Analysis of Indian electricity distribution systems for integration of high shares of rooftop PV

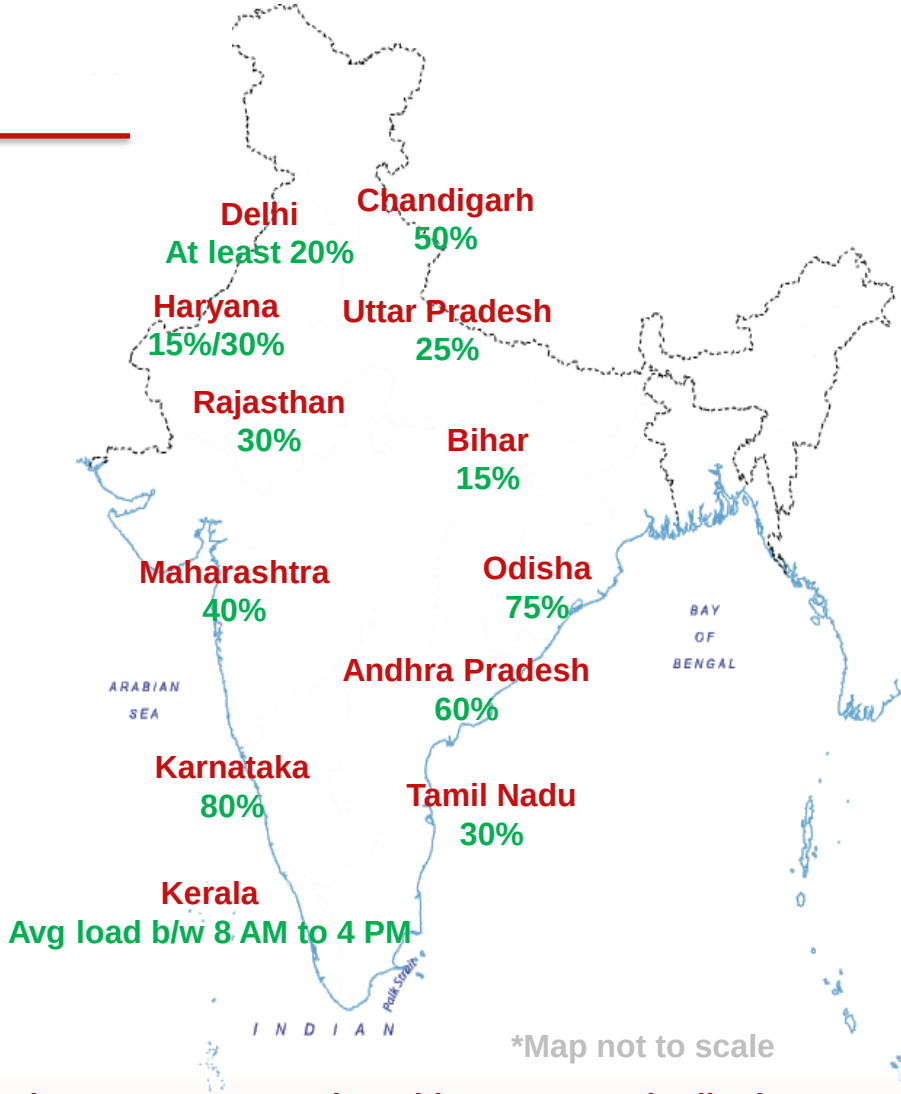
By Joerg Gaebler, IGEN – Solar, GIZ India

Key technical question:

How much distributed PV can be integrated in the distribution network without needing any infrastructure upgrades ?

Grid Integration Problem

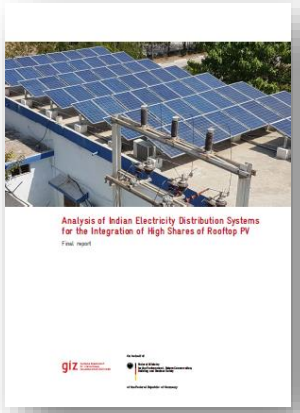
- Out of the 40 GW target only 1 GW is achieved as of 01/18 (MNRE)
- All states have regulatory framework for promotion of rooftop PV via net metering mechanism
- Different states lay down different restrictions for rooftop PV integration
  - Limited scientific basis setting these restrictions
  - Only solution proposed - upgrade the transformer / network
  - Concern that high shares of rooftop PV will harm the network ("*fear of unknown*")



Restrictions on PV Penetration with respect to Distribution transformer Rated Capacity

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Study on "Analysis of Indian electricity distribution systems for integration of high shares of rooftop PV"



On behalf of:

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

of the Federal Republic of Germany

In partnership with:

Ministry of New and Renewable E
Government of India

Government of India
Ministry of New and Renewable Energy

Consulting support:

energynautics
solutions for sustainable development

GSES global sustainable energy solutions India

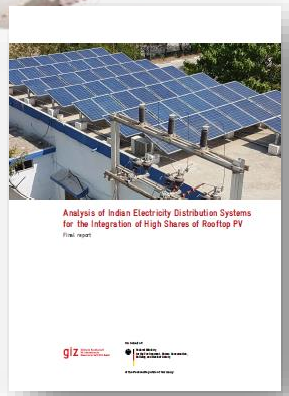
Partner Distribution licensees:

BSES
BSES Rajdhani Power Limited

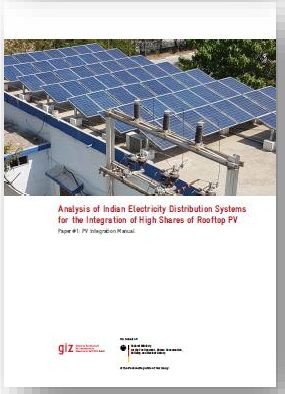
प्रकाश एवं विकास

All reports can be downloaded at: link can be found on the last slide

Main Report

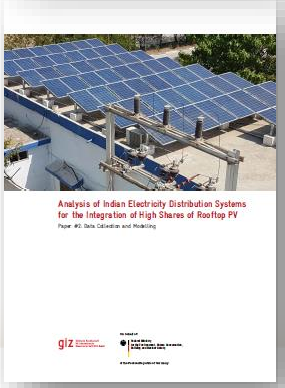


Paper 1: PV Integration manual



Brief, high-level overview of the main issues, technical and non-technical and some approaches to carry out similar studies

Paper 2: Data Collection and Modelling

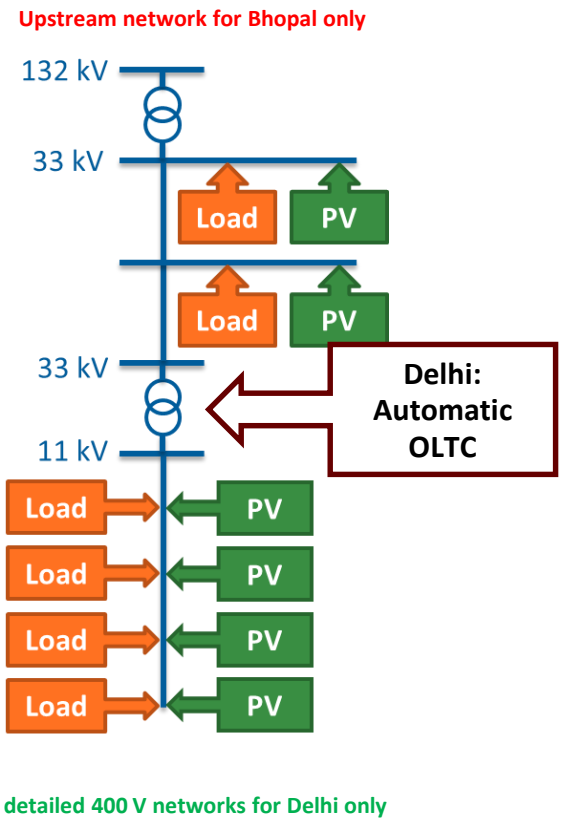


Data requirements for distribution grid impact study, and how gaps in the data can be closed either by the use of qualified assumptions or by additional data collection and monitoring measures.

