Potential Solutions to Mitigate the Impacts of LCT

Appendix K

Alejandro Navarro Espinosa

alejandro.navarroespinosa@manchester.ac.uk

Supervised by Dr Luis(Nando) Ochoa

3rd October 2014

The University of Manchester, Manchester

Outline

- Objectives
- Problem Description
- Mitigating actions
  - Loop Connection
  - OLTC
  - Energy Storage
- Economic Comparison
- Conclusions

Objectives

- Project objective:
  - Understand the characteristics, behaviour, and future needs of Low Voltage Distributions Networks with high penetration of low carbon technologies.
- Research objective:
  - Maximise the penetration of low carbon technologies minimising the impacts on LV networks.
- Presentation objective:
  - **Proposing possible mitigating actions for increasing the penetration of LCT in LV network in a stochastic framework.**

Problem Description: Introduction

- Impacts Assessment of Low Carbon Technologies (LCT) penetration in real LV networks.
- Requirements for solving the problem:
  - Monte Carlo analysis to cope with the **uncertainty** (LCT size and location, sun profile, heat requirements, EV utilization, load profile, etc.)
  - **Time Series** Analysis – 5 min synthetic data.
  - Three-phase **unbalanced** power flow – OpenDSS.
- Inputs data:
  - Load and LCT **profiles**.
  - Real UK **networks** (topology and characteristics).

Problem Description: Methodology

This process is repeated 100 times for each feeder and penetration level (% of houses with PV panels).

Loads
- Random allocation for each customer node.

LCT
- Random allocation of sites and sizes.

Power Flow
- Time Series Simulation.
- 3 Phase four wire power flow

All the solution are implemented in each simulation

Outline

- Objectives
- Problem Description
- Mitigating actions
  - Loop Connection
  - OLTC
  - Energy Storage
- Economic Assessment
- Conclusions

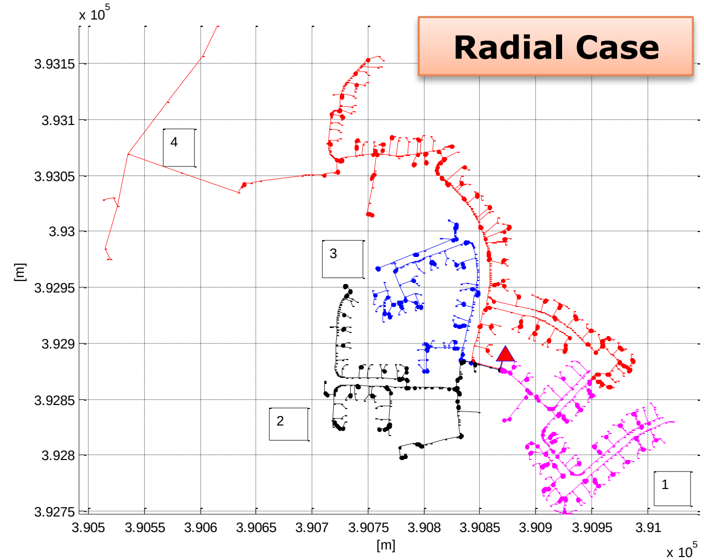
Mitigating Actions

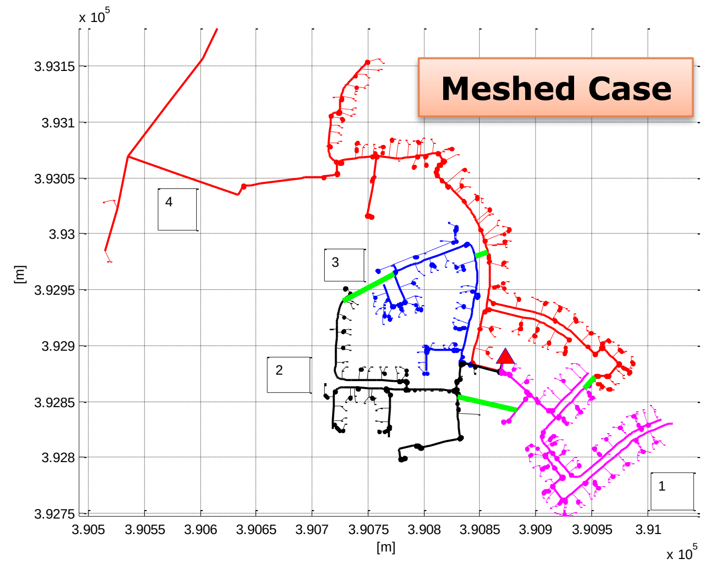
- Can we decrease the impacts of LCT on LV distributions networks?
- Can we increase the hosting capacity of LV networks?
- Mitigation Actions explored:
  - Loop operation of LV networks.
  - OLTC operation in 11kV/430V Transformers.
  - Energy Storage

Mitigating Action: Loop Connection

- Objective:
  - Explore and identify the technical benefits of meshed operation in LV feeders (typically operated in radial configuration).
- Methodology:
  - One real LV network is modelled without (radial operation) and with meshed connection (the connection was also explored in pairs).

Way_NO	Number of Segments	Length [m]	Number of MPANs
4	1141	2290	70
3	483	868	31
2	499	920	26
1	865	1287	53
Total	2988	5365	180



