PV Hosting Capacity Study for New Delhi and Bhopal

Commissioned by: Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH

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german cooperation
DEUTSCHE ZUSAMMENARBEIT

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Technology Options

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Conclusions and Recommendations

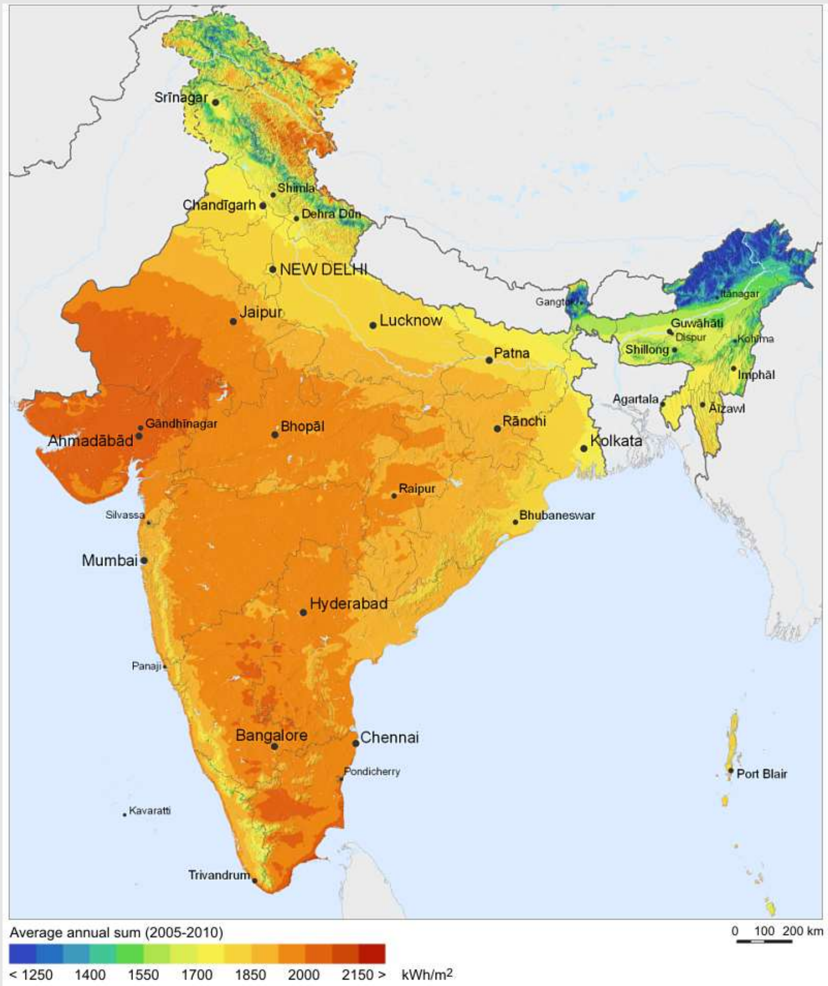
Introduction

Objectives and Background

India plans to increase ist PV capacity to 100 GW by 2022, 40 GW of which will be rooftop installations.

Within this study, four distribution grids in Delhi and Bhopal were selected and modelled in DIgSILENT PowerFactory based on data provided by the distribution companies.

These simulation models were used to analyze the impact of rising shares of rooftop PV on these grids.



Modelling and Scenarios

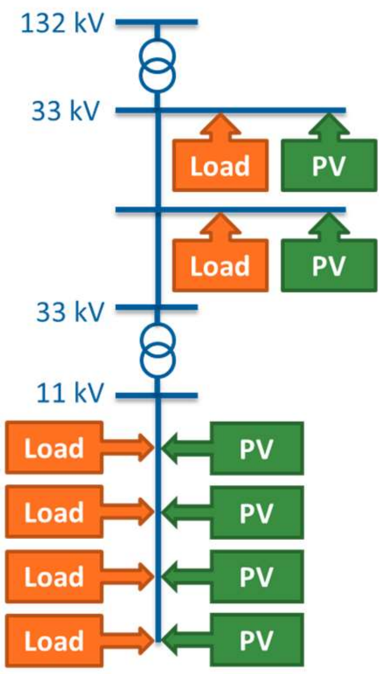
Model Grids

	Delhi urban	Delhi rural 1	Delhi rural 2	Bhopal urban	Bhopal rural
Supplied from	33 kV	66 kV	66 kV	132/33 kV	33 kV
Dominant cable/line type	300XLPE cable, 5.7 MVA	Dog ACSR OHL, 5.7 MVA	Dog ACSR OHL, 5.7 MVA	Rabbit ACSR OHL, 2.9 MVA	Raccoon ACSR OHL, 3.8 MVA
Length OHL	-	19.8 km	16.7 km	2.7 km	11.0 km
Length UG cables	3.1 km	10.9 km	2.6 km	-	-
Total length	3.1 km	30.7 km	19.3 km	2.7 km	11.0 km
Installed DT capacity	5.4 MVA	5.2 MVA	4.6 MVA	2.2 MVA	3.7 MVA
Peak load	2.5 MW	3.4 MW	3.0 MW	1.1 MW	1.6 MW

Scenarios – PV Distribution along the Feeder

PV equal distribution

Upstream network for Bhopal only



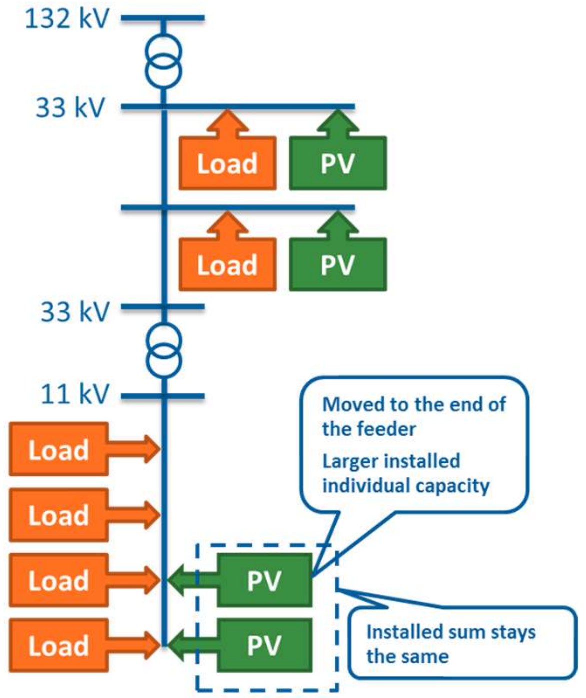
+ detailed 400 V networks for Delhi only

PV development may not always be homogeneous.

A concentration of PV capacity at the end of a feeder has a higher impact on voltage than homogeneous distribution.

PV end of feeder

Upstream network for Bhopal only



+ detailed 400 V networks for Delhi only

Technology Options

Technology Options (Overview)

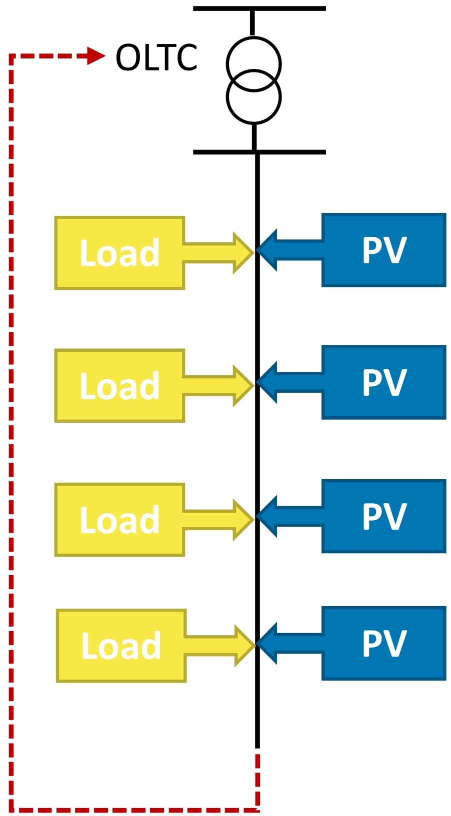
Measure	Abbreviation
Base case	base
OLTC with automatic voltage regulation at MV level	mvoltc
Wide area control	wide area control
Shunt compensators for voltage control	shuntvcontrol
PV inverters with fixed non-unity power factor	fixed PF
Active voltage control by PV inverters (Q(U) characteristic)	qvchar
On-load tap changing DT	oltc
PV cap at certain percentage of installed panel capacity	cap pv
Reinforcements of lines, cables transformers	grid reinforcement
PV storage battery deployment – own consumption	storage ownConsumption
PV storage battery deployment – peak shaving	storage peakShaving
Demand side management	dsm

- If the PV induced reversed flow on a feeder becomes too high, voltage limits may be violated.
- High reversed flows can also overload assets in the grid, lines and transformers.
- The conventional way of dealing with such issues is network reinforcement.
- Grid operators in countries and areas with high penetration levels of distributed integration have developed and introduced a number of measures that can increase the hosting capacity of a grid without grid reinforcements.
- Grid reinforcements may be an inefficient way of dealing with issues that only appear during peak PV feed-in and thus relatively rarely.