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

DIFFERENCES DELHI VS. BHOPAL



Delhi uses 66 or 33 kV for primary distribution, while Bhopal uses 33 kV exclusively.

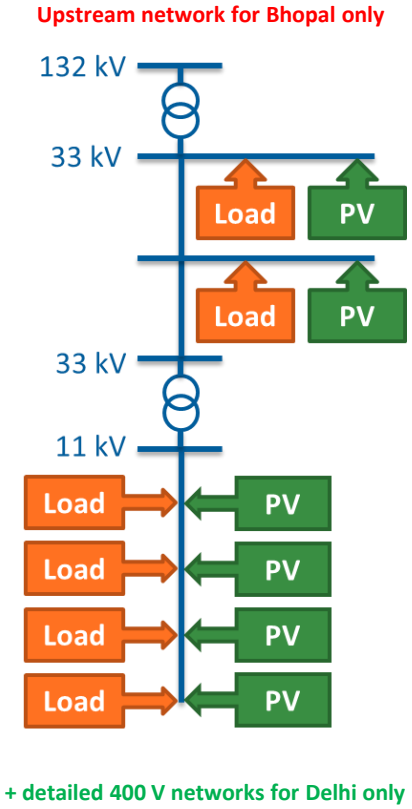
Main difference: In Bhopal, the **132/33 kV** on-load tap changing transformer is the **last instance of voltage control.** Voltage and loading in the 33 kV grid thus directly impact 11 and 0.4 kV levels and must thus be considered in the simulations.

Delhi is currently retrofitting all **66/11 kV** and **33/11 kV** OLTC transformers with **automatic voltage control**. 11 kV is thus decoupled from the **upstream network**, which **need not be modelled**.

For one feeder in Delhi, data was available to **model the low voltage level** (400 V) in detail. All other models used aggregated models for 400 V.

2 EXEMPLARY SCENARIOS/ 1DAY – PV DISTRIBUTION ALONG THE FEEDER

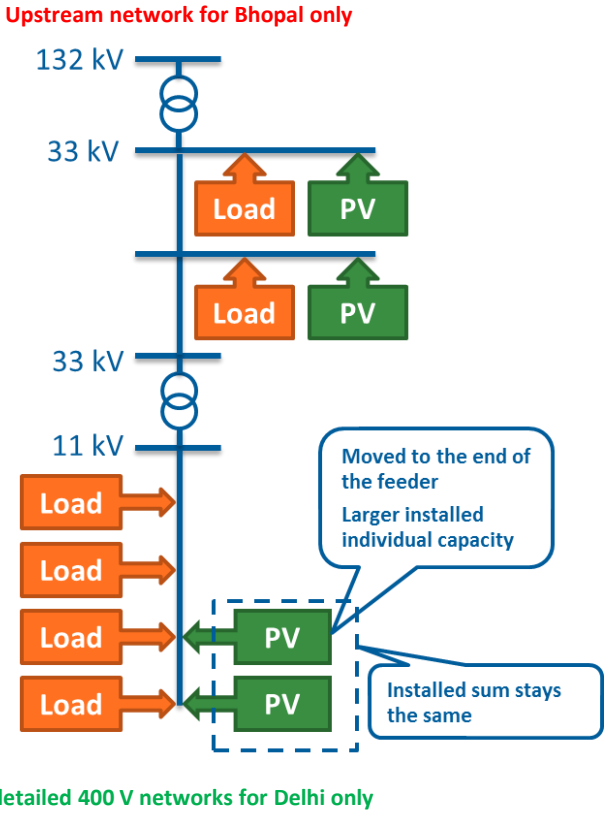
PV equal distribution



PV development may not always be homogeneous.

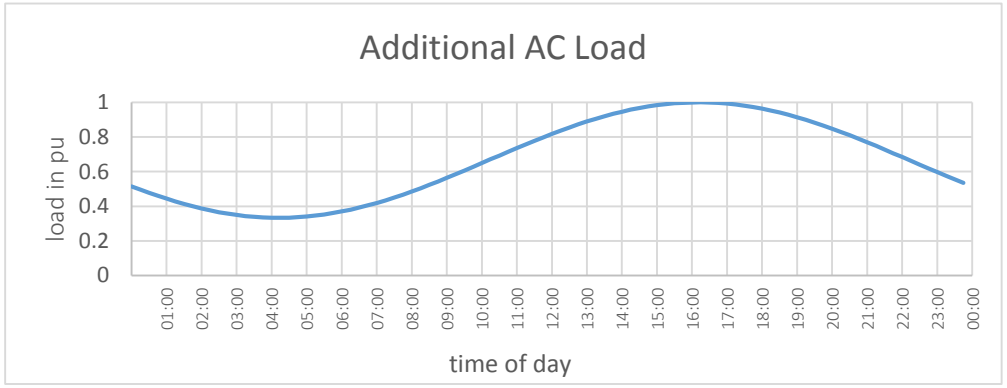
A concentration of PV capacity at the end of a feeder has a higher impact on voltage than homogeneous distribution.

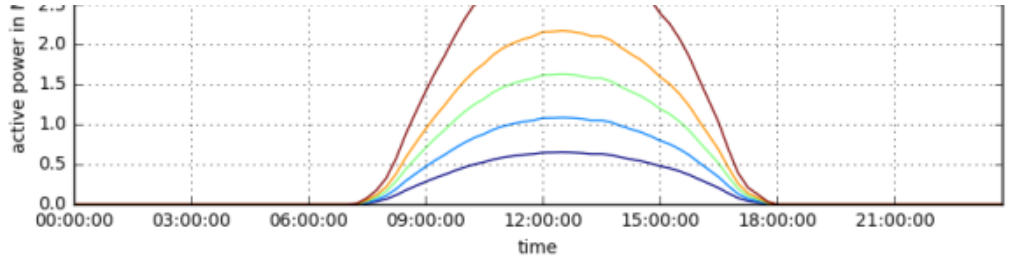
PV end of feeder

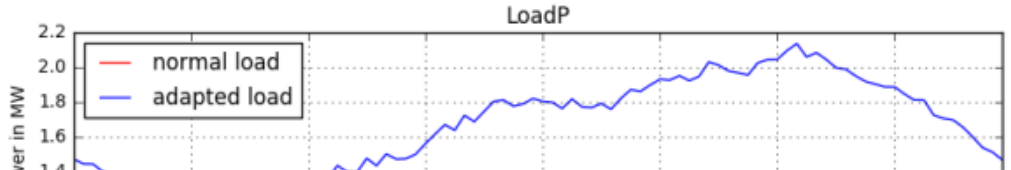


SCENARIOS – ADAPTED LOAD

Additional Load is added with the assumption that there would be a **25% <u>energy consumption (kWh)</u>** increase in the load (5% per year for 5 years, 2016 to 2022), typically with regard to Air-Conditioning, where a high evening peak is considered