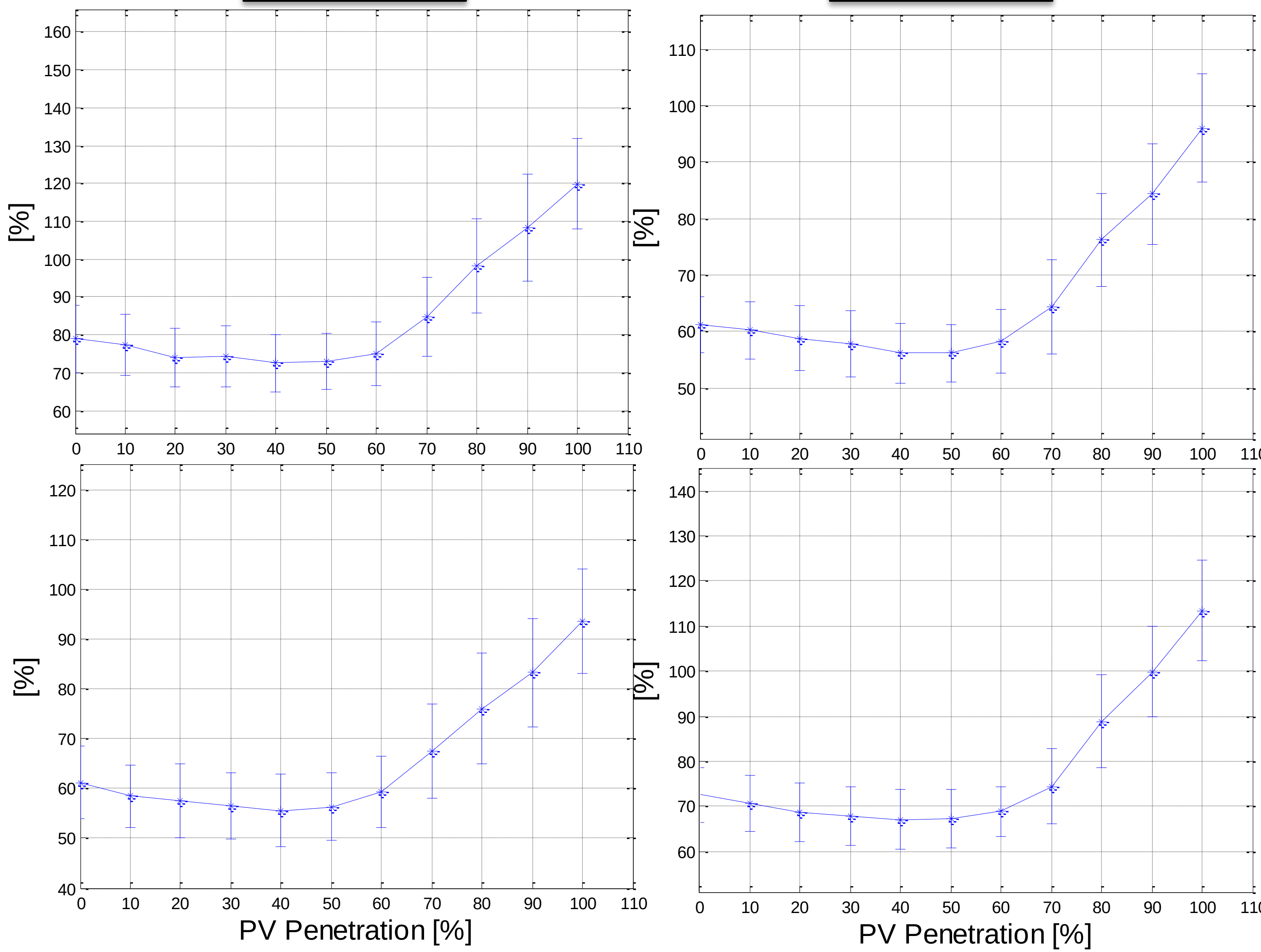


Utilization Level: Two-Feeders linked/Case I

Before | After

Feeder 4

Feeder 1



Connection between feeder 1 and 4

Voltage Problems: Two-Feeders linked/Case I

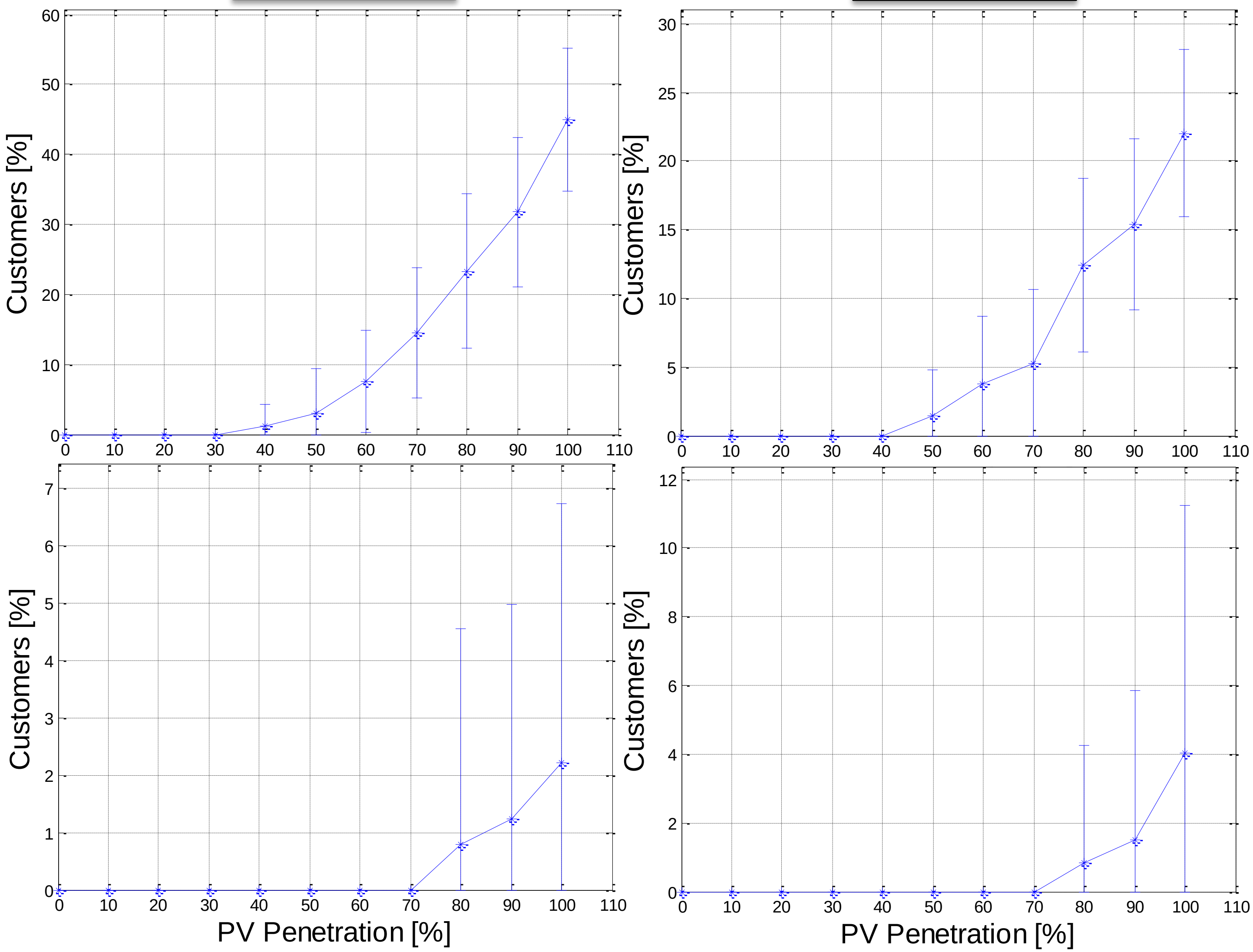
Before

After

Feeder 4

Feeder 1

Connection between feeder 1 and 4



Utilization Level: Two-Feeders linked/Case II

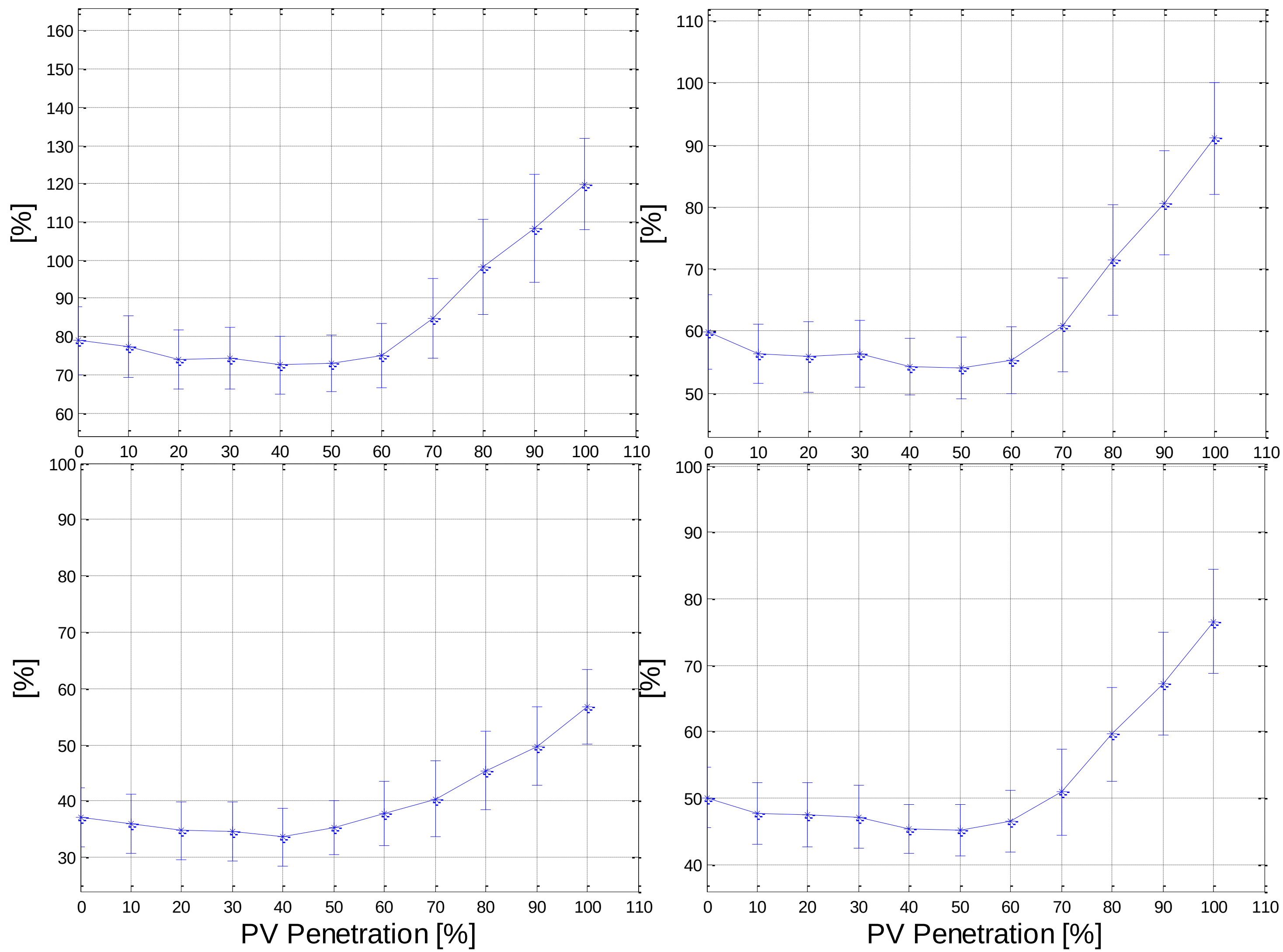
Before

After

Feeder 4

Feeder 3

Connection between feeder 3 and 4

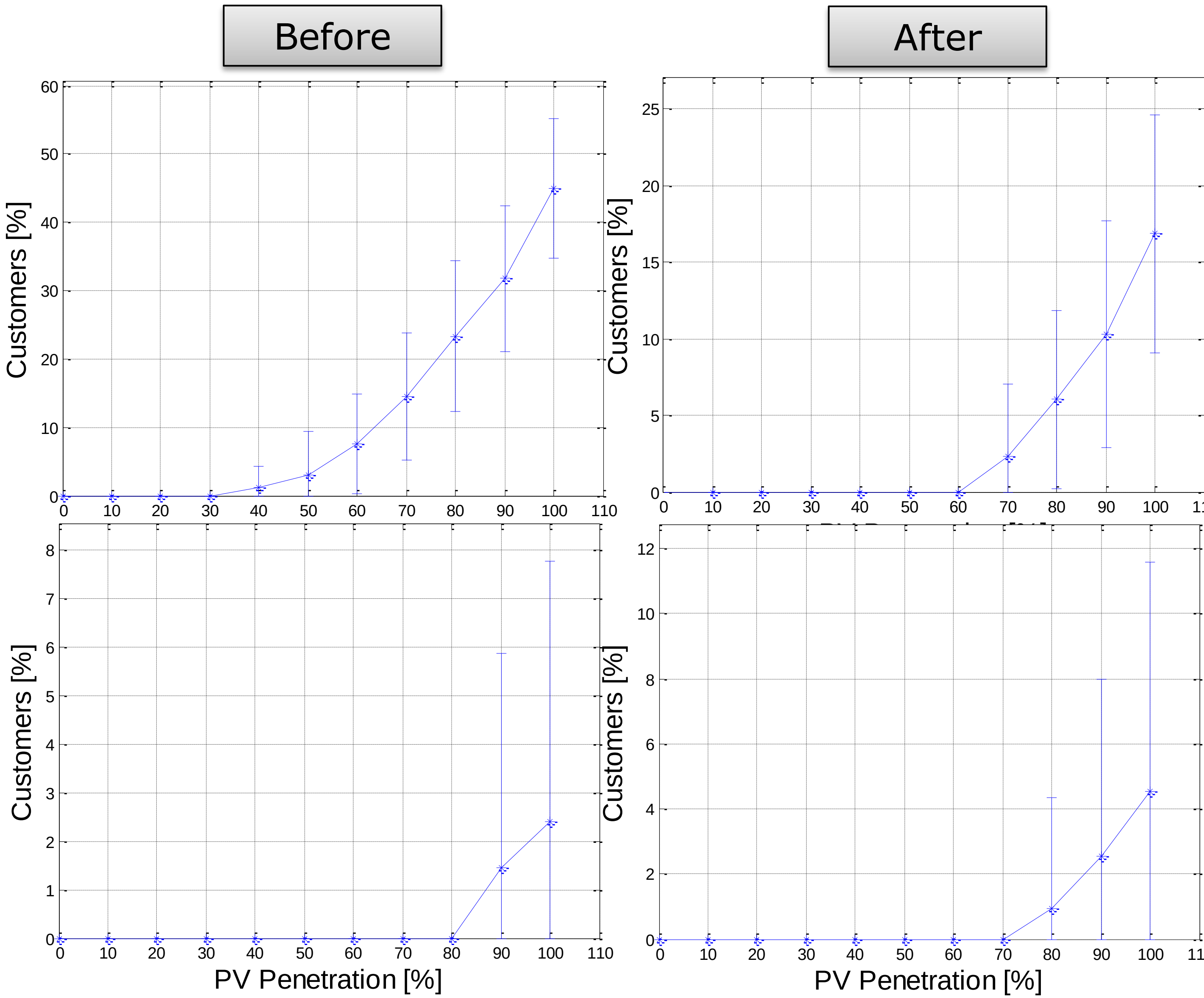


Voltage Problems: Two-Feeders linked/Case II

Feeder 4

Feeder 3

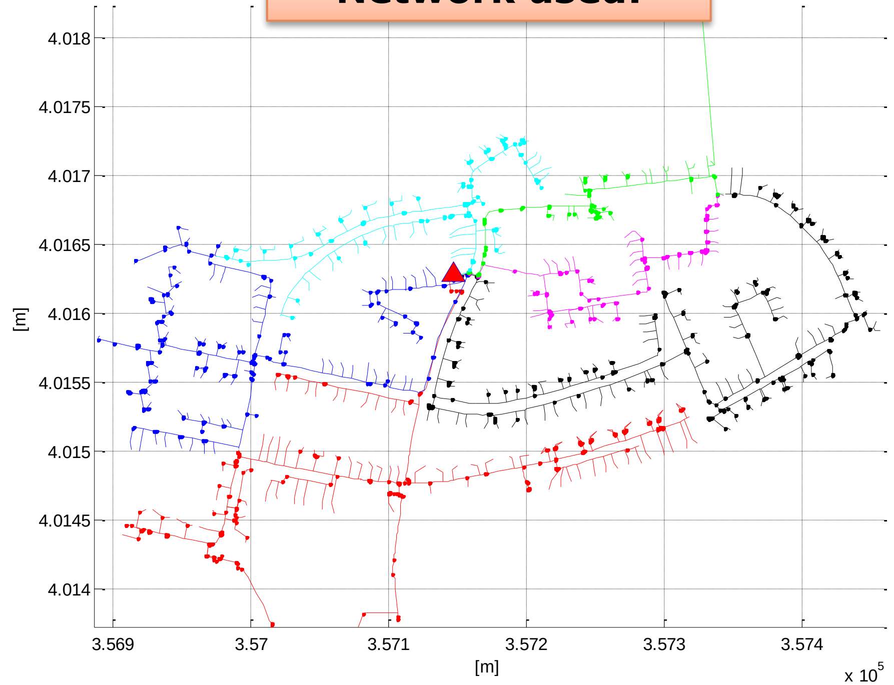
Connection between feeder 3 and 4



Mitigating Action: OLTC Operation

- Methodology:
  - Impact Assessment Methodology
- Technologies:
  - Photovoltaic panels (**PV**)
  - Electric vehicles (**EV**)
- Cases under analysis:
  - Business as usual (without OLTC)
  - OLTC with local control
  - OLTC with remote control
- OLTC features:
  - Control cycle 5 minutes.
  - Regulation +/-8%.
  - 9 tap positions.

Network used:



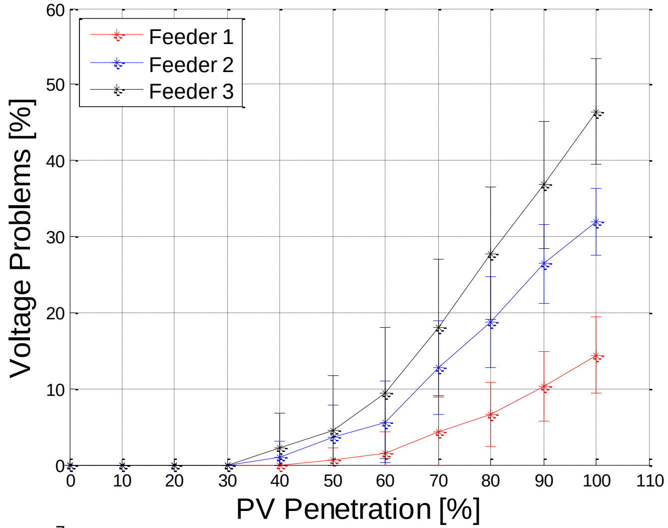
Feeder	Length (m)	No. of Customers
1	2479	83
2	1823	68
3	2312	100
4	779	30
5	670	21
6	1220	49