Technology Option: Wide Area Control

Measure	Abbreviation
Base case	base
OLTC with automatic voltage regulation at MV level	mvoltc
Wide area control	wide area control
Shunt compensators for voltage control	shuntvcontrol
PV inverters with fixed non-unity power factor	fixed PF
Active voltage control by PV inverters (Q(U) characteristic)	qvchar
On-load tap changing DT	oltc
PV cap at certain percentage of installed panel capacity	cap pv
Reinforcements of lines, cables transformers	grid reinforcement
PV storage battery deployment – own consumption	storage ownConsumption
PV storage battery deployment – peak shaving	storage peakShaving
Demand side management	dsm

66/33 kV to 11 kV transformer is controlled with discrete on load tap changers which control voltage at different points nf the feeder. These can be at 11 kV or 400 V level



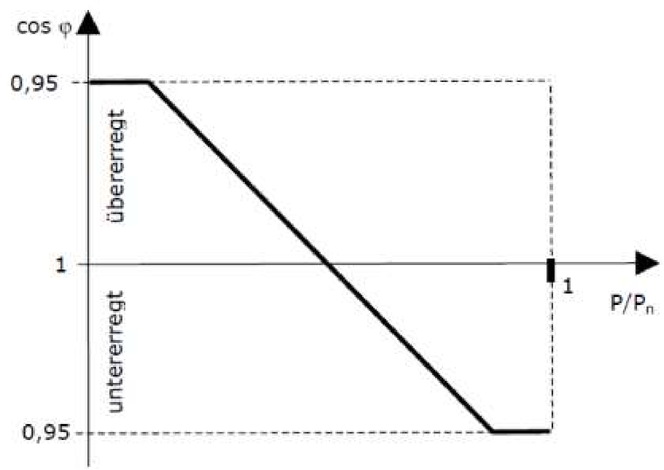
Technology Option: Reactive Power

Measure	Abbreviation
Base case	base
OLTC with automatic voltage regulation at MV level	mvoltc
Wide area control	wide area control
Shunt compensators for voltage control	shuntvcontrol
PV inverters with fixed non-unity power factor	fixed PF
Active voltage control by PV inverters (Q(U) characteristic)	qvchar
On-load tap changing DT	oltc
PV cap at certain percentage of installed panel capacity	cap pv
Reinforcements of lines, cables transformers	grid reinforcement
PV storage battery deployment – own consumption	storage ownConsumption
PV storage battery deployment – peak shaving	storage peakShaving
Demand side management	dsm

Reactive power from PV inverters can be used to mitigate voltage problems.

PV inverters can either be operated at a fixed power factor, or with a Q(V) or Q(P) characteristic.

Technology is available and widely used.



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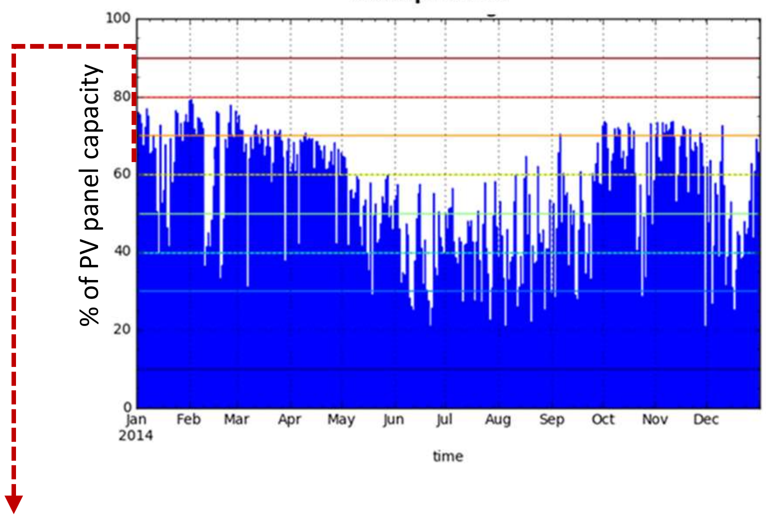
Technology Option: Inverter Cap

Measure	Abbreviation
Base case	base
OLTC with automatic voltage regulation at MV level	mvoltc
Wide area control	wide area control
Shunt compensators for voltage control	shuntvcontrol
PV inverters with fixed non-unity power factor	fixed PF
Active voltage control by PV inverters (Q(U) characteristic)	qvchar
On-load tap changing DT	oltc
PV cap at certain percentage of installed panel capacity	cap pv
Reinforcements of lines, cables transformers	grid reinforcement
PV storage battery deployment – own consumption	storage ownConsumption
PV storage battery deployment – peak shaving	storage peakShaving
Demand side management	dsm

PV panels usually do not reach their full peak output due to heat and dust.

Independently of that, peak power situations are rare anyways.

Example data



Capping the inverter somewhere here would reduce peak feed-in while losing only a small amount of yearly energy.

Bhopal: Cap at 75 % of peak power (53 % of panel capacity)
Delhi: Cap at 70 % of peak power (50 % of panel capacity)

→ less than 3 % of energy lost annually

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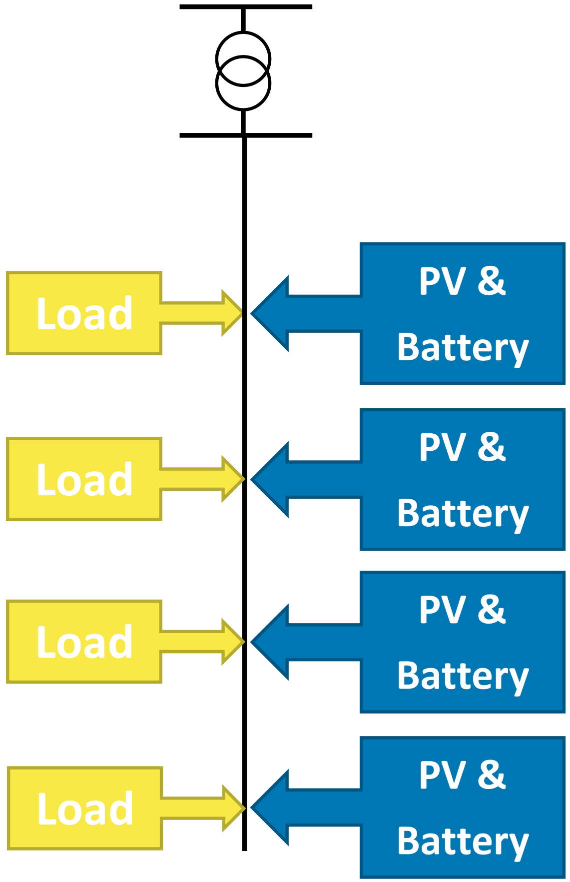
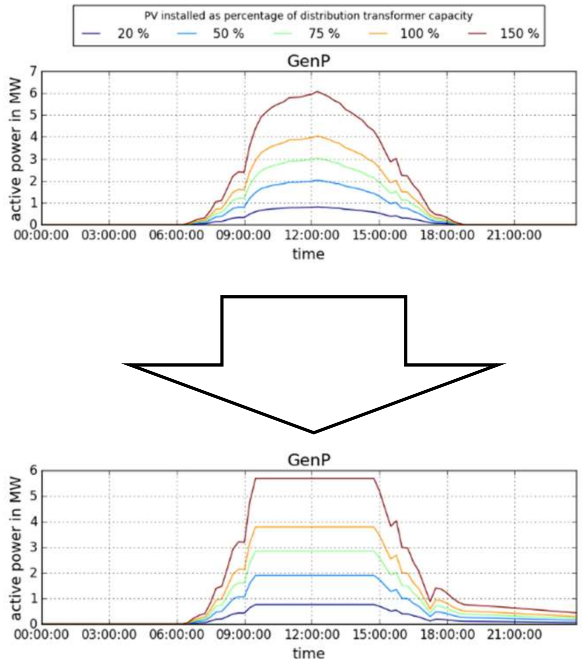
Technology Option: Storage Peak Shaving