SIMULATIONS

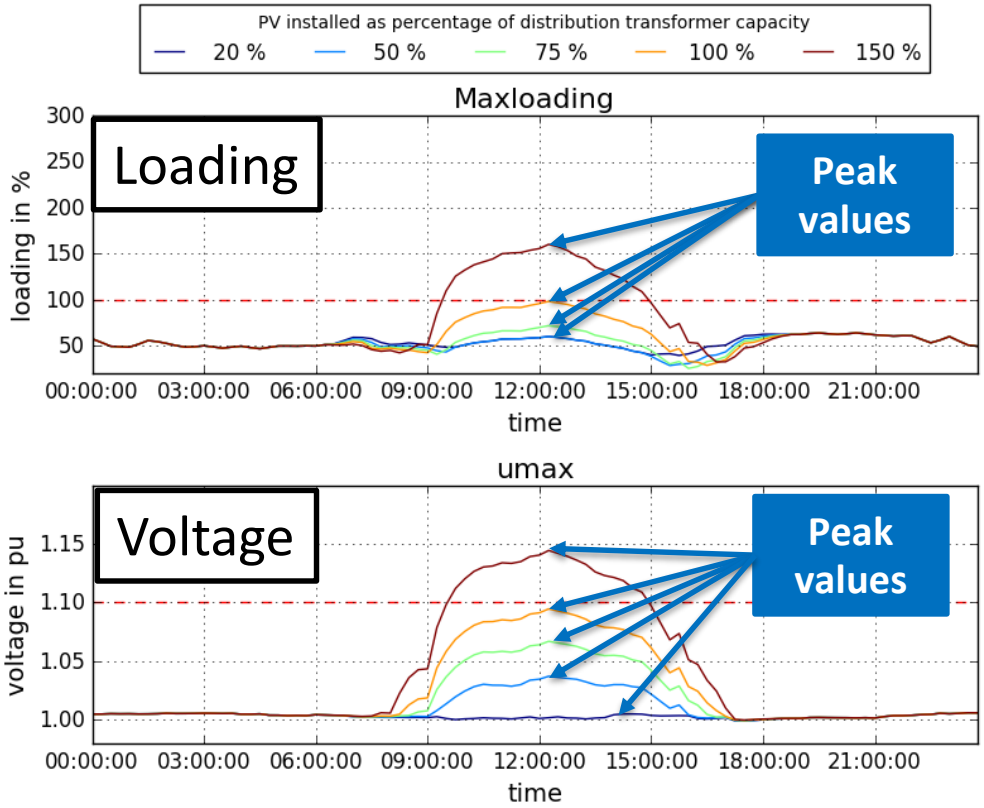
Stepwise increase of installed PV generation

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

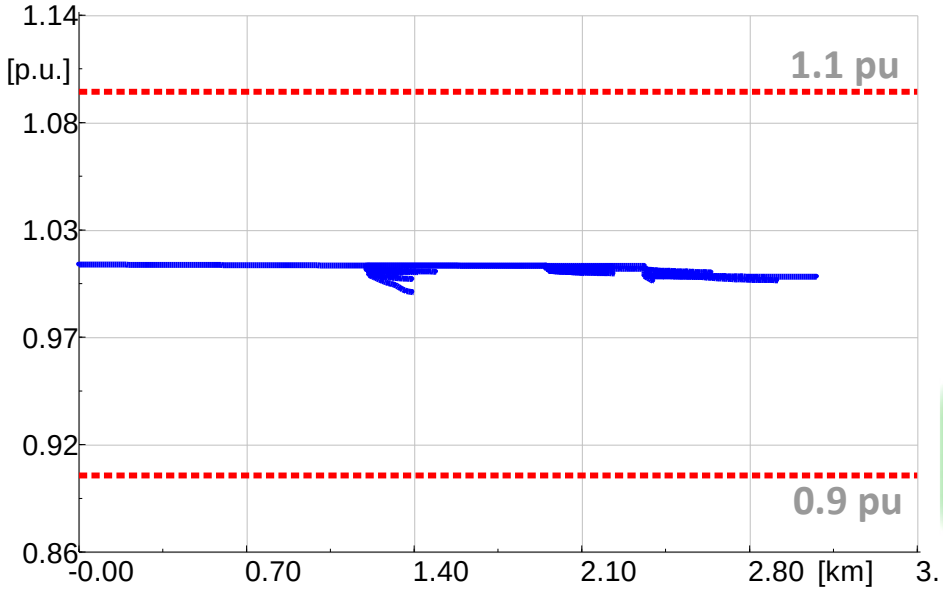
- **Highest voltage**
- **Highest loading at every time step regardless of position in the grid**

Peak loading and peak voltage get stored for each variation of installed PV

RESULTS ON INCREASING PV PENETRATION

PV Penetration:
20 % of DTs

Voltage



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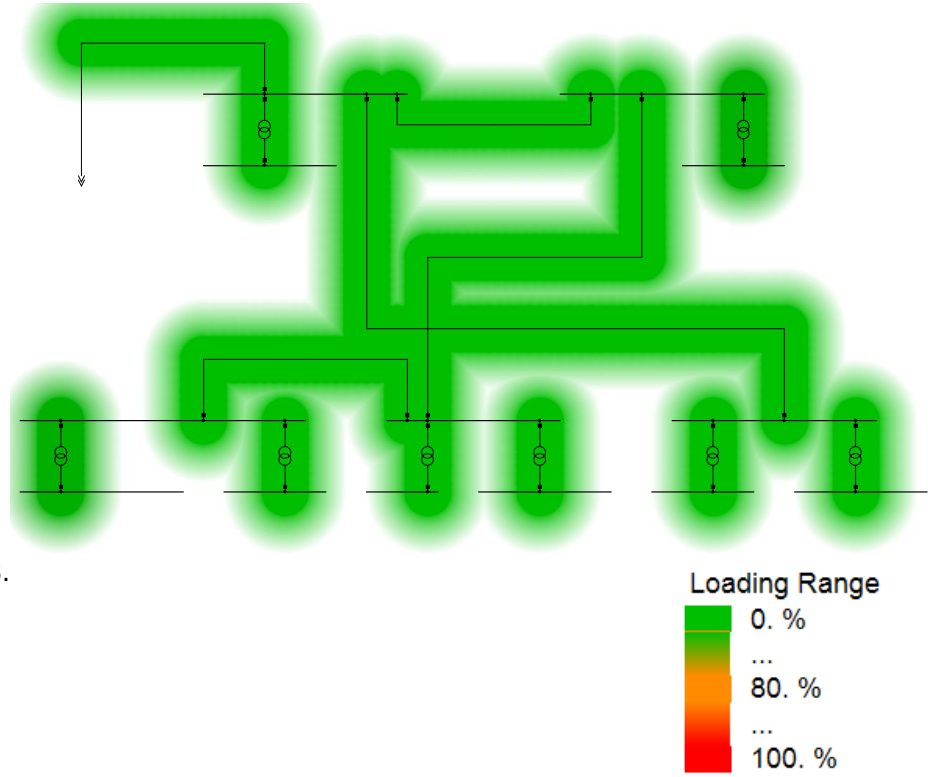
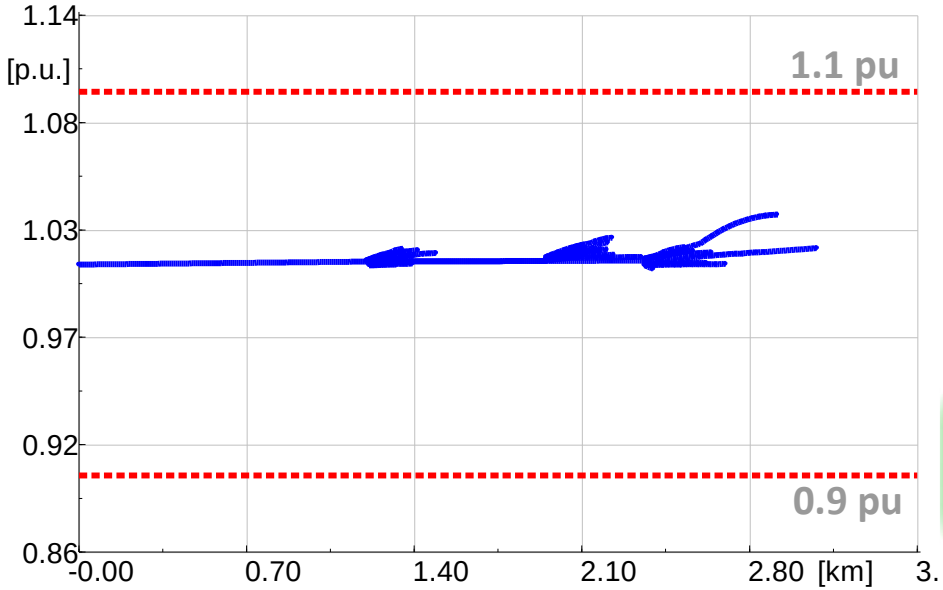


