2012-2014); CEATI’s Smart Grid Taskforce (2012-2014) and SOIG WG (2009-2011); Corporate Directorships at Smart Grid Canada (2012-2019), India Smart Grid Forum (2015-2018), Toronto Atmospheric Fund (2015-2017), Ryerson University (2007-2010), TV Ontario (2001-2007), Scarborough Hospital (2002-2004) and as Chair of Engineers Without Borders (2000-2006), Canadian Club of Toronto (2003-2004) and President Indo-Canada Chamber of Commerce (1998-2000).

He is a Senior Life Member of the IEEE; a Life Fellow of the Canadian Academy of Engineering; and a registered Professional Engineer in Ontario. He has co-authored over 50 leading technical papers in Advanced Grid systems; actively lectures at Conferences and Universities and was honoured with the Queen Elizabeth II Diamond Jubilee Medal in 2012 (among other citations and awards). He holds a B.Tech (Hons) in Electrical Power from IIT, India, an M.Eng in Electrical Power from University of Toronto and an MBA from the Schulich School of Business, York University, Toronto.