Measure	Abbreviation
Base case	base
OLTC with automatic voltage regulation at MV level	mvoltc
Wide area control	wide area control
Shunt compensators for voltage control	shuntvcontrol
PV inverters with fixed non-unity power factor	fixed PF
Active voltage control by PV inverters (Q(U) characteristic)	qvchar
On-load tap changing DT	oltc
PV cap at certain percentage of installed panel capacity	cap pv
Reinforcements of lines, cables transformers	grid reinforcement
PV storage battery deployment – own consumption	storage ownConsumption
PV storage battery deployment – peak shaving	storage peakShaving
Demand side management	dsm





Battery optimized for peak shaving gets added to every PV system

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Simulations and Results

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Simulations

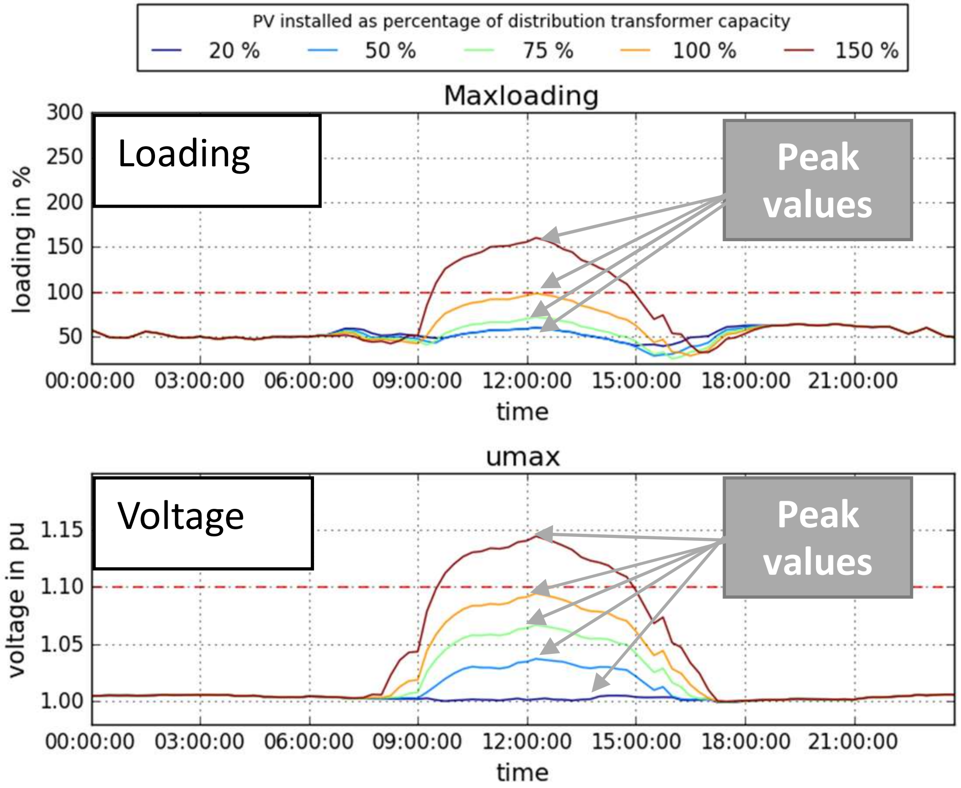
Stepwise increase of installed PV generation

Delhi urban		Delhi rural		Bhopal urban		Bhopal rural	
% of DT	MW	% of DT	MW	% of DT	MW	% of DT	MW
20%	1.1	15%	1.5	30%	3.9	30%	10.9
50%	2.7	40%	3.9	50%	6.5	50%	18.2
75%	4.1	75%	7.4	75%	9.8	75%	27.2
100%	5.4	100%	9.8	100%	13.0	100%	36.3
150%	8.1	150%	14.7	150%	19.5	150%	54.5

Both rural feeders combined

Bhopal: Including upstream PV and parallel feeders

Simulations



Simulation of a full day with

- **Maximum PV infeed profile**
- **Minimum load**

Evaluation of

- **Highest voltage**
- **Highest loading**

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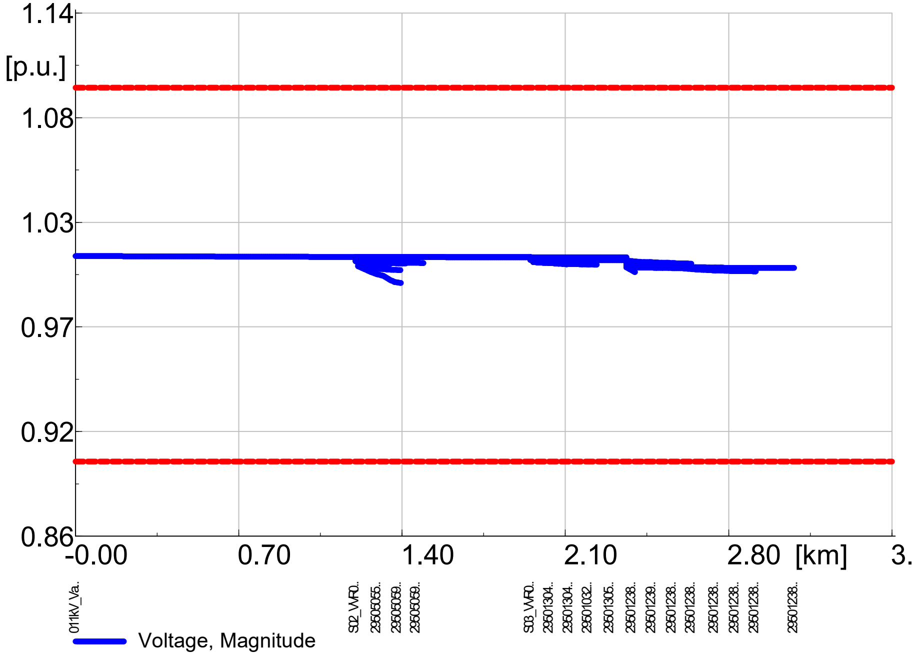
Results on Increasing PV Penetration

PV Penetration: **20 %** of DTs

Voltage



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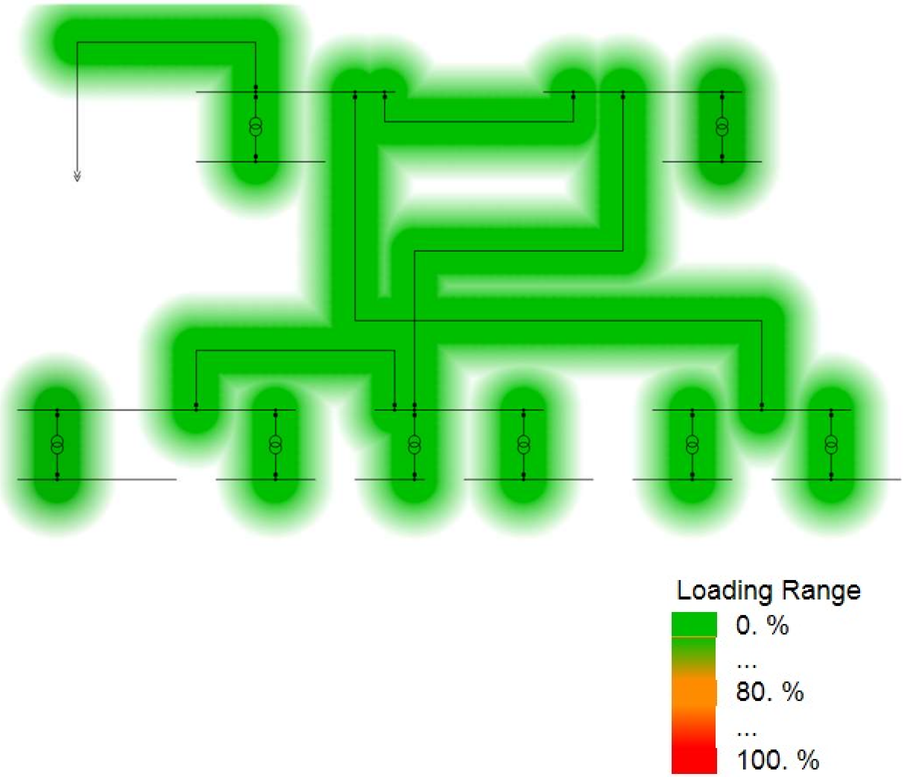