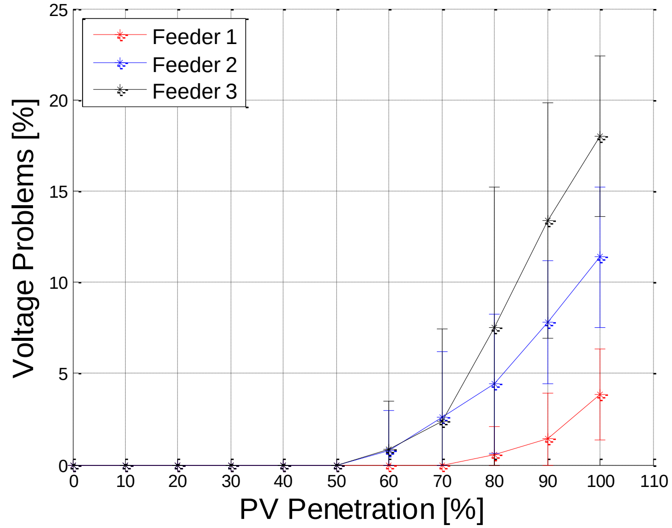
OLTC Operation: Results

Without Control

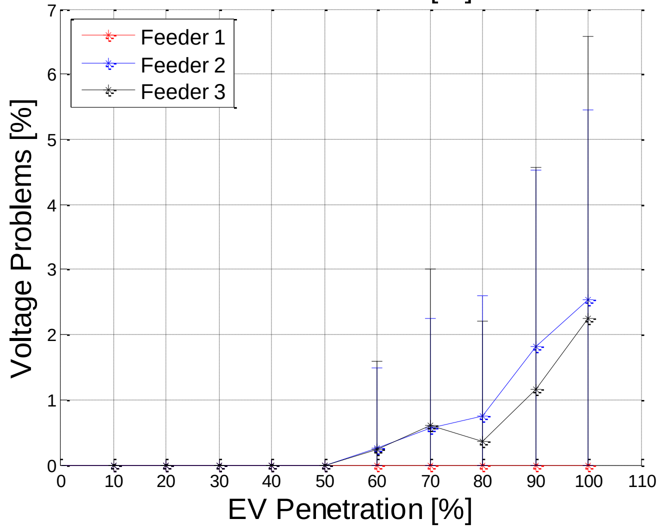
Local control: Information from the busbar Voltage target: PV 235V, EV 245V

PV





EV



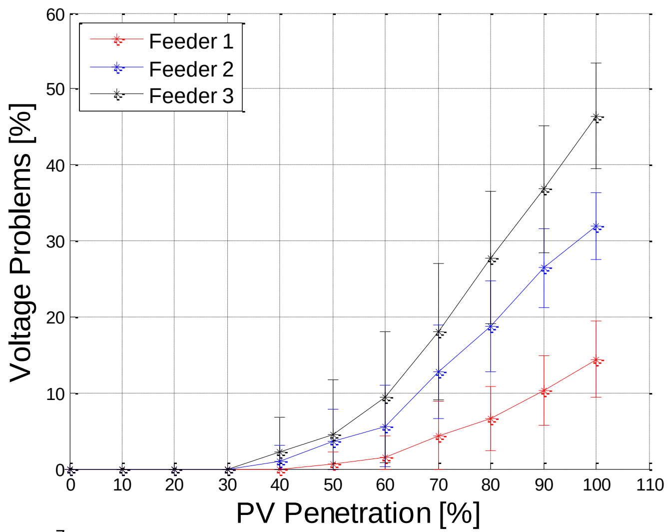
The voltage problems are solve for the EV case

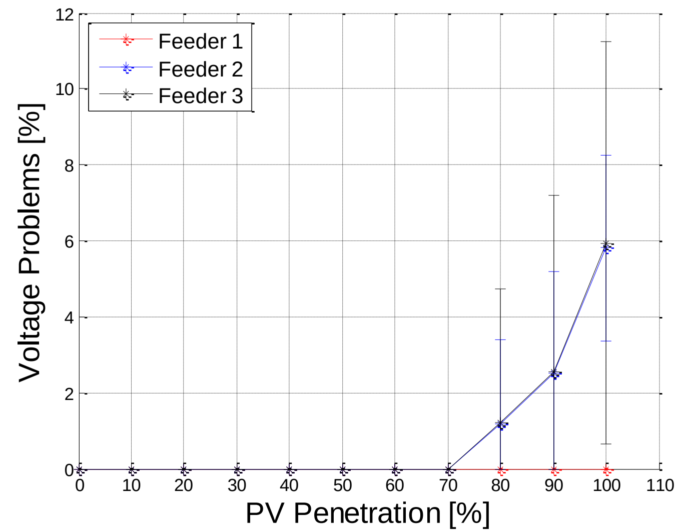
OLTC Operation: Results

Business as usual

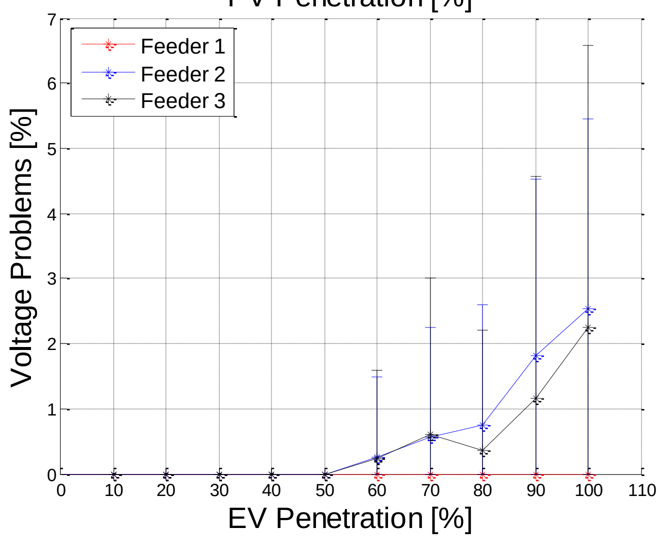
Remote control: Information from the furthest customer in the longest feeder

PV





EV



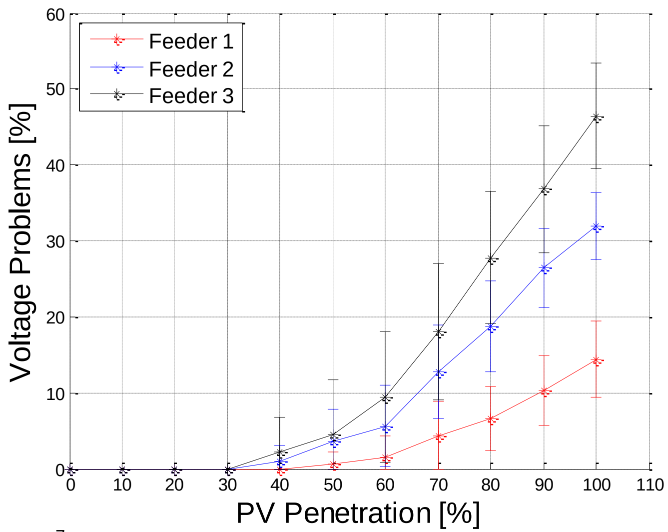
The voltage problems are solve for the EV case

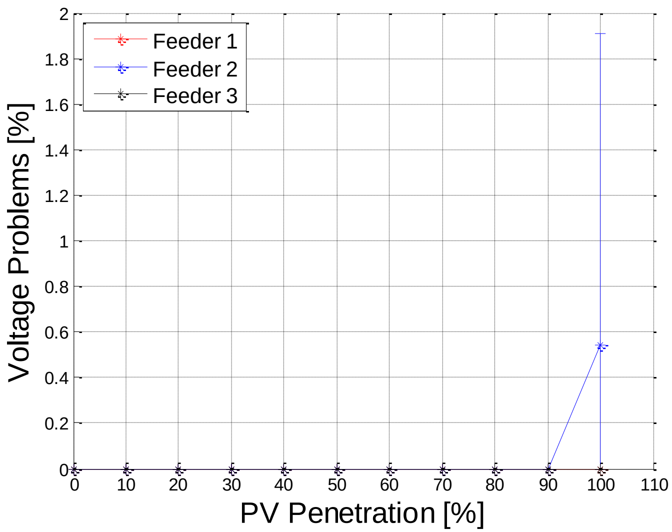
OLTC Operation: Results

Business as usual

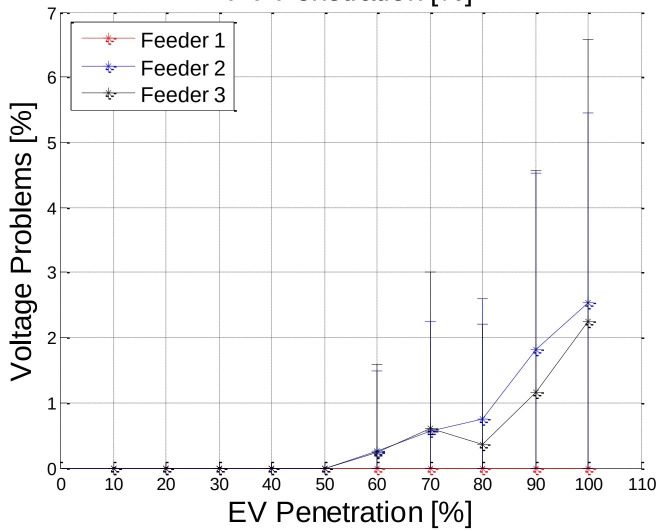
Remote control: Information from the furthest customer in the longest feeder

PV





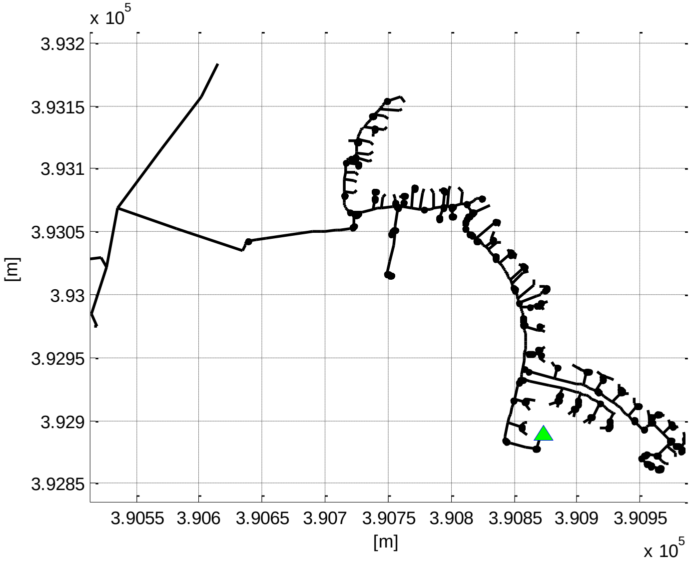
EV



Modification in the OLTC Design: +12%/-4%

Mitigating action: Energy Storage

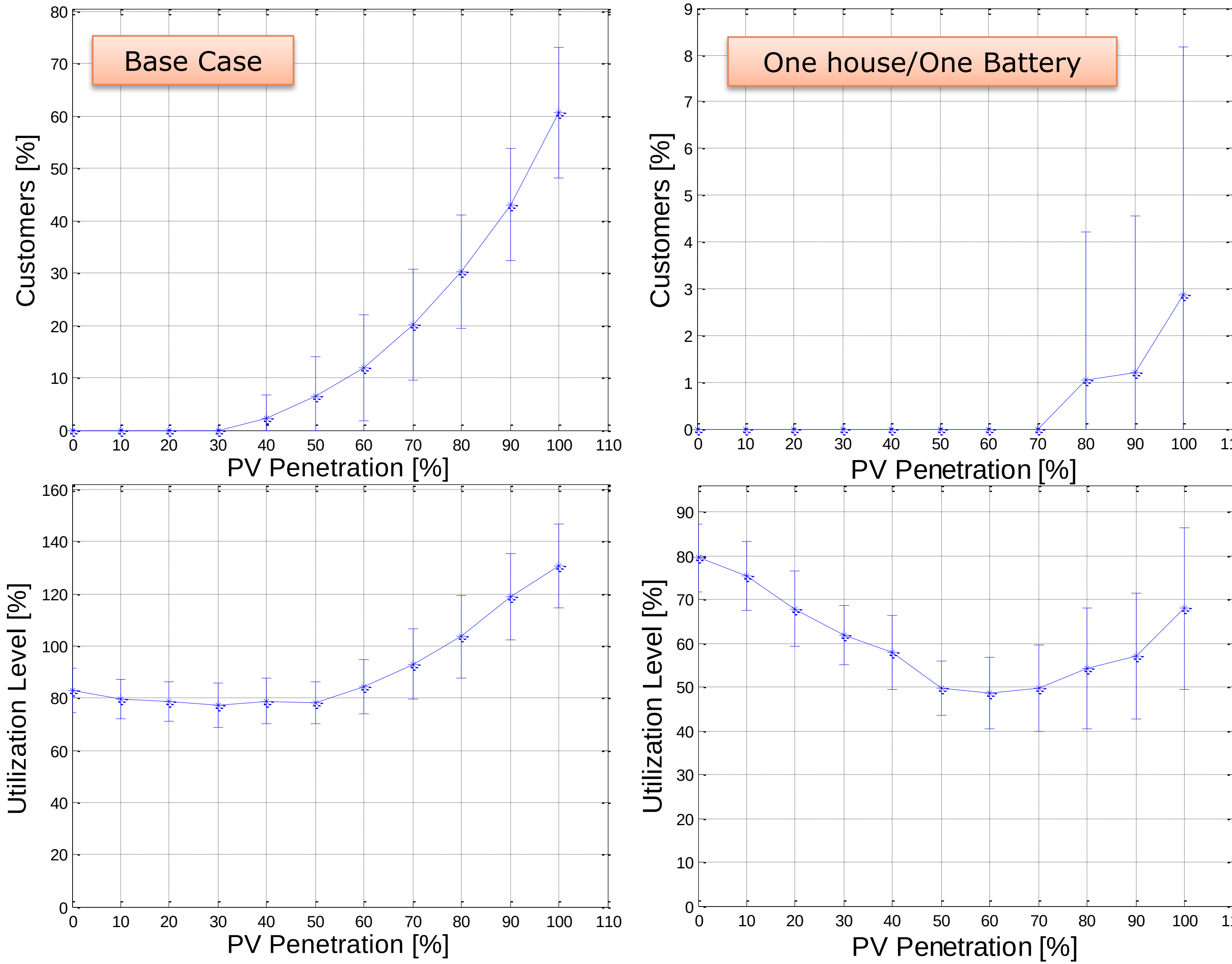
- Explore the utilization of energy storage units in specific locations in the feeder to increase the PV hosting capacity.
- Cases to explore:
  - One house/one battery
  - One feeder/one battery