RESULTS DELHI URBAN (1)

PV Penetration:
50 % of DTs

Voltage



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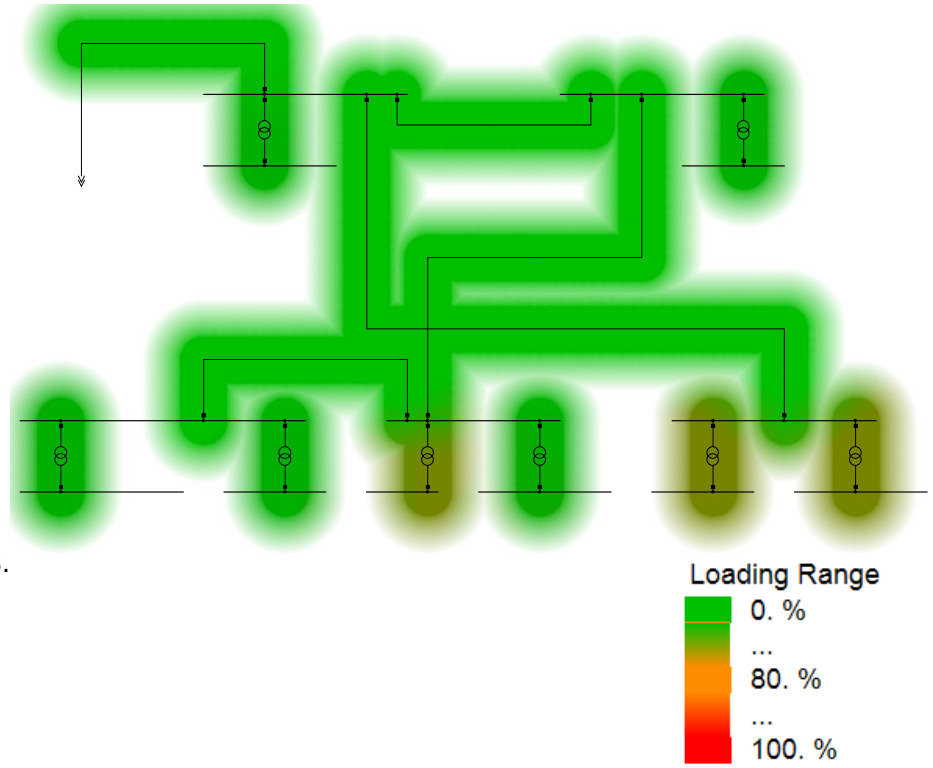
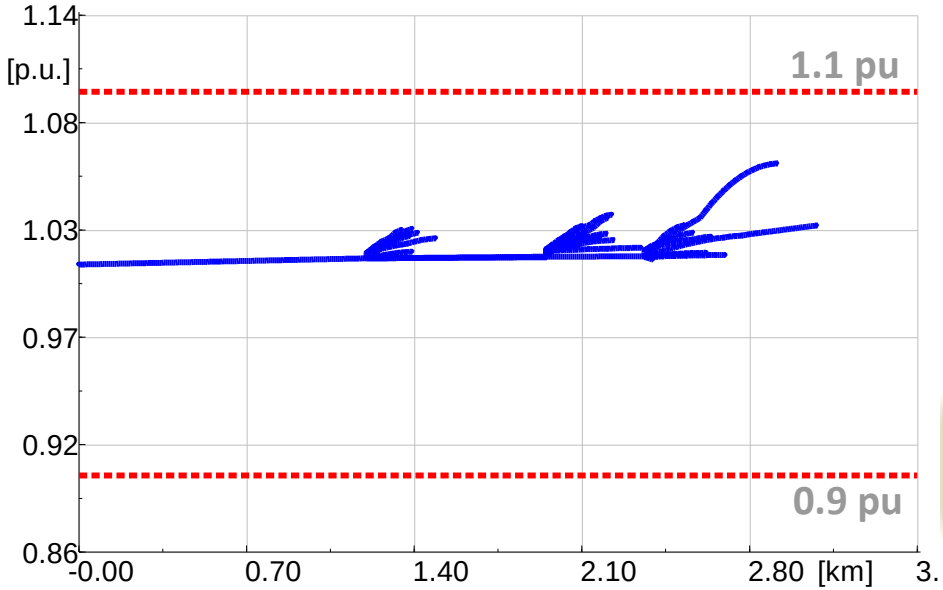


RESULTS DELHI URBAN (2)

PV Penetration:
75 % of DTs

Voltage



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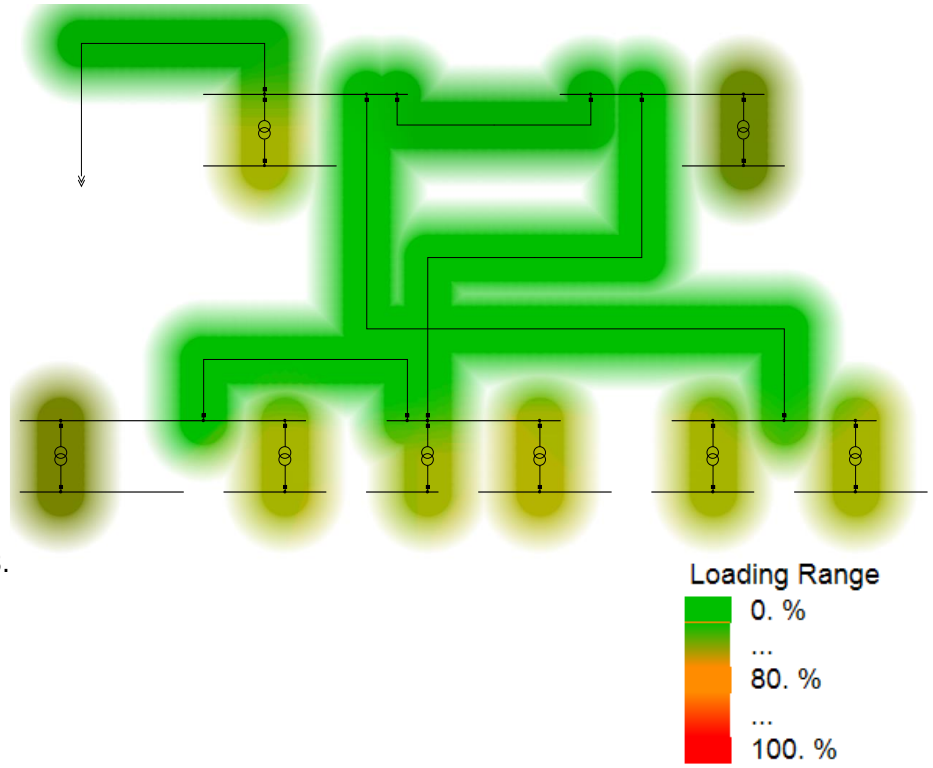
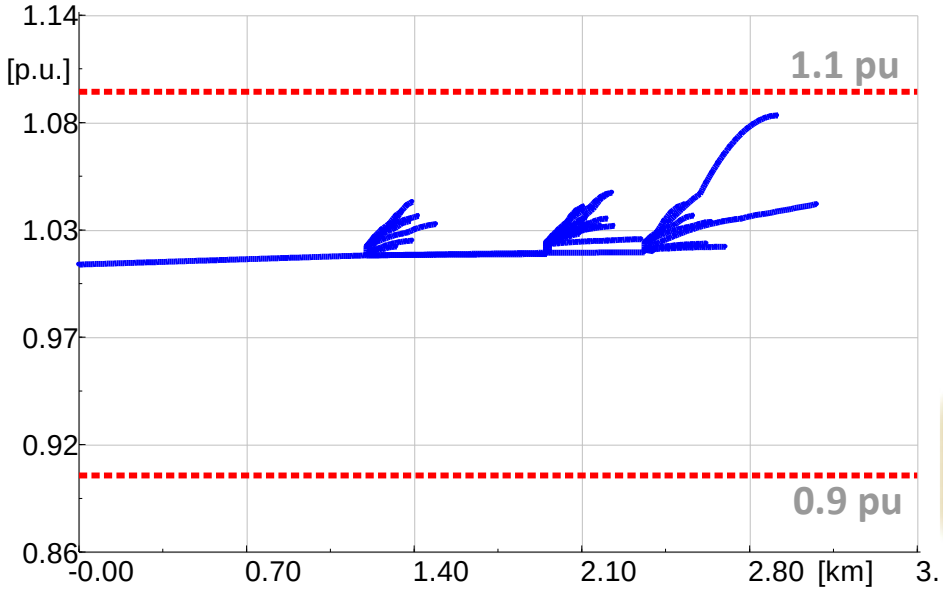