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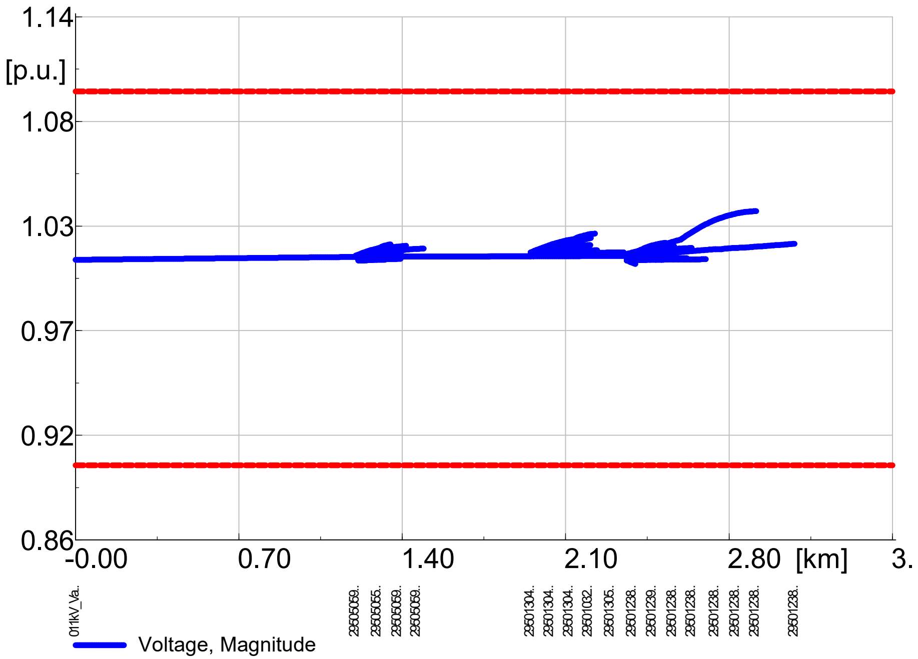
Results Delhi urban (1)

PV Penetration: **50 %** of DTs

Voltage



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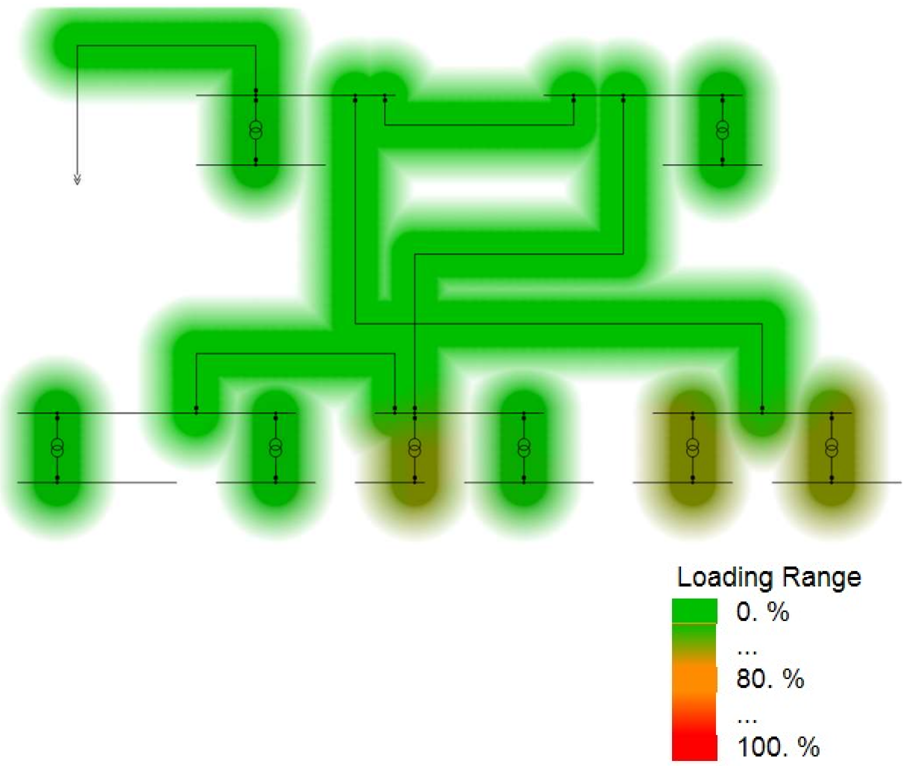

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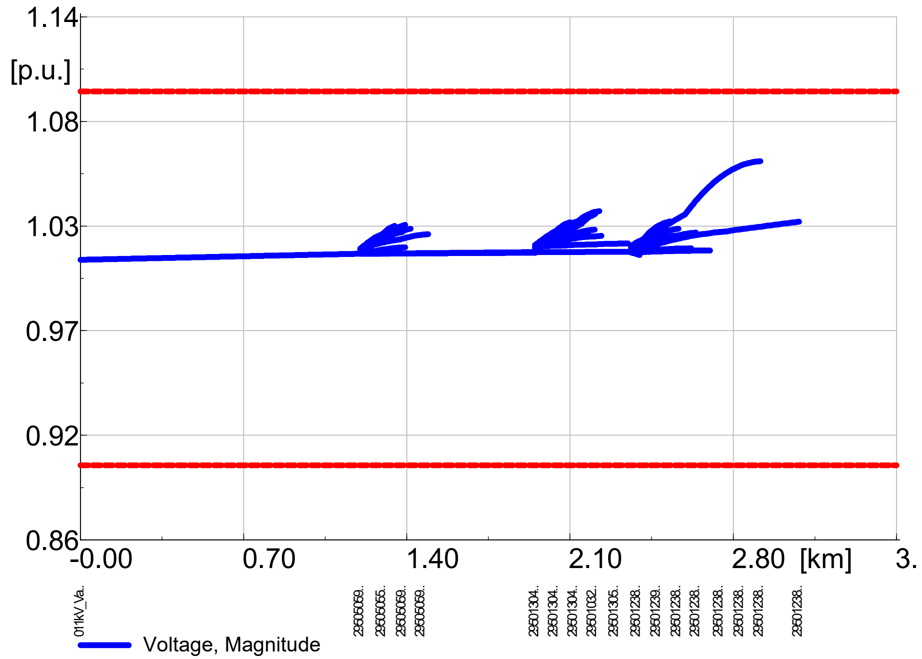
Results Delhi urban (2)

PV Penetration: **75 %** of DTs

Voltage



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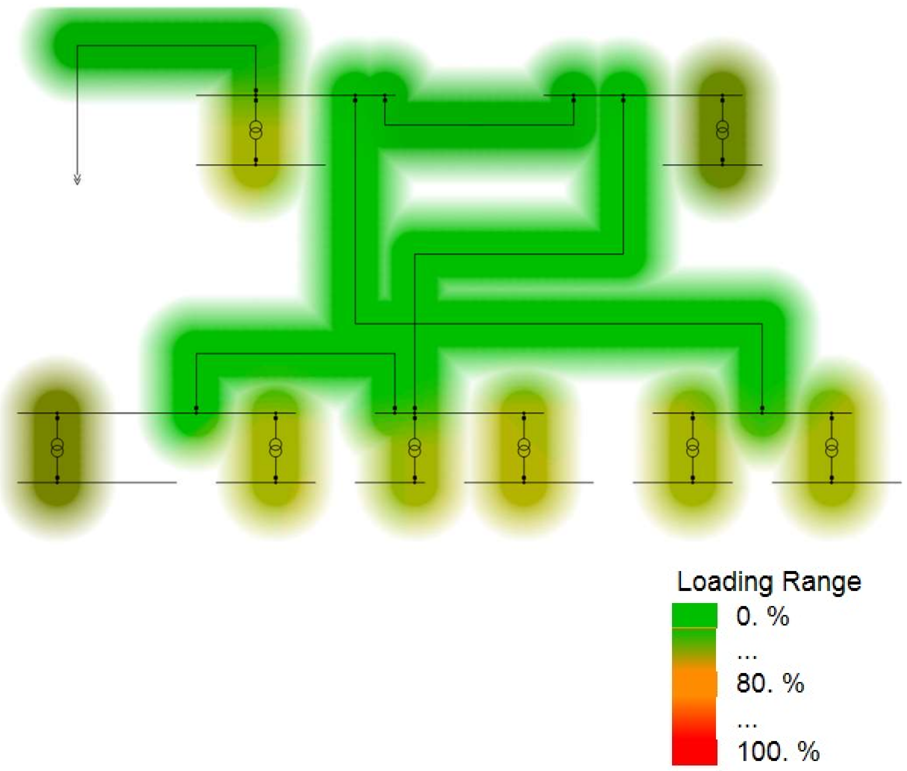
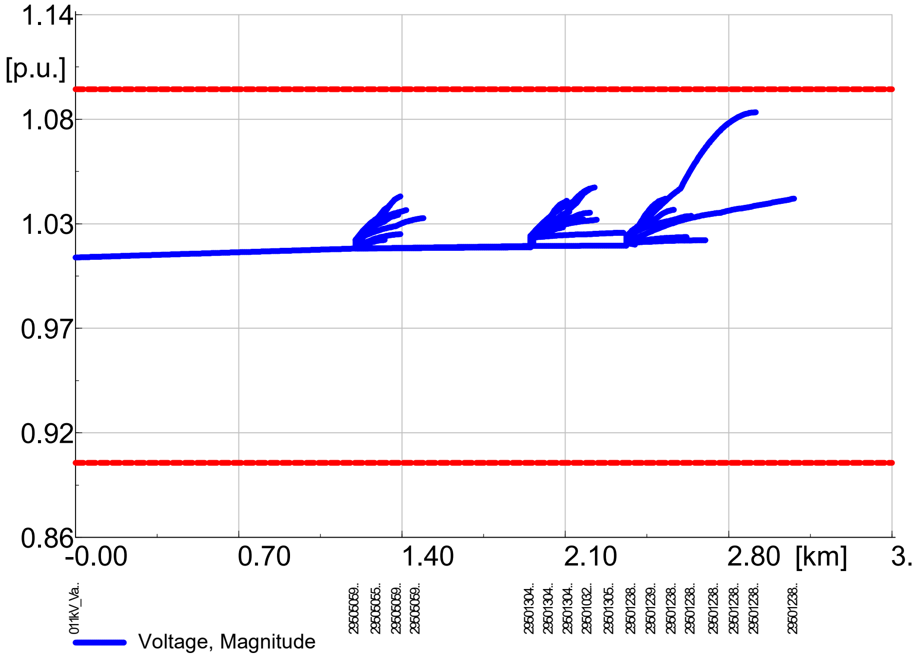