Feeder 4: 2.2 km 70 loads

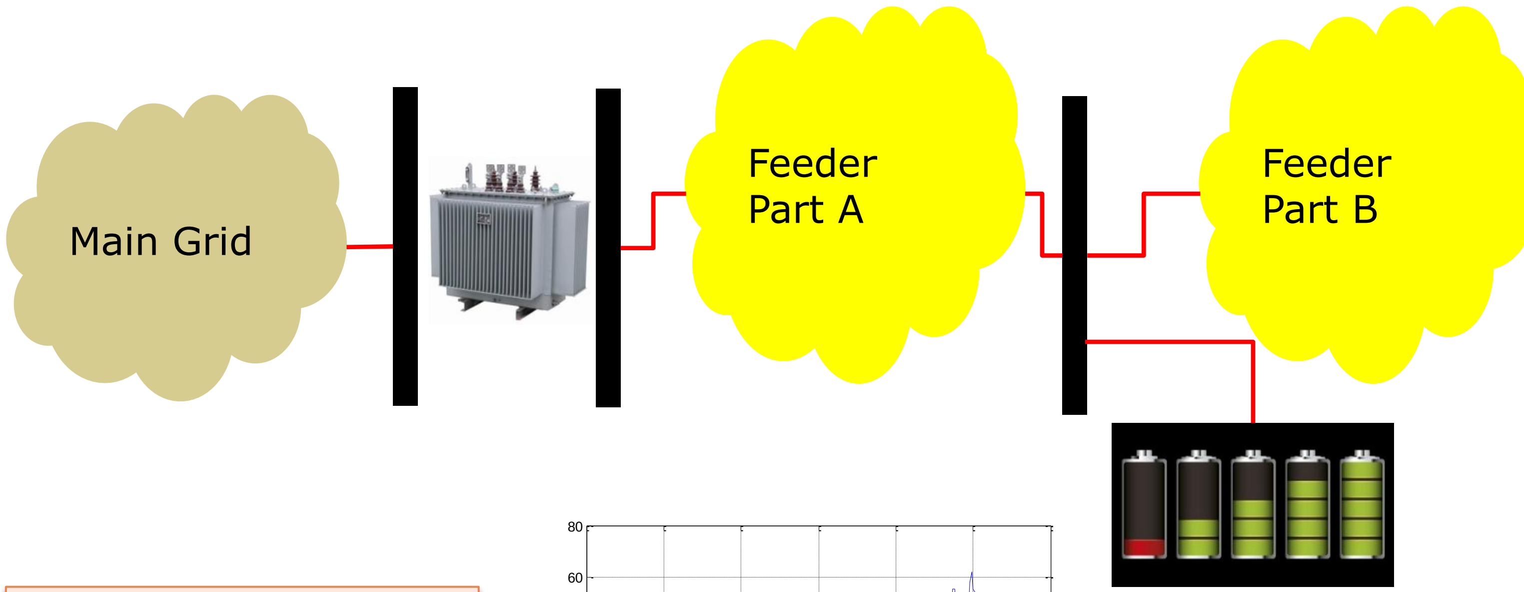
Energy Storage: One House/One Battery

The battery is sized to use most of the energy stored during the day

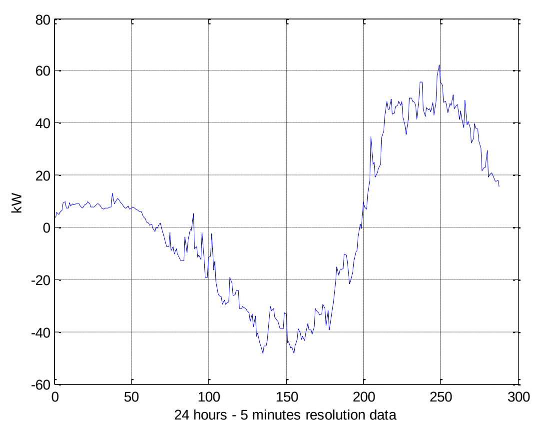


Energy Storage: One Feeder/One Battery

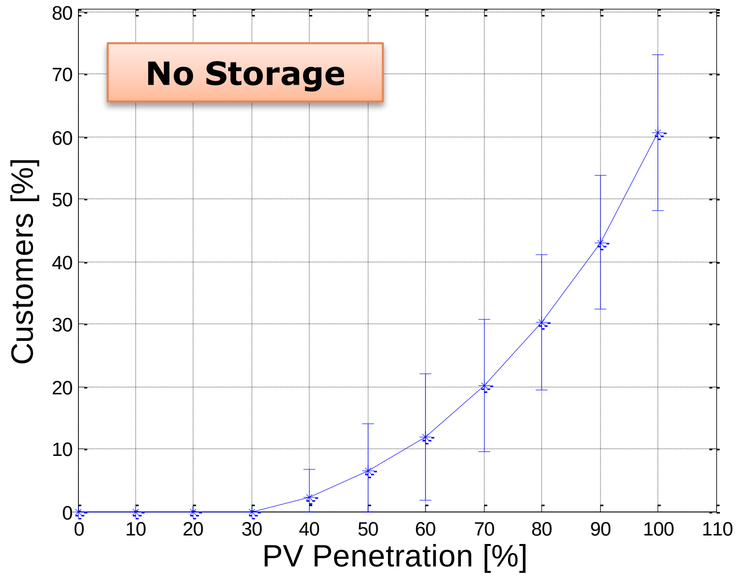
- Part A + Part B = Total feeder
- Part B has X% of the customers downstream.

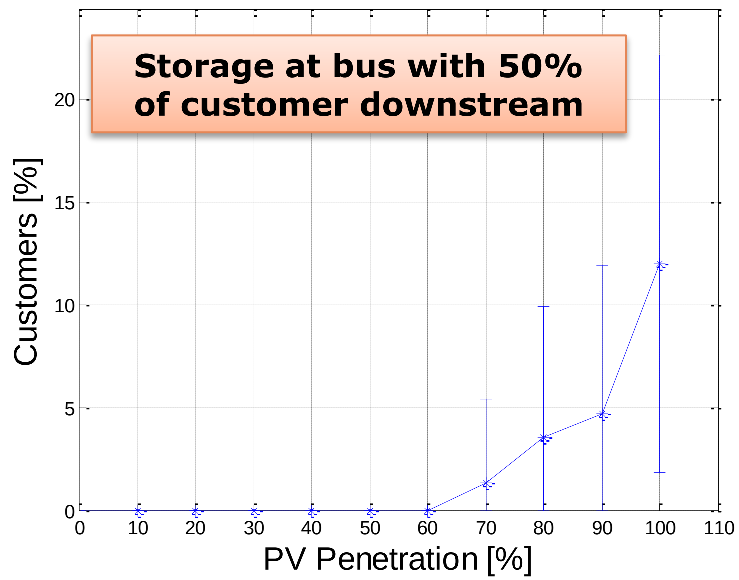


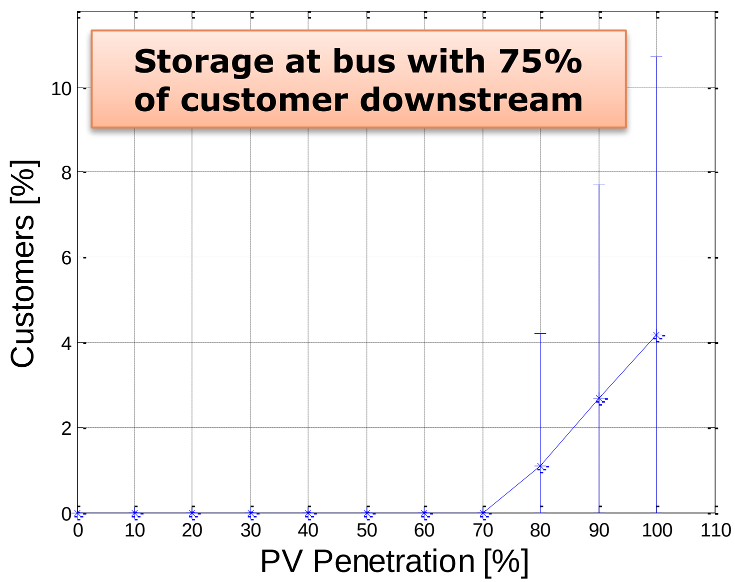
The battery is in follow mode according to the net demand.
The size is selected to used the energy daily.