RESULTS DELHI URBAN (3)

PV Penetration:
100 % of DTs

Voltage



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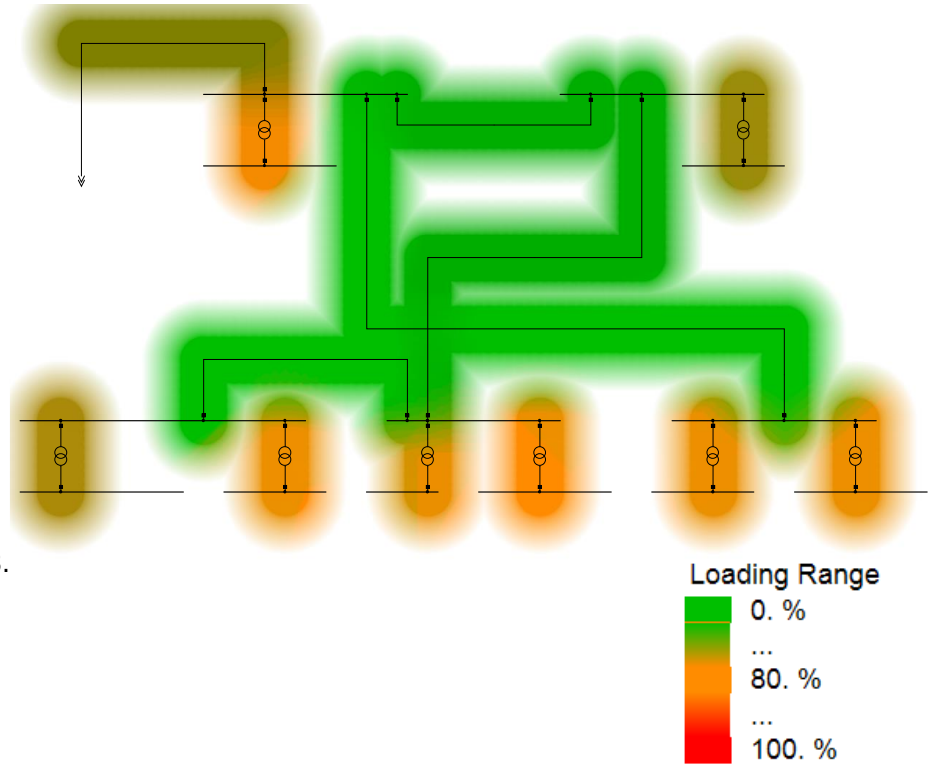
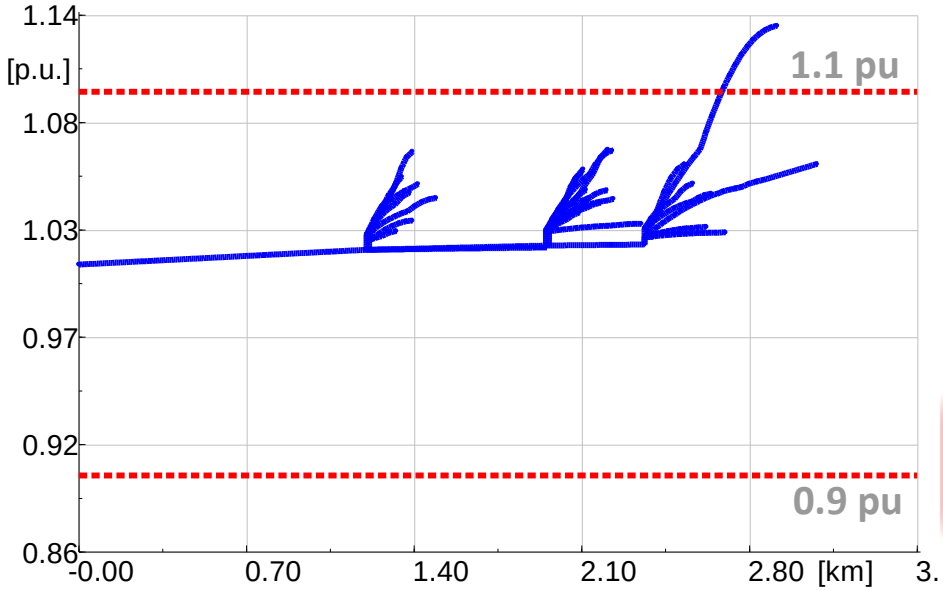


RESULTS DELHI URBAN (4)