Results Delhi urban (3)

PV Penetration: **100 %** of DTs

Voltage



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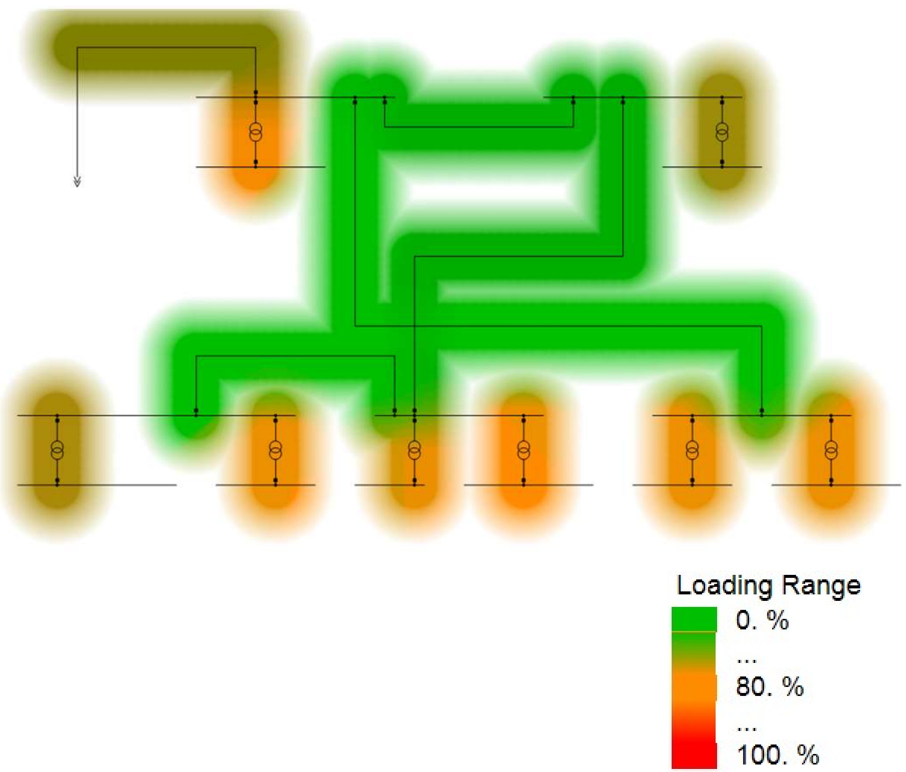

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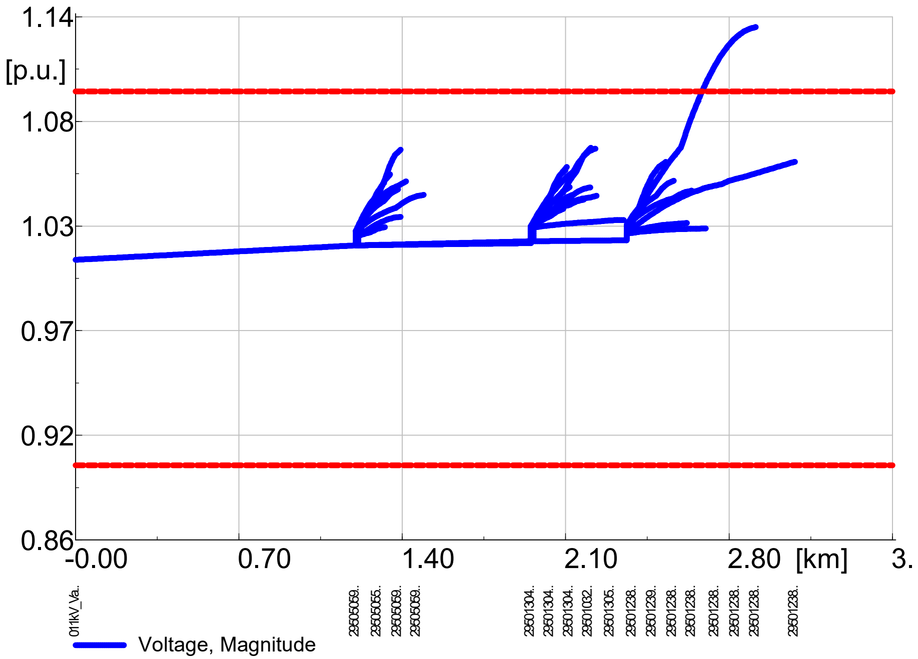
Results Delhi urban (4)

PV Penetration: **150 %** of DTs

Voltage



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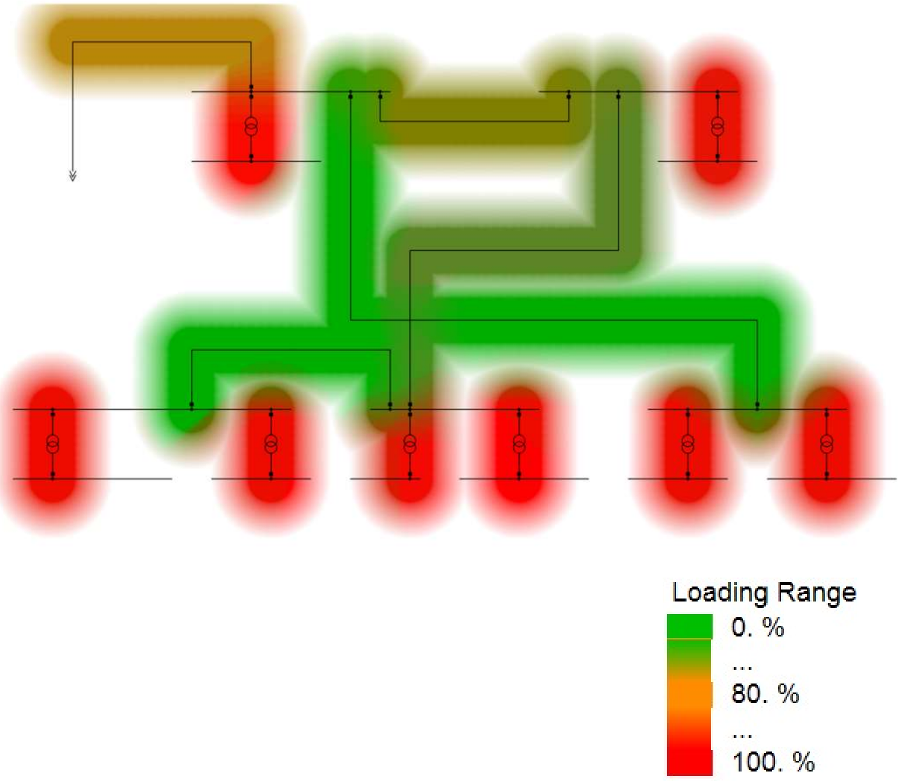