One Feeder/One Battery: Voltage Analysis

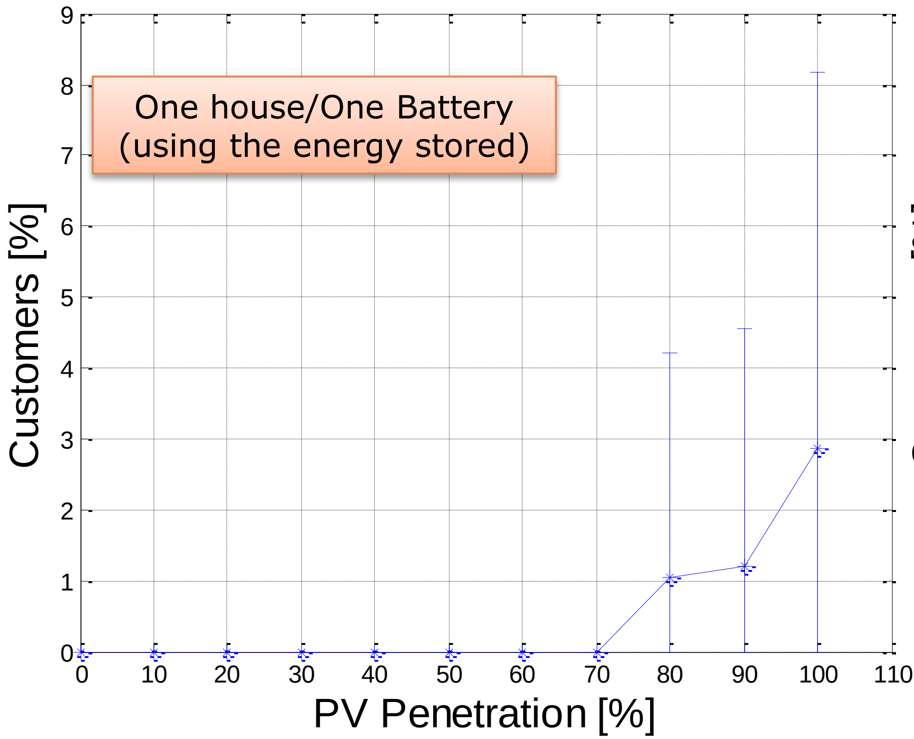


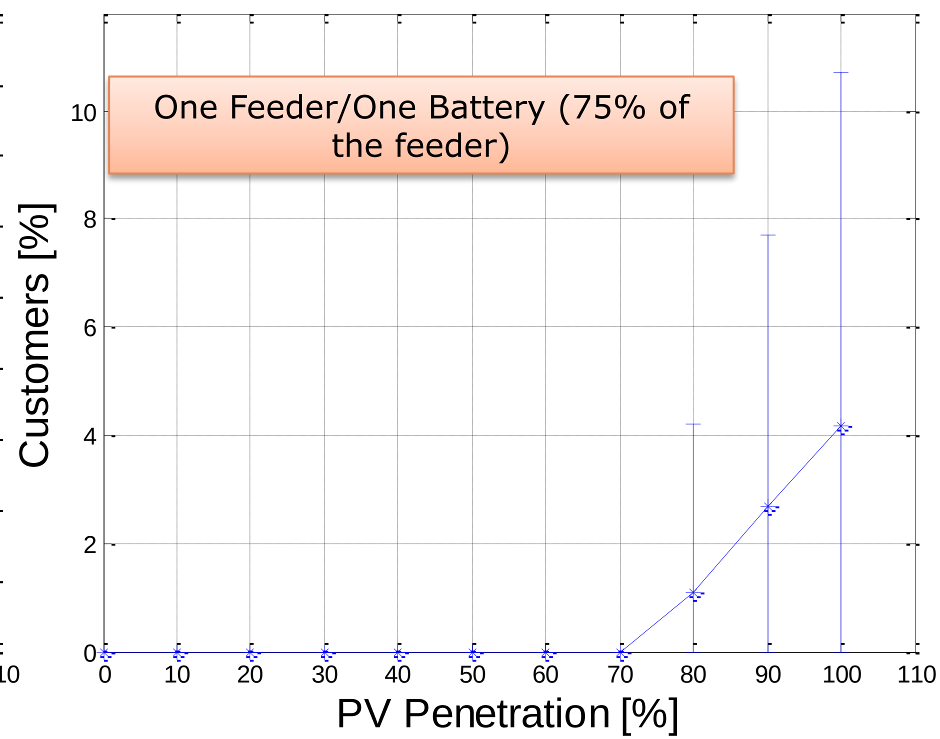




Energy Storage: Comparison

- One house/One Battery and One Feeder/One Battery

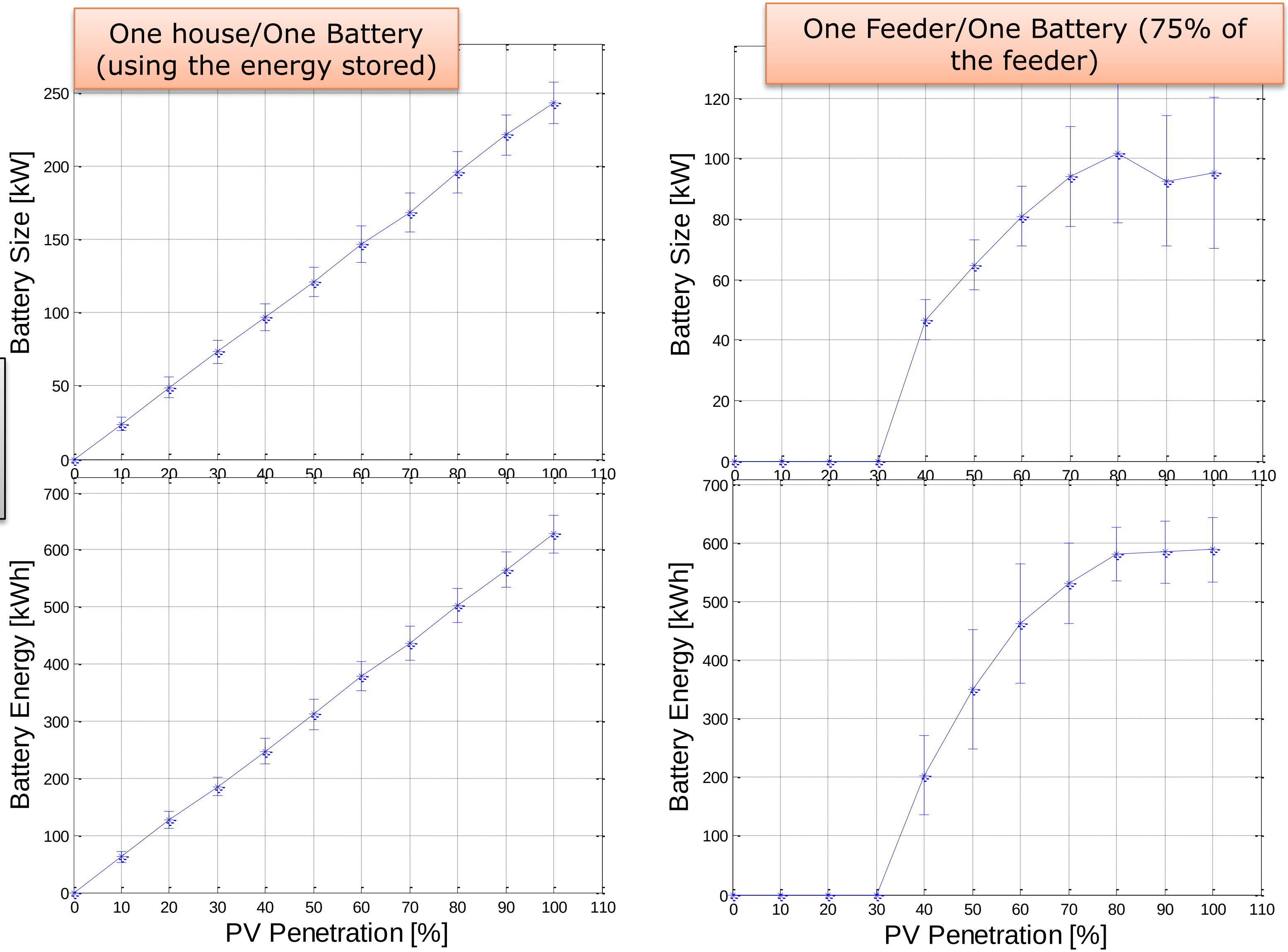




The problems are delayed from 40% (base case) to 80% and the magnitude of the problems is similar in both solutions

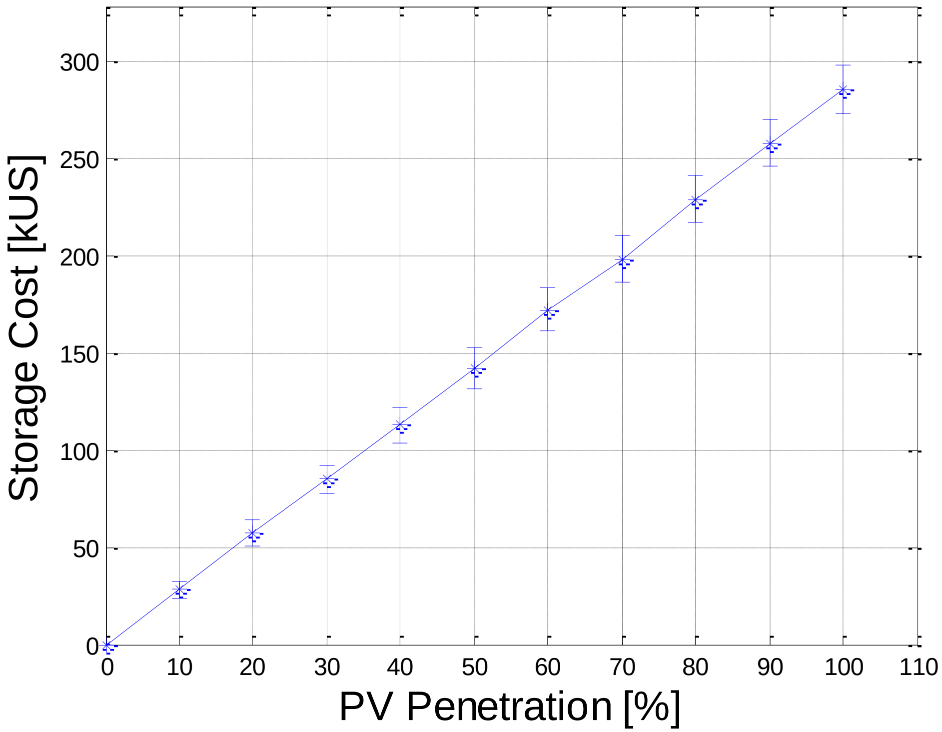
Energy Storage: How to decide?

Capacity and Energy

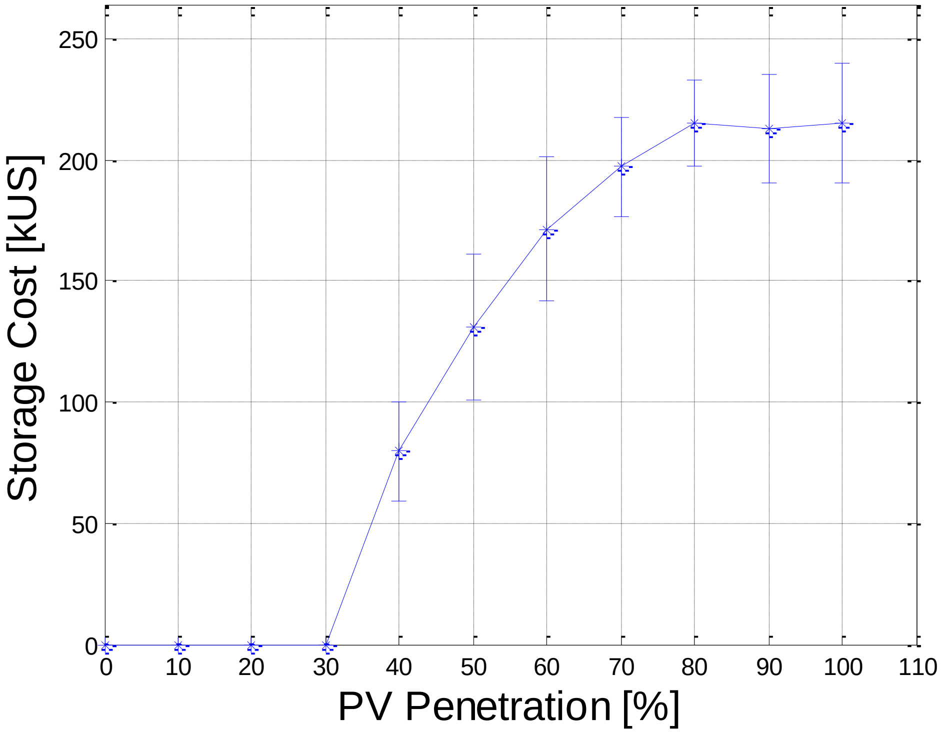


Energy Storage: How to decide?

One house/One Battery (using the energy stored)



One Feeder/One Battery (75% of the feeder)



Capacity Cost: 400 US/kW Energy Cost:300 US/kWh

Outline

- Objectives
- Problem Description
- Mitigating actions
  - Loop Connection
  - OLTC
  - Energy Storage
- Economic Assessment
- Conclusions

Economic Assessment

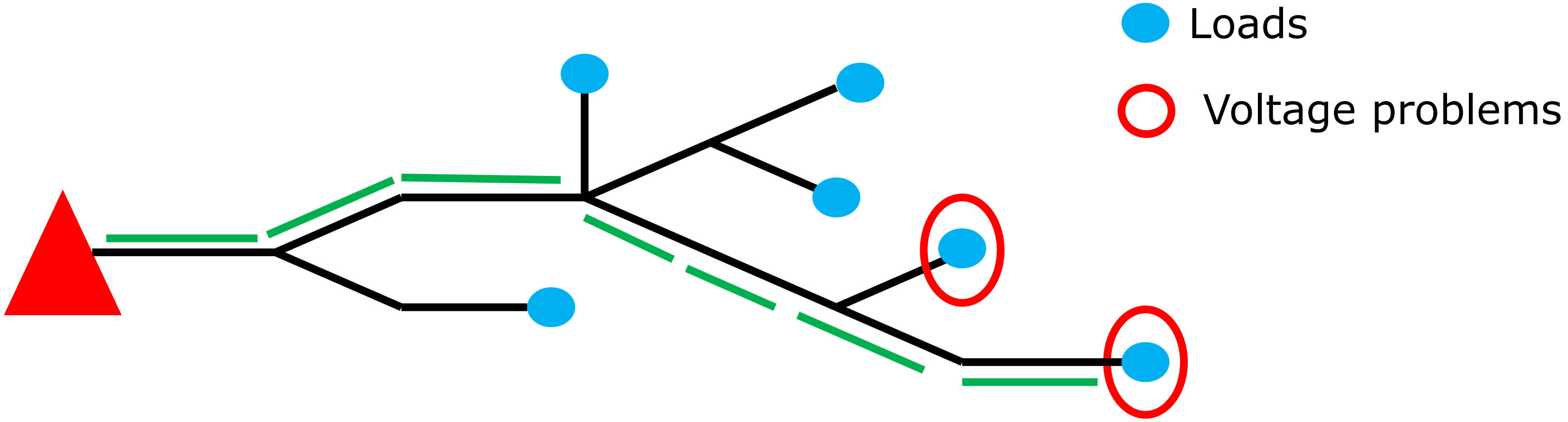
- Benchmarking Cost: How much is the network reinforcement cost for enabling certain LCT penetration?