PV Penetration:
150 % of DTs

Voltage



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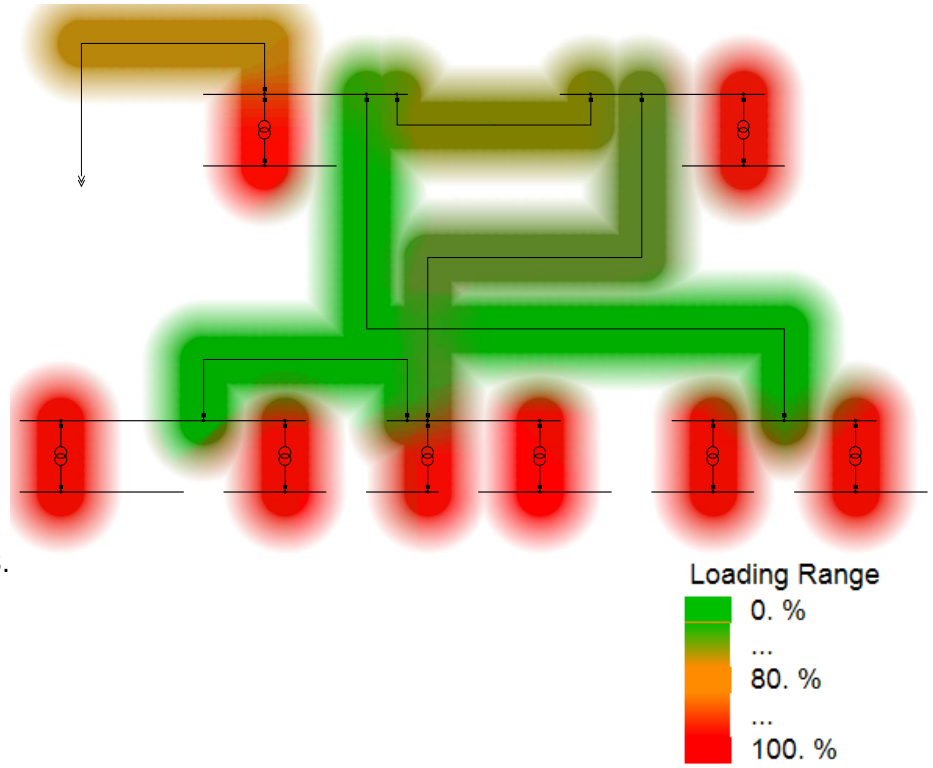
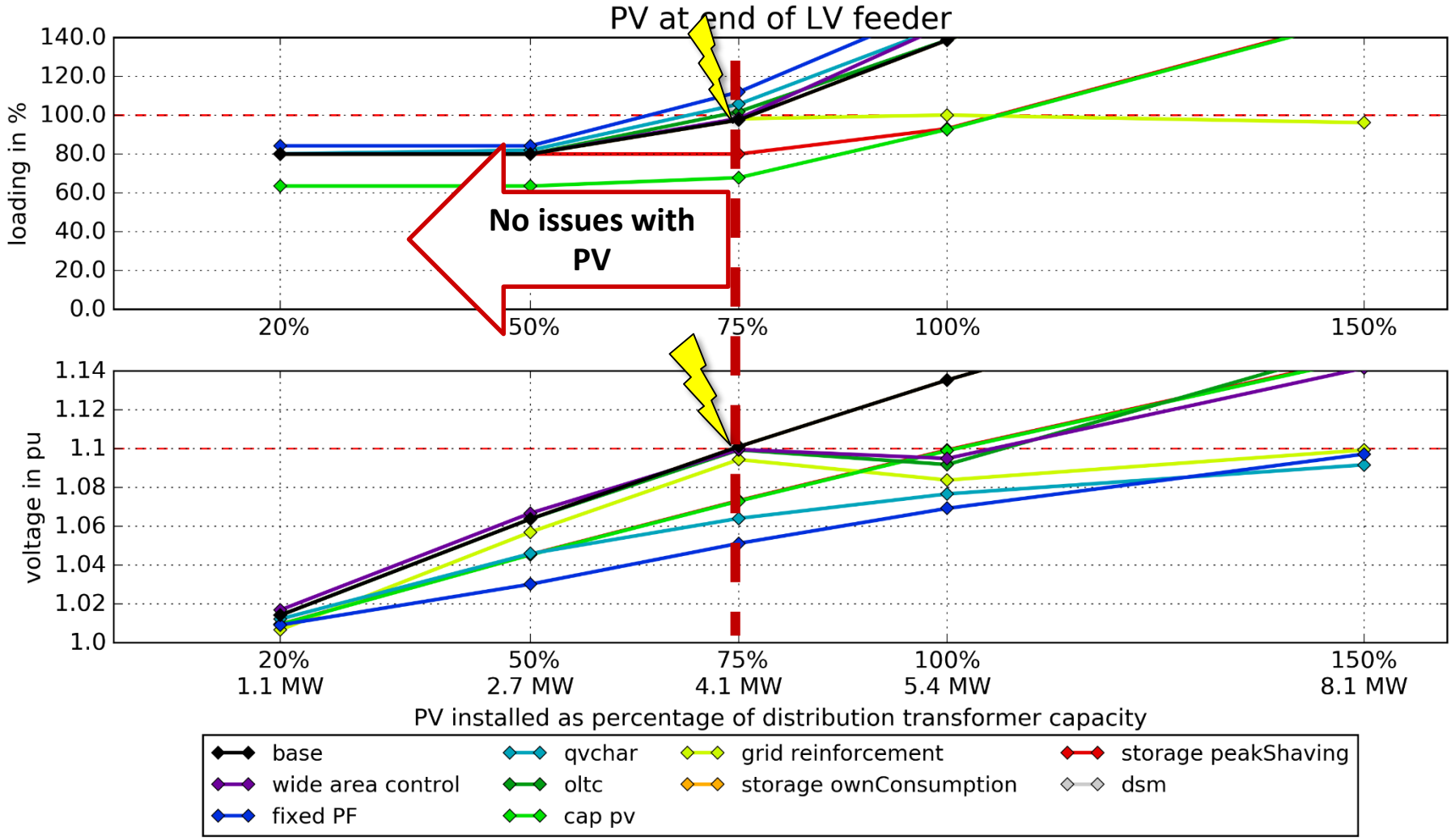


RESULTS DELHI URBAN (6)



C & R

- **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

PV Port + store

How can we address the peak(s)?

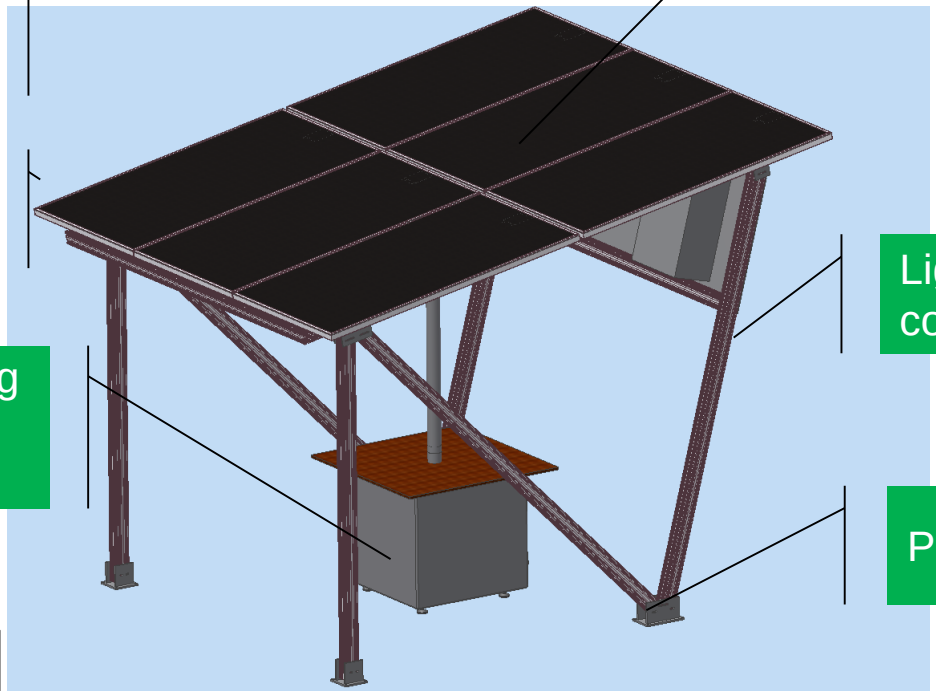
Use of distributed storage with PV: a win-win for both the consumers and distribution licensees

Plugs in regular power socket

PV PORT & store

Six glass-glass modules (300-350 Wp)

Meets 2x the annual electricity demand of an Indian Home



Sprinkler mechanism for cleaning

Light weight collapsible structure

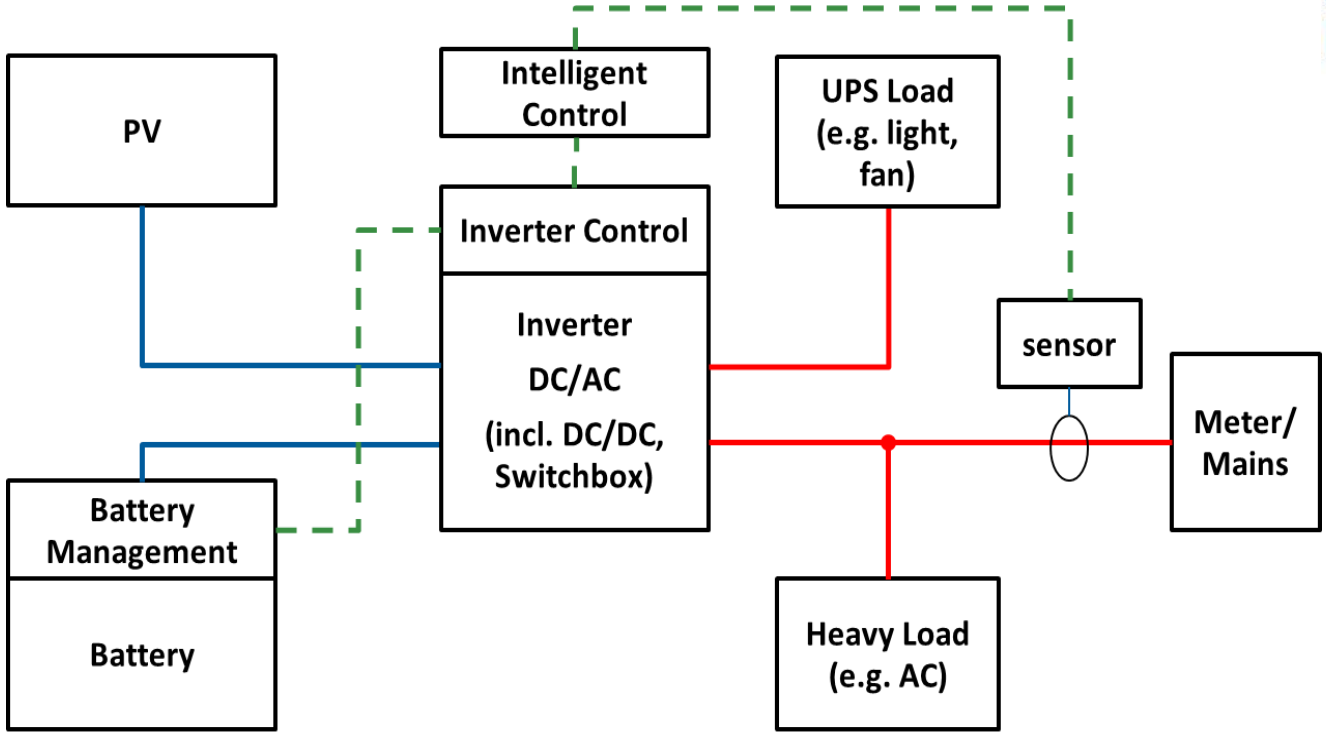
Central Cube housing batteries / inverters / control mechanism