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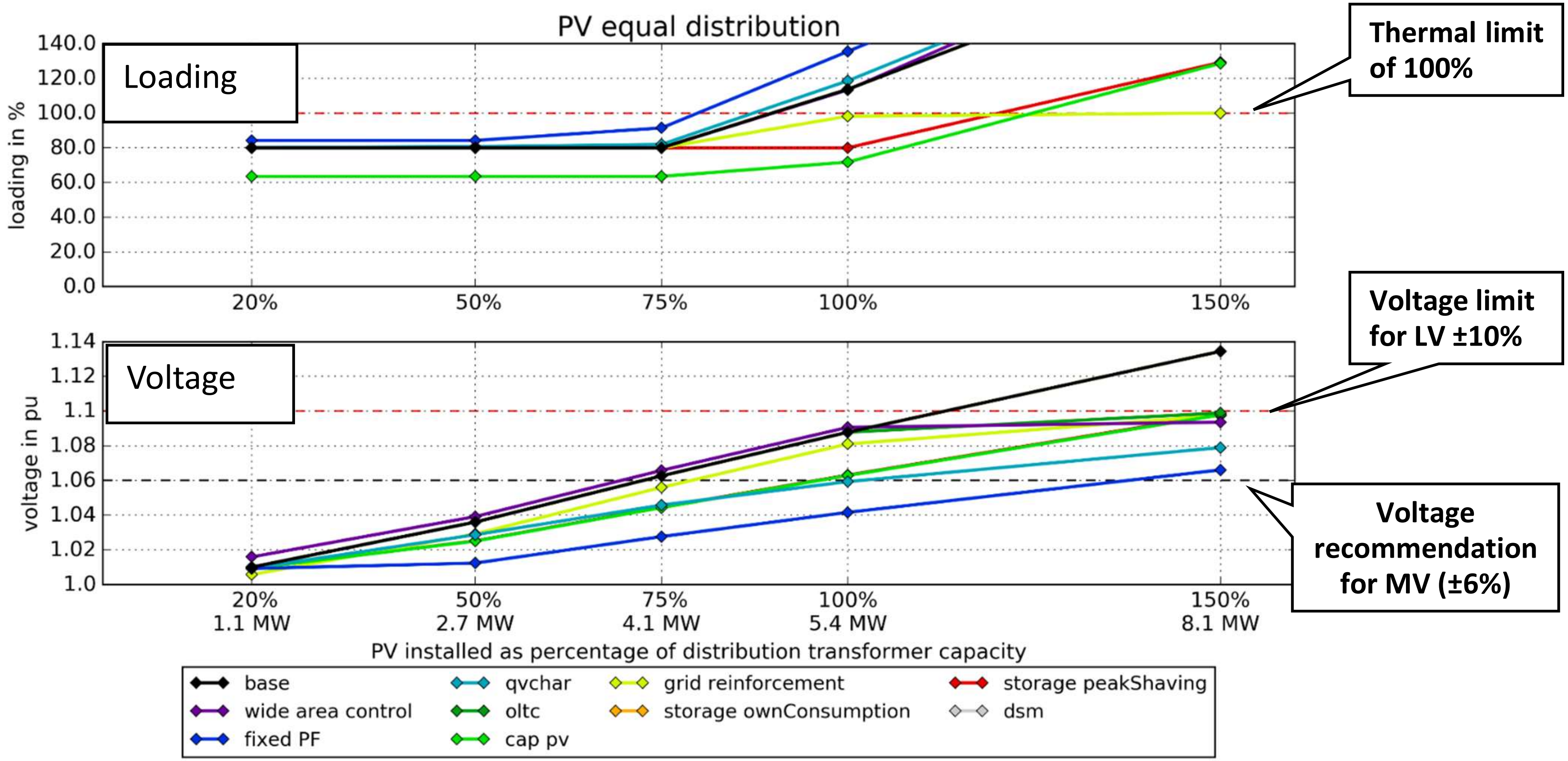
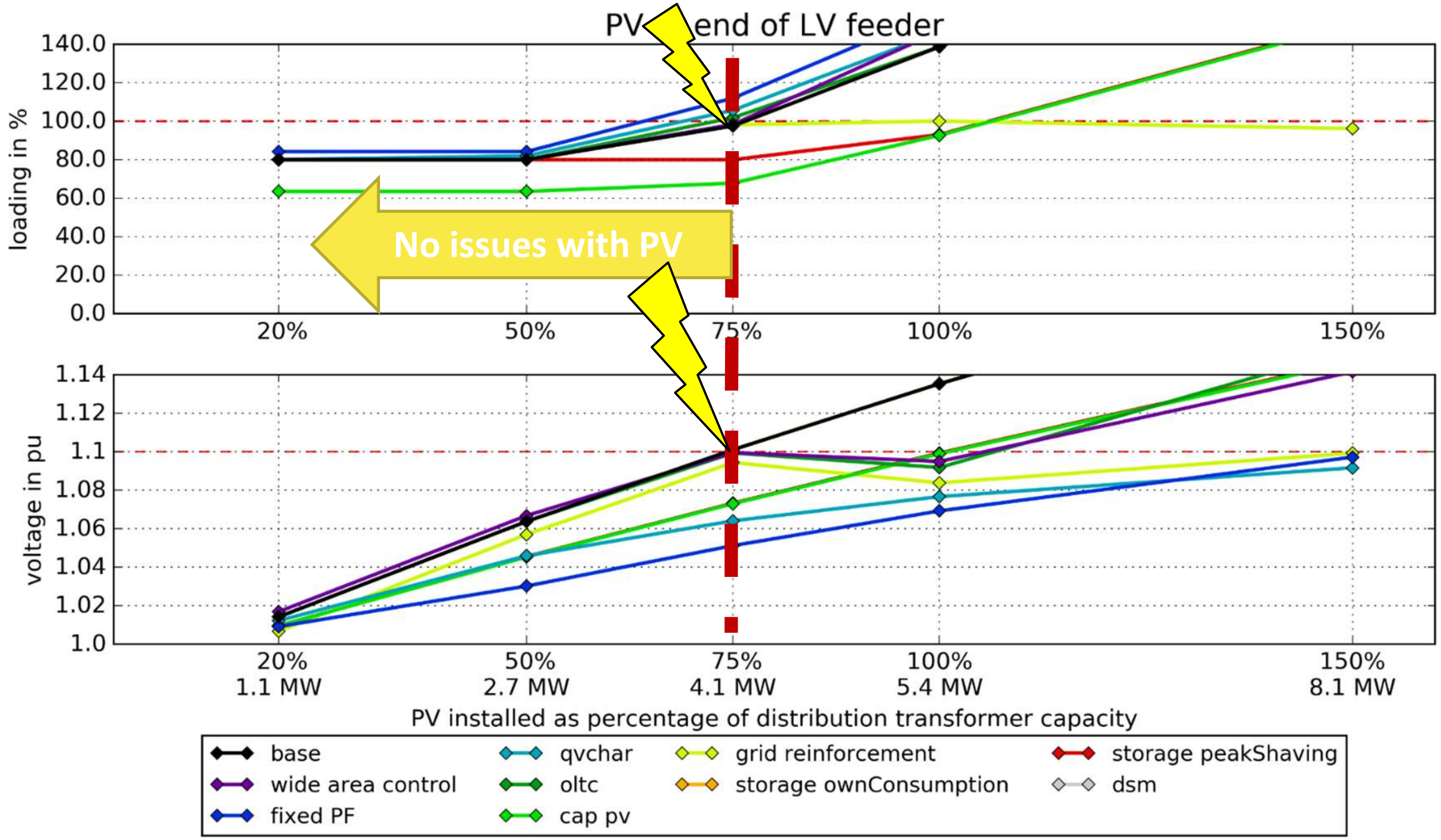
Results Delhi urban: Technology Options