- Network reinforcement:
  - Traditional approach to face load growing.
  - Very expensive alternative (mainly due the installation cost).
  - 140 £/m for main cables and 80 £/m for services cables (urban areas).

Economic Assessment: Network Reinforcement

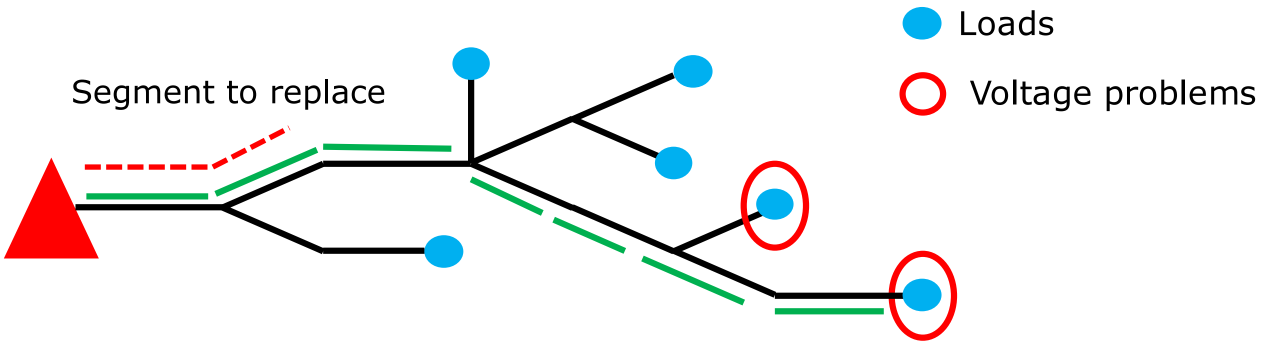
The following algorithm has been implemented:

1. Identification of customers with voltage problems.
2. Identification of the “worst customer” (voltage rise or voltage drop)
3. Identification of the main path between the secondary substation and the worst customer.
4. Division of the main path in segments of 100 meters.



Economic Assessment: Network Reinforcement

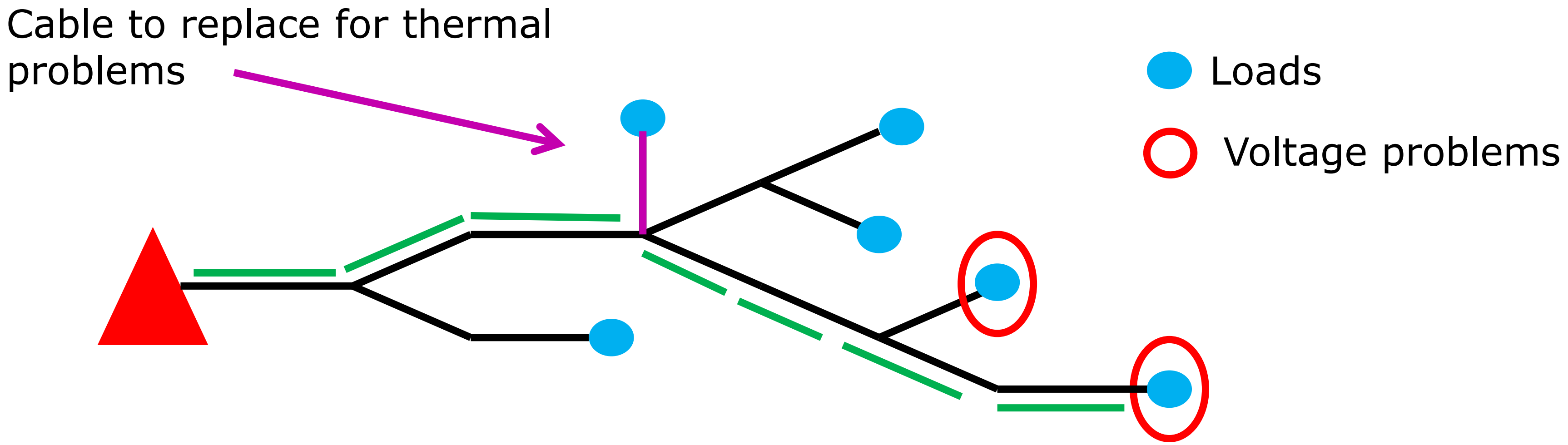
5. For the first segment (100 m) the cable is replaced by the next bigger cable available.
6. A power flow is run and the voltages are checked:
    5. If the voltages are not yet within the Standard:
        5. and there is still one bigger cable available, go to step 5.
        6. If there is not a bigger cable available, go to step 5, but for the next 100 m segment.
    6. If there are not more problems, stop.



Economic Assessment: Network Reinforcement

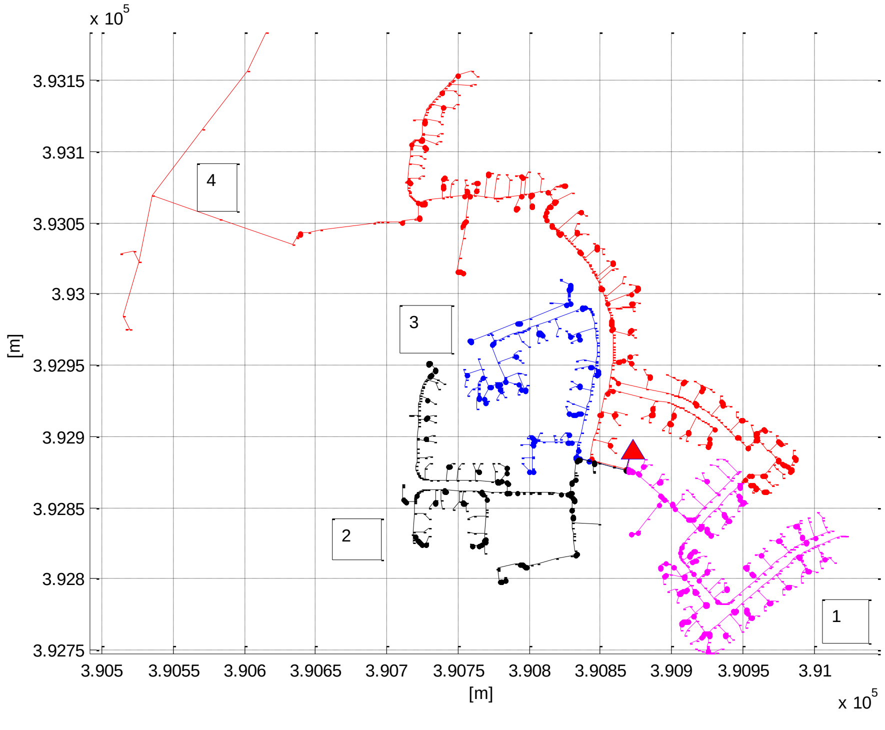
7. Once the voltage problems are fixed, the thermal problems are checked.

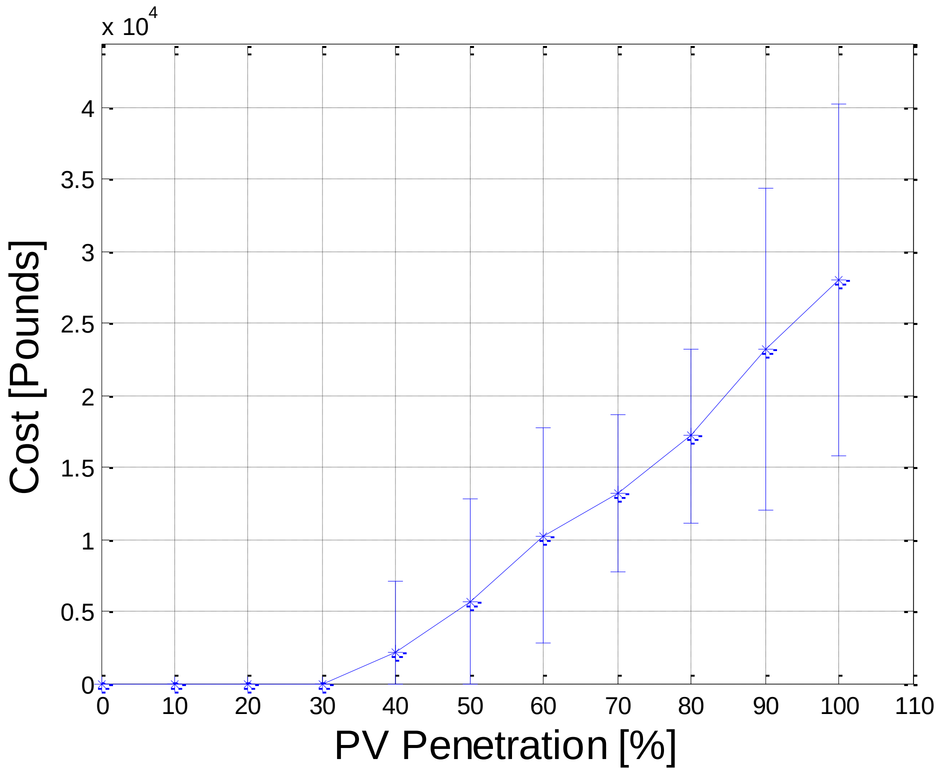
   7.1 Each cable with thermal problems is replaced for the minimum size bigger than the rating required.



Economic Assessment: Loop Connection

- Network reinforcement cost:





Economic Assessment: Loop Connection

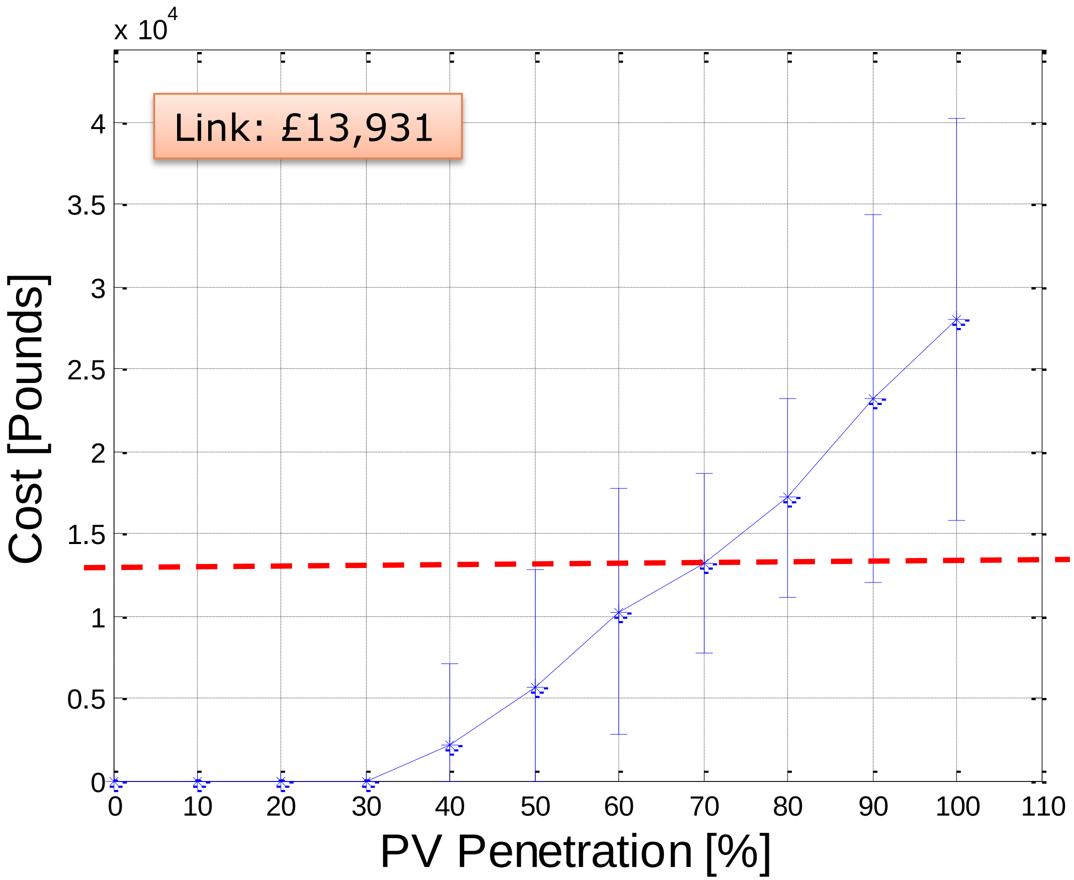
- Loop Connection cost:

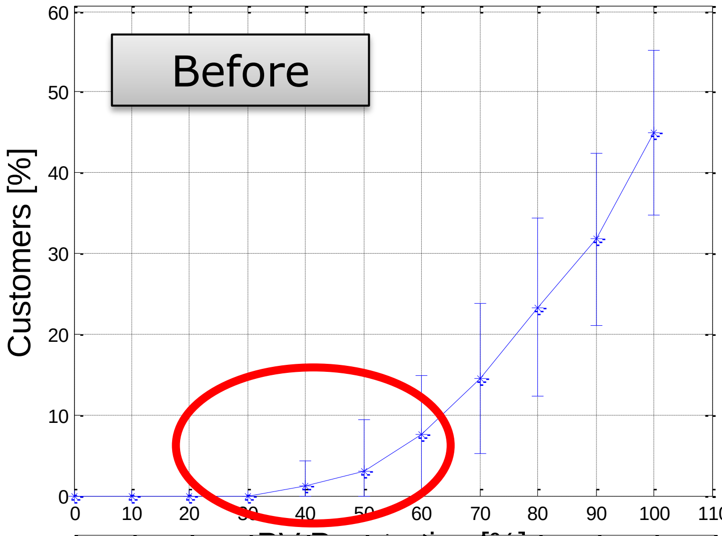
Equipment Type	Voltage Level	Assumptions	Unit Costs	Installation Costs	Total
Link Box	LV	Replacement or new link boxes to create mesh points from Network Studies	£ 650	£ 1,298	**£ 1,948**
Link box Switch	LV	3 for every link box or mesh point (assume 1 link box for every 2 LV feeders)	£ 2,000	£ 135	**£ 2,135**
Gateway		1 per every 3 link box switches plus 1 per distribution substation	£ 1,250	£ 135	**£ 1,385**
Circuits breakers (Weezap)	LV	3 for every LV feeder	£ 4,500	£ 135	**£ 4,635**
Joints	LV	2 Joints required for each new link box	£ 100		**£ 100**
Cable	LV	Assume 10m per new link box + extra for interconnection points from Mark's work	£ 17		**£ 17**
Monitoring	LV	1 every five LV feeders. Measuring the most electrically remote point from each distribution substation	£ 2,205	£ 2,100	**£ 4,305**

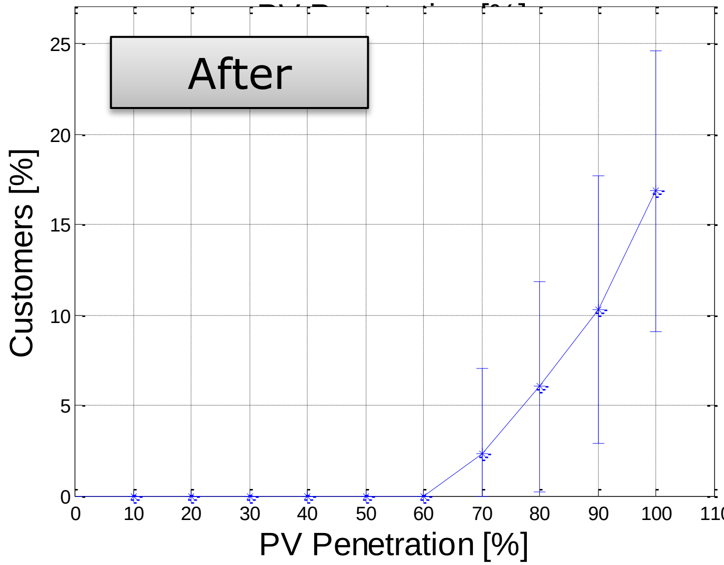
Two Feeder Connection without monitoring: £13,931

is this expensive?

Economic Assessment: Loop Connection

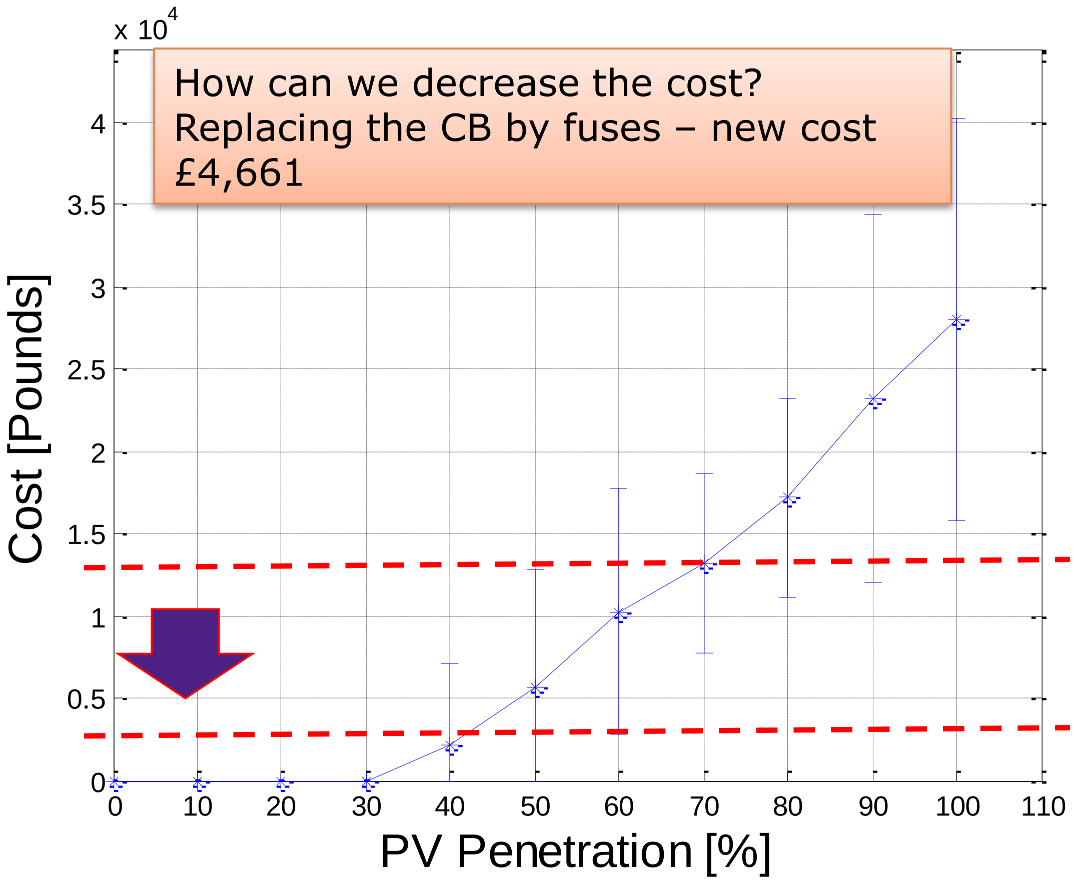


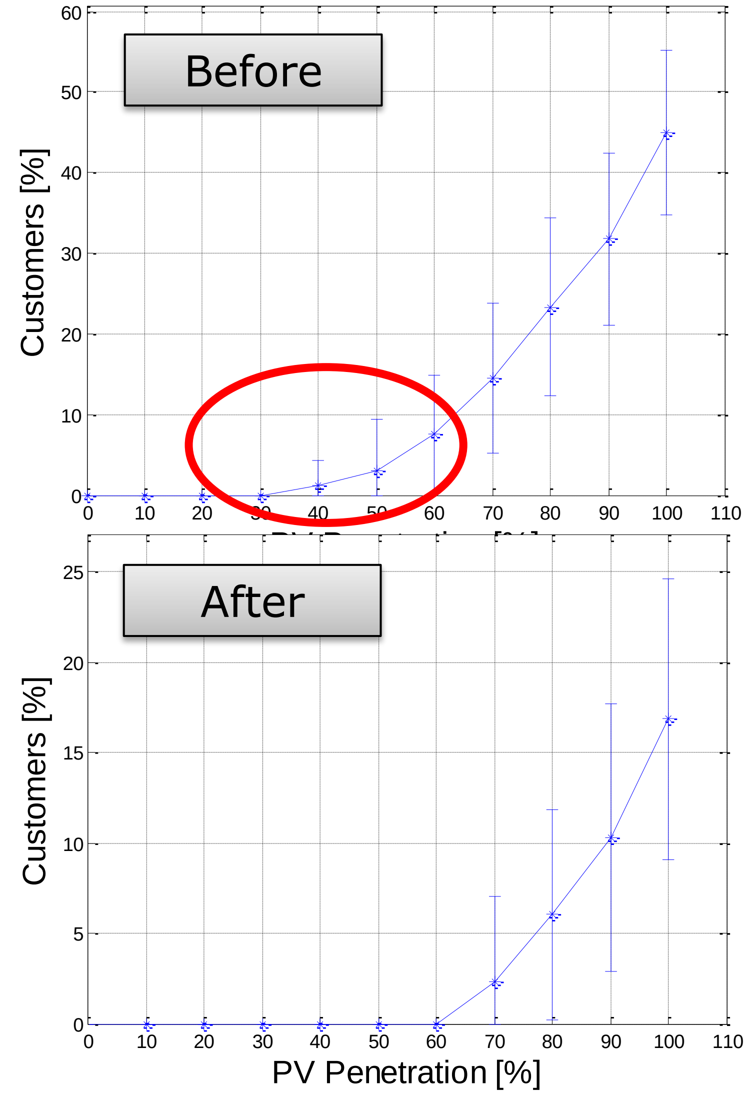




The loop connection is not solving the problems for the penetration levels when is cheaper than the reinforcement cost.

Economic Assessment: Loop Connection

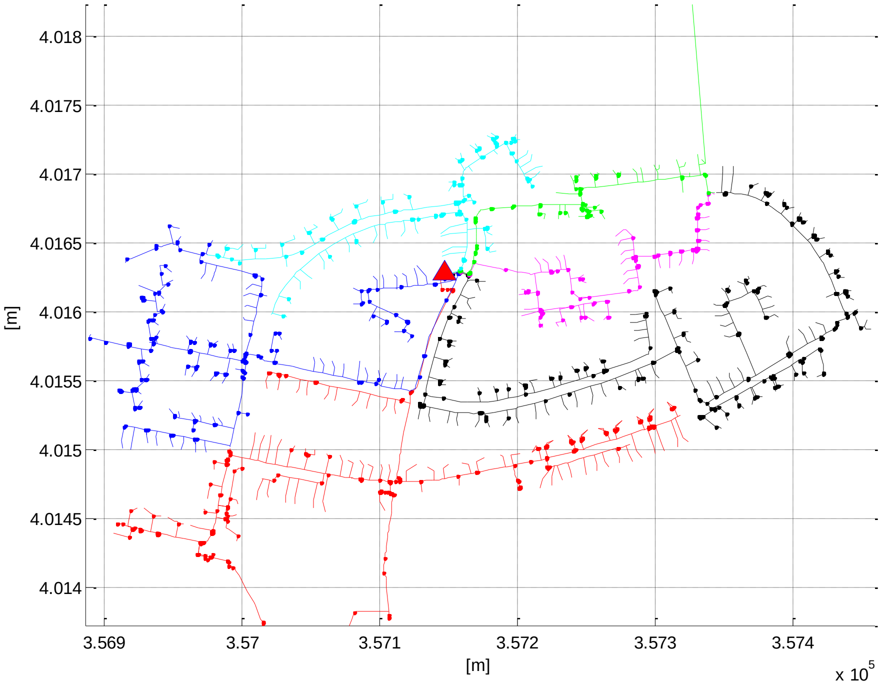


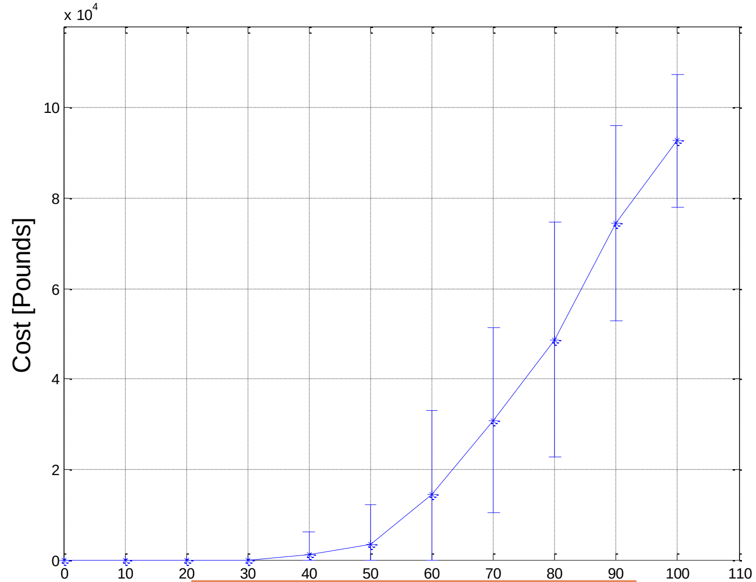


Now the network reinforcement for this network is competitive – **Challenge**: **How is the reliability affected?**