Puncture less foundation

Acts as dead weight

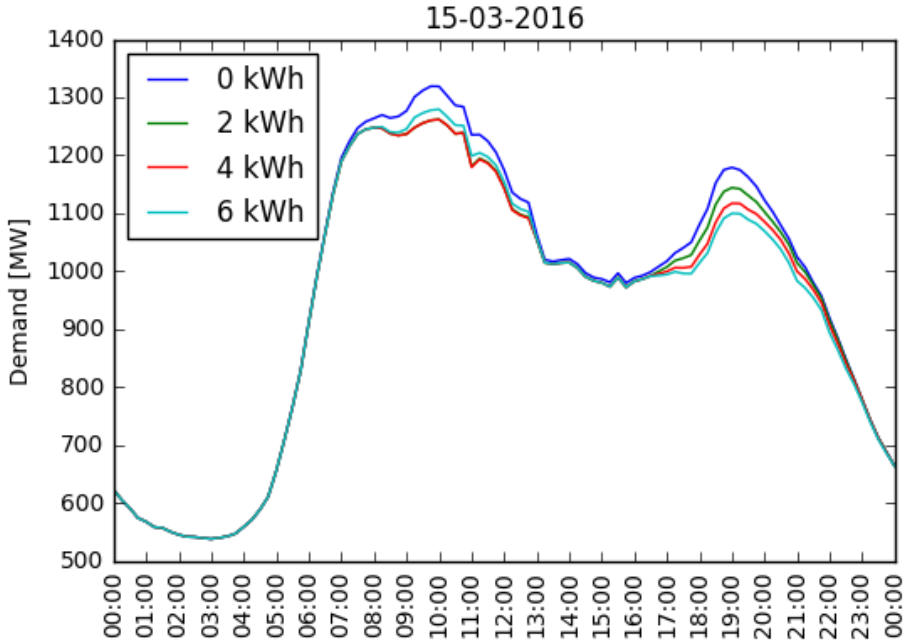
PV PORT & store

Electrical configuration of PV Port + Storage

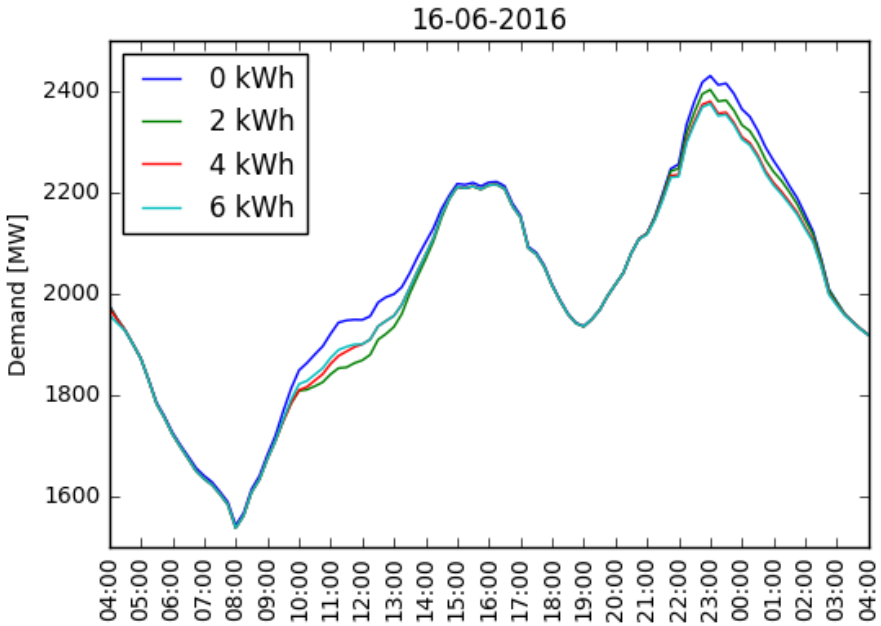


Benefit to the Distribution licensees (contd..)