Results Delhi urban: Scenario „PV at end of feeder“



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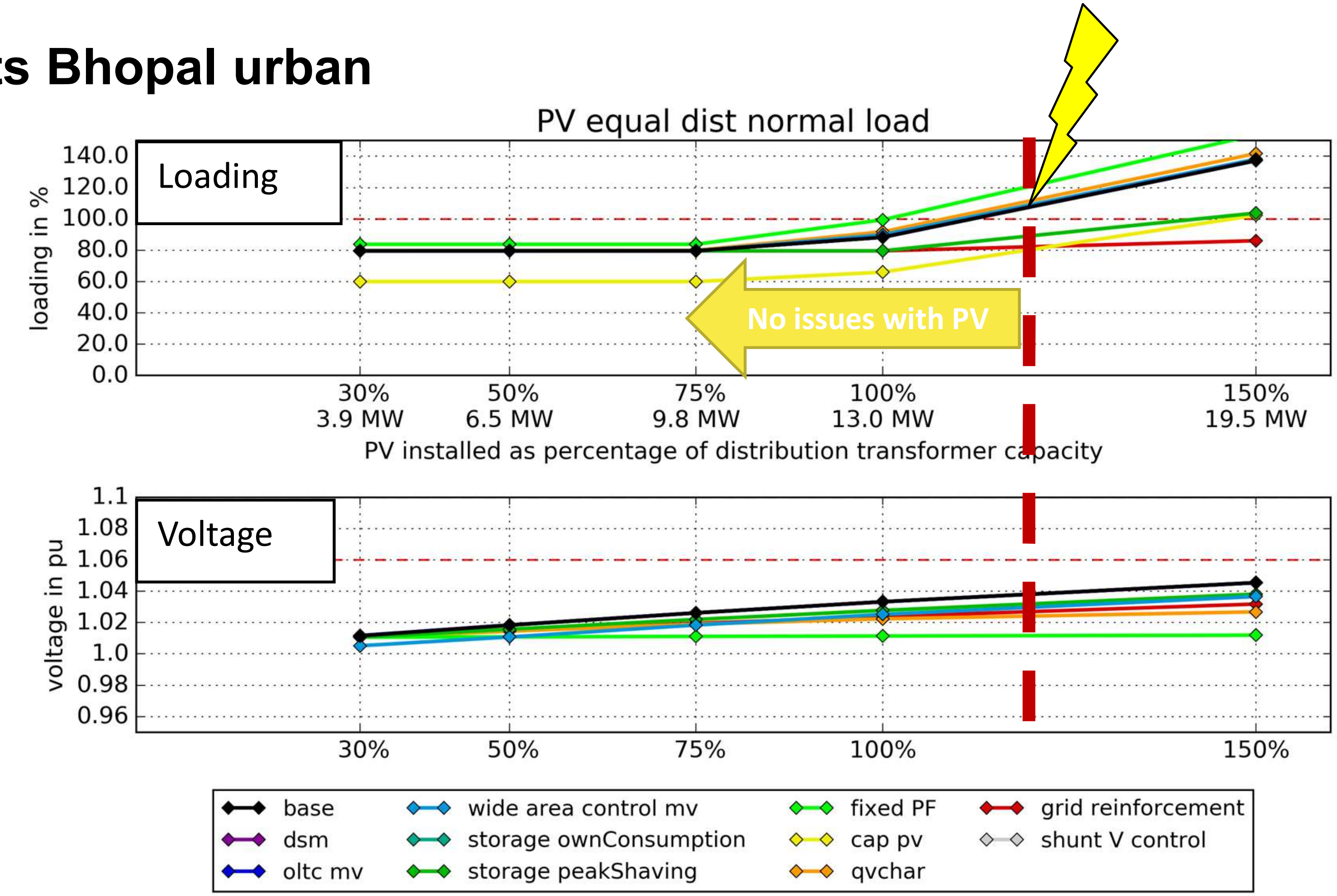
Results Bhopal urban



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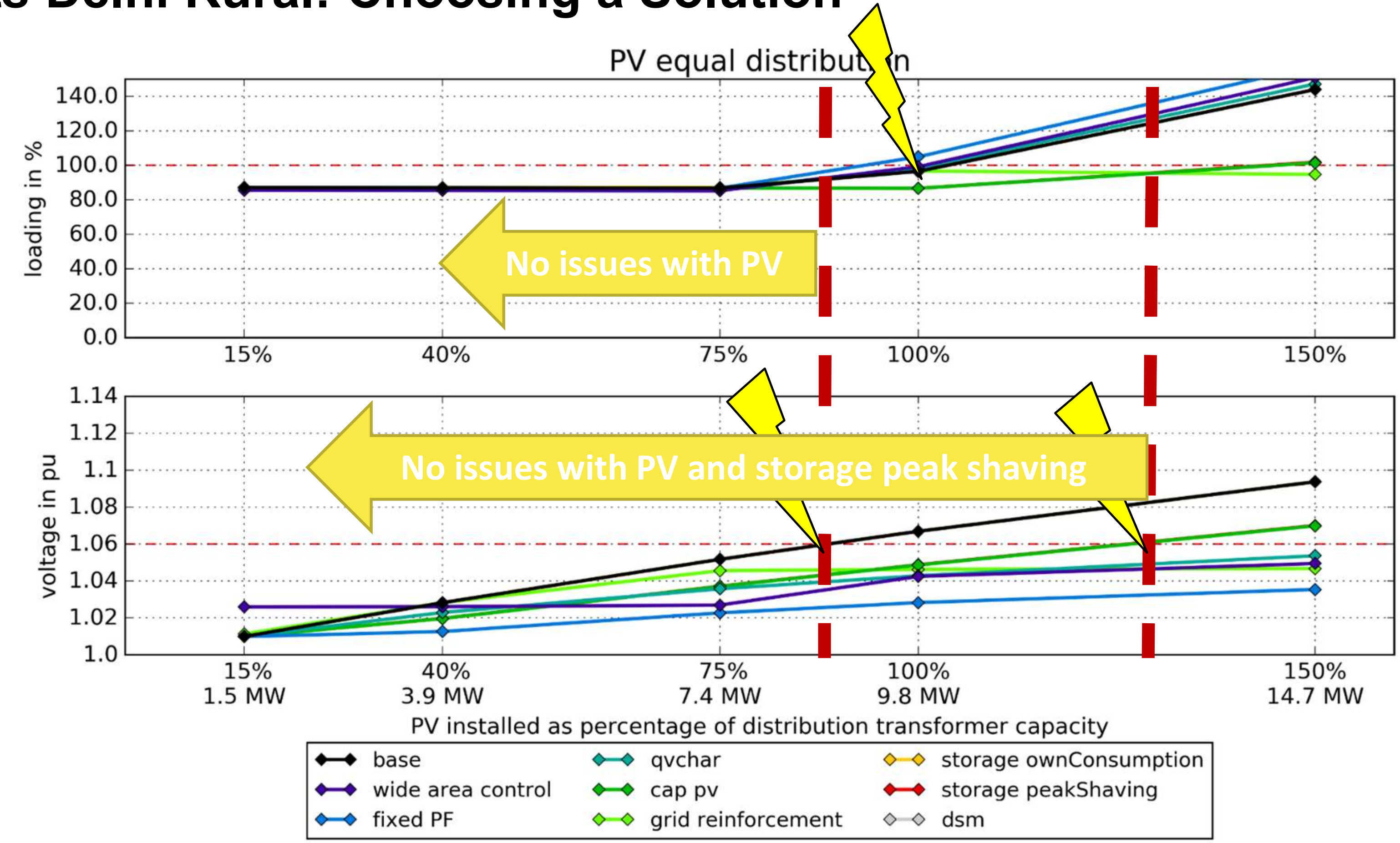
Results Delhi Rural: Choosing a Solution