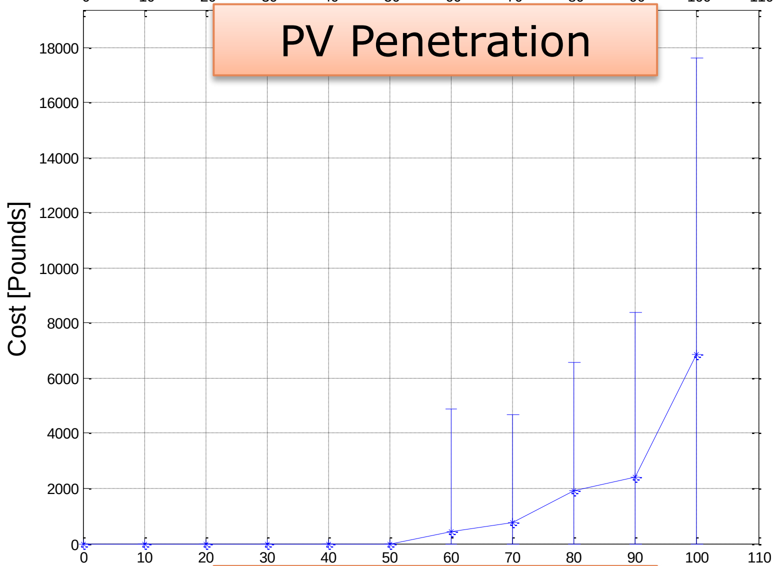
Economic Assessment: OLTC

- Network reinforcement cost:





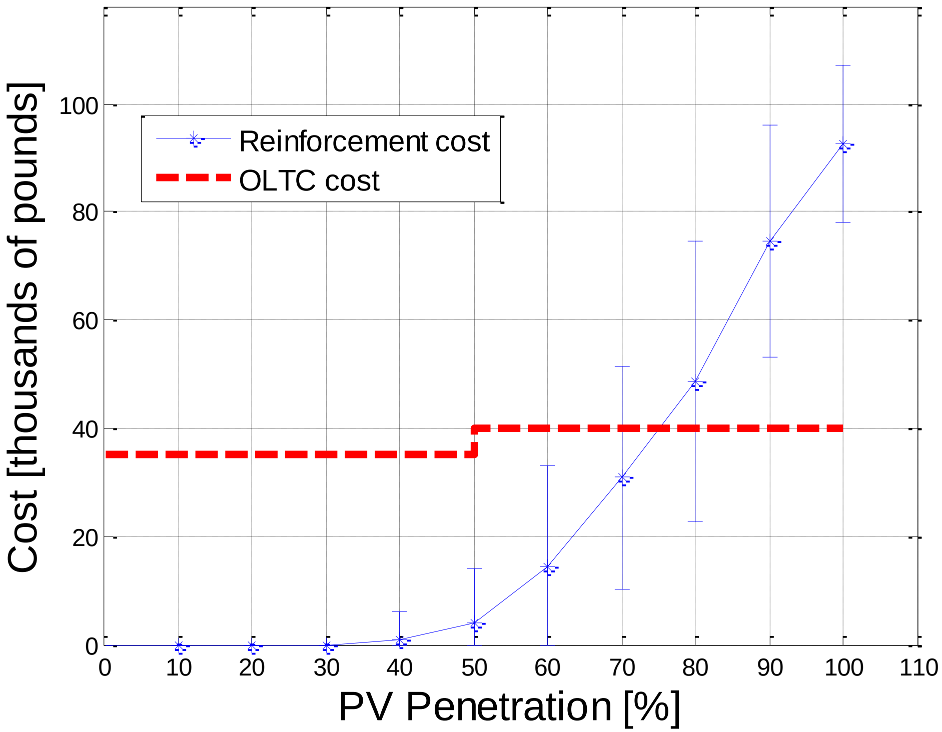
PV Penetration

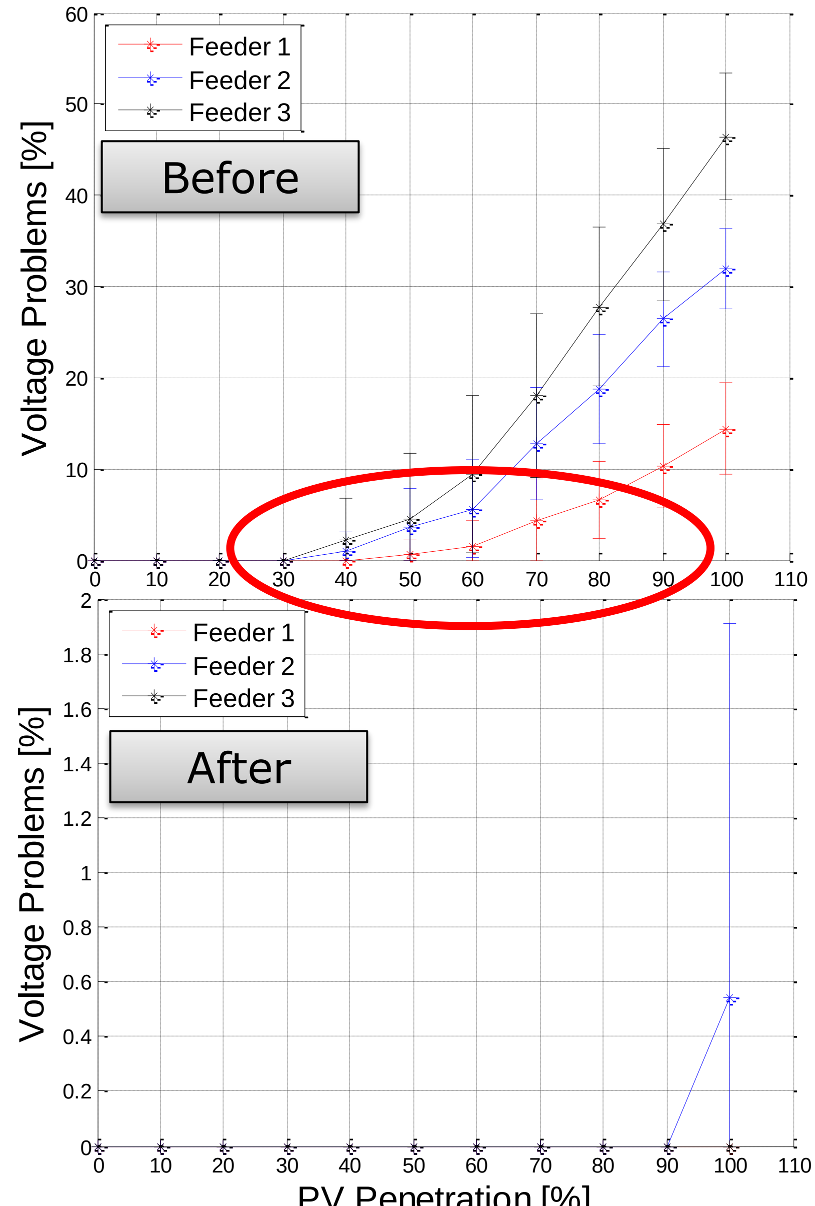


EV Penetration

Economic Assessment: Loop Connection

OLTC: £36,000
OLTC+ICT: £40,000





The OLTC is more economic efficient for higher penetration levels

Outline

- Objectives
- Problem Description
- Profiles Creation
- Impact Assessment
- Multi-Feeder Analysis
- Mitigating Actions
- Conclusions

Conclusions

- Loop connection of LV feeders
  - Is effective as it "shares" the problems
  - PV hosting capacity was significantly increased (From 40% to 70%)
- OLTC in LV networks:
  - It increases the hosting capacity and reduces the magnitude of possible problems
  - The monitoring can be incorporated progressively with the LCT penetration.

Conclusions

- Energy Storage:
  - The storage sizing must take into account the capacity of using the energy stored (otherwise the problems could be shifted form one day to another).
  - The “one house/one battery” approach leads to a higher installed capacity than the “one feeder/one battery” approach for similar results.
- Network reinforcements
  - Still play an important role but depends on the forecast LCT penetration

Dissemination: Publication List

1. A. Navarro Espinosa and L. F. Ochoa, "On the Cascading Effects of Residential-Scale PV Disconnection Due to Voltage Rise," **IEEE Power and Energy Society General Meeting**, **Maryland 2014**.
2. A. Navarro Espinosa, L. F. Ochoa, and Dan Randles, "Assessing the Benefits of Meshed Operation of LV Feeders with Low Carbon Technologies," Innovative Smart Grid Technologies Conference – **IEEE PES ISGT 2014**, **Washington 2014**.
3. A. Ballanti, A. Navarro Espinosa, L. F. Ochoa, and F. Pilo, "Assessing the Benefits of PV VAR Absorption on the Hosting Capacity of LV Feeders," in **IEEE PES 4th European Innovative Smart Grid Technologies** (ISGT 2013), **Copenhagen 2013**.
4. A. Navarro Espinosa, L. F. Ochoa, P. Mancarella, and D. Randles, "Impacts of Photovoltaics on Low voltage Networks: A Case Study for the North West of England," in 22th International Conference on electricity Distribution (**CIRED 2013**), **Stockholm 2013**, no. June, pp. 10–13.
5. A. Navarro Espinosa, L. F. Ochoa, and D. Randles, "Monte Carlo-Based Assessment of PV Impacts on Real UK Low Voltage Networks," in 2013 **IEEE Power and Energy Society General Meeting**, **Vancouver 2013**, pp. 1–5.
6. A. Navarro Espinosa, L. F. Ochoa, and P. Mancarella, "Learning from Residential Load Data: Impacts on LV Network Planning and Operation," in Sixth **IEEE PES Transmission and Distribution**: Latin America Conference and Exposition, **Montevideo 2012**.

Dissemination: Publication List

Collaborations related with LCTs:

1. Y. Zhou, A. Navarro Espinosa and J. Mutale, “Security of Supply: Implication of Residential Photovoltaic Panels in Low Voltage Network” 2014 **International Conference on Power System Technology** (POWERCON2014), **Chengdu 2014** (China).
2. L. Zhang, N. Good, A. Navarro Espinosa, and P. Mancarella, “Modelling of Household Electro Thermal Technologies for Demand Response Applications” **Innovative Smart Grid Technologies Conference** (**ISGT-Europe**), **Istanbul 2014**.
3. N. Good, L. Zhang, A. Navarro Espinosa, and P. Mancarella, “Physical modeling of electro-thermal domestic heating systems with quantification of economic and environmental costs,” in **IEEE EUROCON 2013**, **Zagreb 2013**.
4. A. Navarro Espinosa and P. Mancarella, “Probabilistic modelling and assessment of the impact of electric heat pumps on low voltage distribution networks” **Applied Energy**, Volume 127, 15 August 2014, Pages 249-266.

Dissemination: Work in Progress

Publications Submitted:

1. A. Navarro Espinosa and L. Ochoa, "Techno-Economic Assessment of using OLTC in Future UK LV Networks" to the **Innovative Smart Grid Conference** – **Washington 2015**.
2. V. Rigoni, L. Ochoa, G. Chicco, A. Navarro Espinosa and T. Gozel, "Representative Residential LV Feeders: A case study for the North West of England" submitted to **IEEE Transaction on Power Systems.**

Work in progress:

1. A. Navarro and L. Ochoa, "Impacts of Low Carbon Technologies in real Low Voltage Distribution Networks: Probabilistic Assessment Methodology – Part I" for submission to **IEEE Transaction on Power Systems** (expected submission October 2014)
2. A. Navarro and L. Ochoa, "Impacts of Low Carbon Technologies in real Low Voltage Distribution Networks: Cause and Effects in a Multi Feeder Analysis – Part II" for submission to **IEEE Transaction on Power Systems** (expected submission October 2014)

The University of Manchester

Potential Solutions to Mitigate the Impacts of LCT

Appendix K

Alejandro Navarro Espinosa

alejandro.navarroespinosa@manchester.ac.uk

Supervised by Dr Luis(Nando) Ochoa

3rd October 2014

The University of Manchester, Manchester