Analysis of a discom's power demand with 50,000 PV Ports

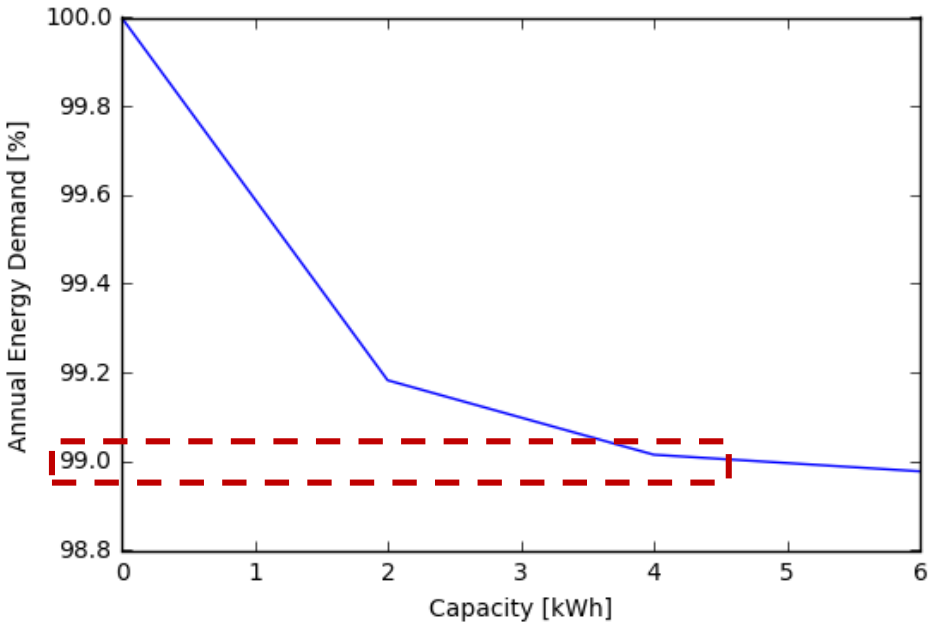


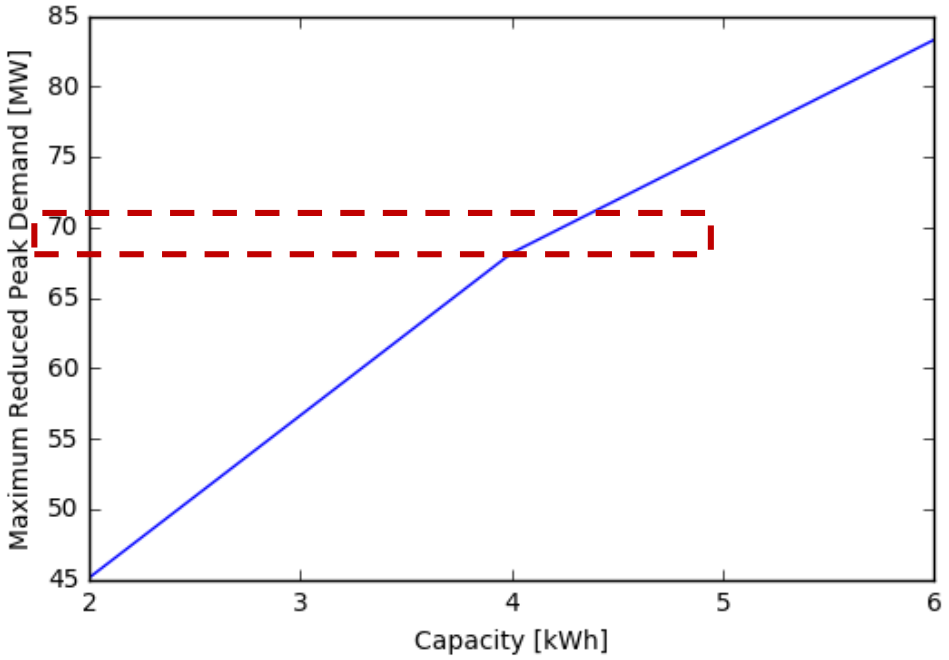
0 kWh = no PV-Port



0 kWh = no PV-Port

Imperatives of PV Port + Store for the DisComGrid





Left: Annual Energy Demand of BRPL with 50,000 PV-Ports,
Right: Maximum Reduced Peak Demand of BRPL with 50,000 PV-Ports. 0 kWh = no PV-Port.

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Equipment Lease to DISCOM Model

RESCO

PV PORT & store

Subsidy on Assets

सत्यमेव जयते

Ministry of New and Renewable Energy
Government of India

Raises Invoice for EMI Payment

Pays EMI

Delivers PV Port & Store via Plug and Save

SRISTI Scheme

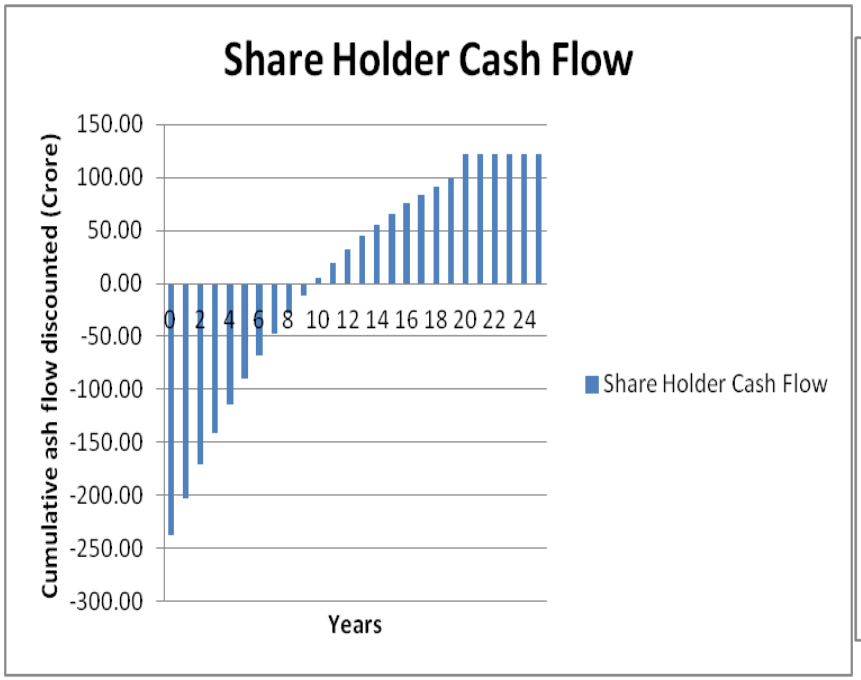
Pays Electricity bill at regulated tariff

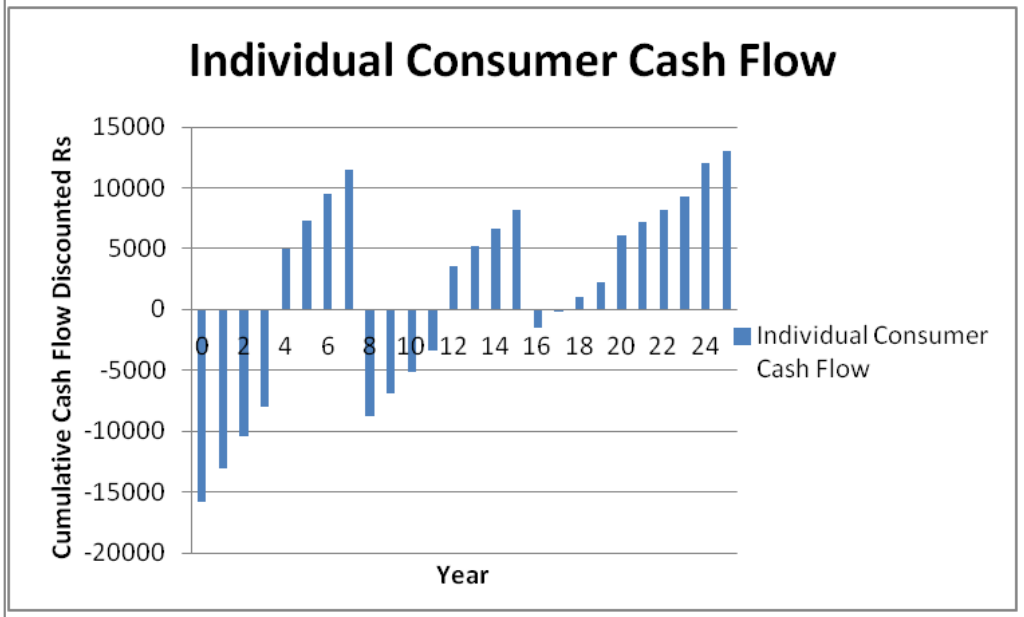
DISCOM

House Owners

Owner of PV System

Scenario 4: At 30% subsidy to RESCO and applicable SRISTI Scheme





At 16% ROE

Consumer Investment:

- Initial Contribution of 10% of the capital cost.
- The Additional capital investment in 8th and 16th year.

PROSUMER

- Buying and installing PV will become **as simple as to a consumer durable product** (e.g. Buying and installing an air conditioner)
- **Mass-scale procurement** could lead to **substantial cost reduction** (e.g. LED by EESL)
- UPS and PV system are **merged in a single product**
- **Subsidies** if any could be **integrated in advance**
- Storage will allow consumers to save more money considering **Time of Day tariff scheme** introduced by DERC
- **Quality assurance and reliability** could be ensured through embedding checks and balances in mass procurement
- **Easy financing** (e.g. Zero interest EMI financing) may be encouraged with Banks
- **Lead time** for installation may be **reduced** from several weeks/months to few days

DISCOM

- **Reduction in peak demand**
- **Increased life** of stressed assets
- **Reliability of the network elements** shall be improved due to reduced stress on the equipment
- Promotion of rooftop in residential market will **reduce the need of cross-subsidy**
- PV ports shall **reduce** the requirement of **purchase of expensive electricity** through exchange market by using firm capacity of storage
  - In several instances Discoms purchase electricity @ more than 5 Rs/kWh
- Reduction in expensive power procurement / backing down expensive power plant will **reduce the overall power purchase cost**

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

Rooftop Photovoltaic project under Indo German Energy Programme

Responsible
Joerg Gaebler

Project Manager
Sandeep Goel

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