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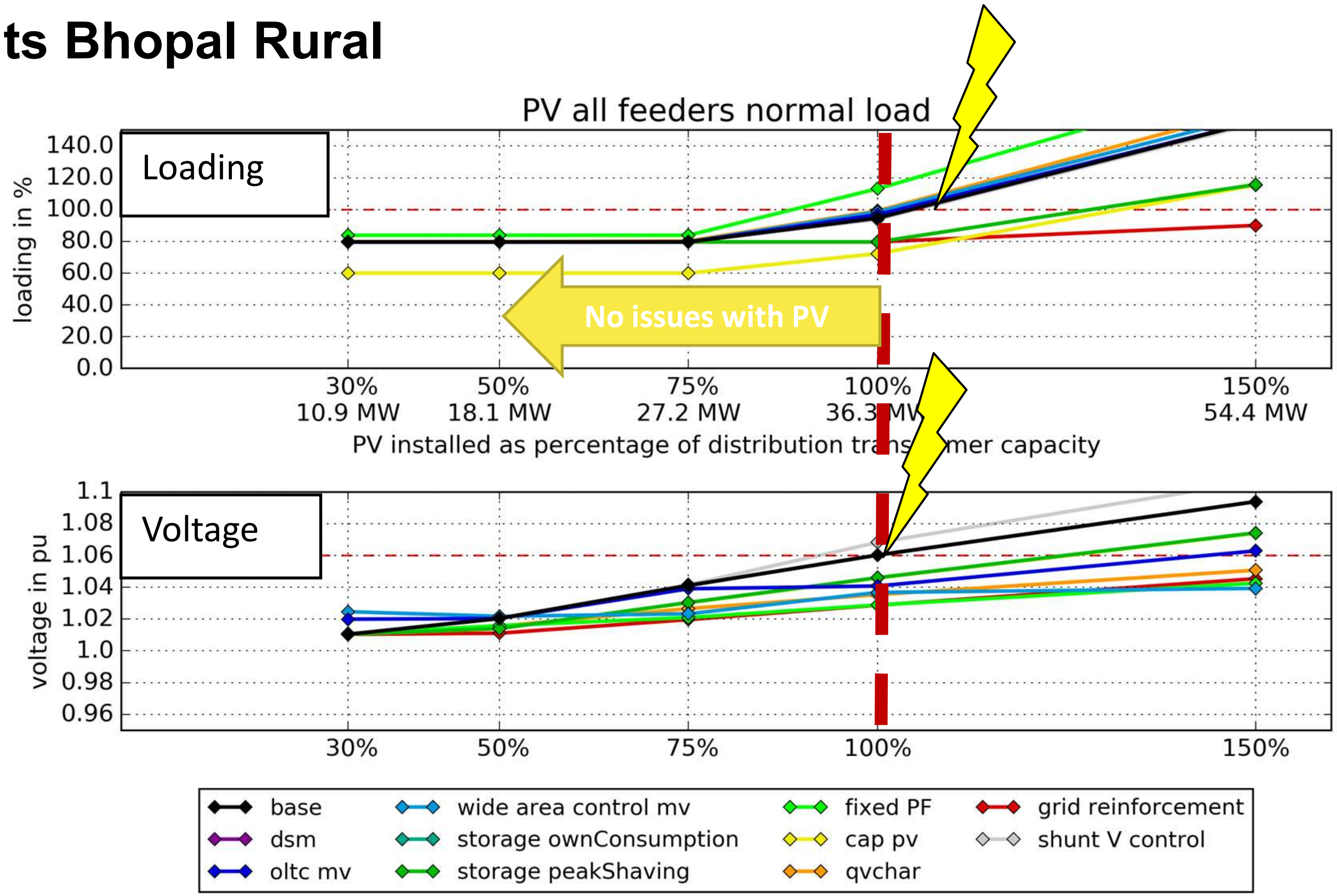
Results Bhopal Rural



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Results Comparison

Measure	Delhi urban, PV equal distribution		Bhopal urban, PV equal distribution		Delhi rural, PV equal distribution		Bhopal rural, PV equal distribution	
base	90%		110 %		90%		100 %	
oltc	90%	o	110%	o	Already in base case		105%	↑↑
wide area control	90%	o	110%	o	105%	↑↑	100%	o
fixed PF	80%	↓	100%	↓	95%	↑	90%	↓
qvchar	90%	o	110%	o	105%	↑↑	100%	o
cap pv	150%	↑↑	145%	↑↑	150%	↑↑	125%	↑↑
storage peakShaving	120%	↑↑	140%	↑↑	125%	↑↑	125%	↑↑

Conclusions and Recommendations

Conclusions

Grids in India are not very different from other grids in the world.

PV systems with an aggregated capacity of up to 75% of the transformer rating can usually be connected without any further measures. In most cases 100% are actually possible.

Above 75% the rural networks suffers predominately from over-voltage issues.

- Voltage issues can be solved with wide area control of the 66/11kV transformer and reactive power provision by the PV systems

Above 75% in the urban network, mostly loading problems occur.

- As the lines are short there is less voltage drop across them.
- Above 75% line loading issues and above 100% distribution transformer overloading have to be considered critical
- Besides conventional network reinforcement, implementing peak-shaving battery systems is a possible solutions

Recommendations: Technology options

Automatic voltage control at 132/33, 220/66 or 220/33 kV should be implemented

Automatic voltage control at 66/11 or 33/11 kV is very beneficial, but not strictly required

Under- and overvoltage can be efficiently eliminated using wide area control

Require voltage control capability by rooftop PV inverters through reactive power

Active power controllability should be required from all PV units

- Large centralized PV power plants should be remotely controllable
- Rooftop PV units should either be capped at 70 to 75 % of their maximum expected output, or be remotely controllable, or be equipped with a peak shaving storage (requires incentive)

Batteries can have additional value: UPS, capping nightpeak, …

Recommendations:
Legal and regulatory framework

Remote control of PV units

- Requires legal framework of operation (When, who and how to use)
- Require voltage control capability from PV inverters, controlled by grid operator
- Active power curtailment requires agreed remuneration of lost energy
- Recommended to align the voltage control requirements with the German low voltage grid code, most PV systems already comply

Capping of PV at 70 or 75 % would have to be specified in grid code and net metering scheme, and checked for legal complications

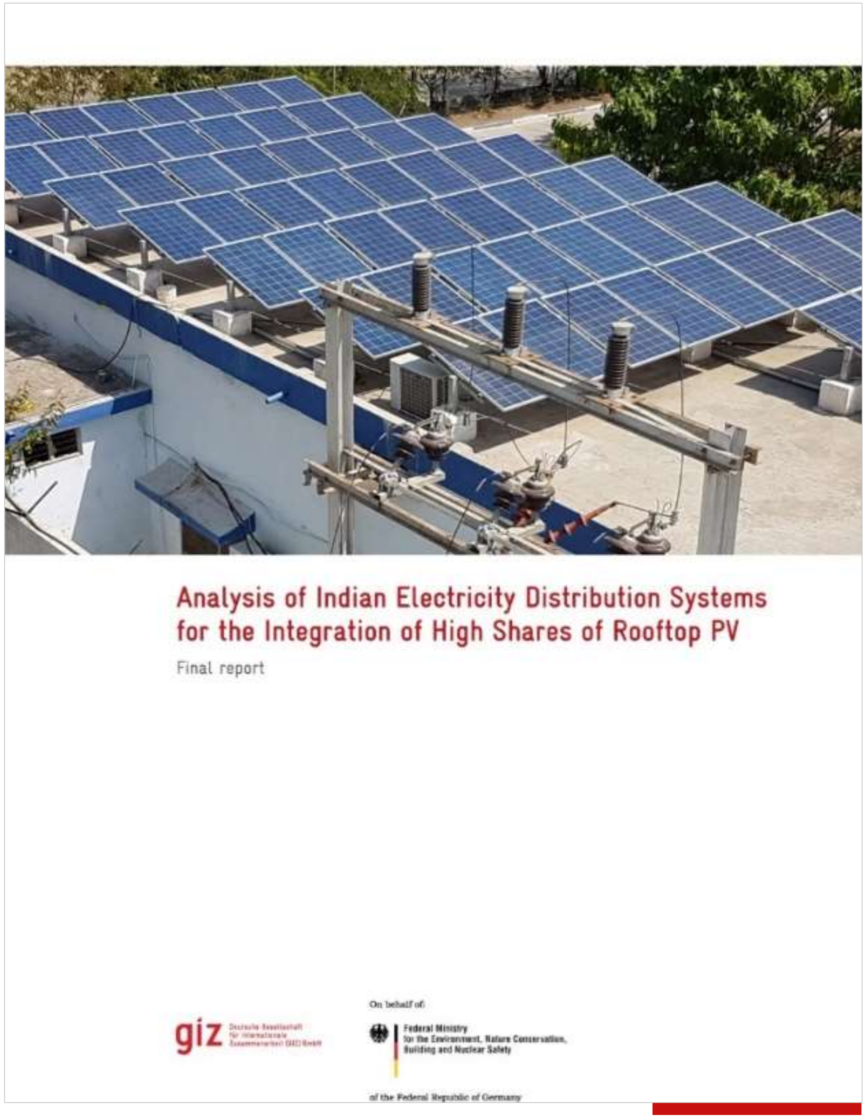
PV batteries require incentives for installation and running them in peak shaving mode

Grid code requirements should be developed in coordination with transmission system operators (Example: frequency response of PV units)

Thank you

Report can be downloaded at

http://www.comsolar.in/what-we-do/capacity-development/grid-integration-study/



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