



trolley:2.0

for smart cities



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Introduction

PV

PV + Storage

Storage

EV Charger



Introduction

The Trolleybus Grid

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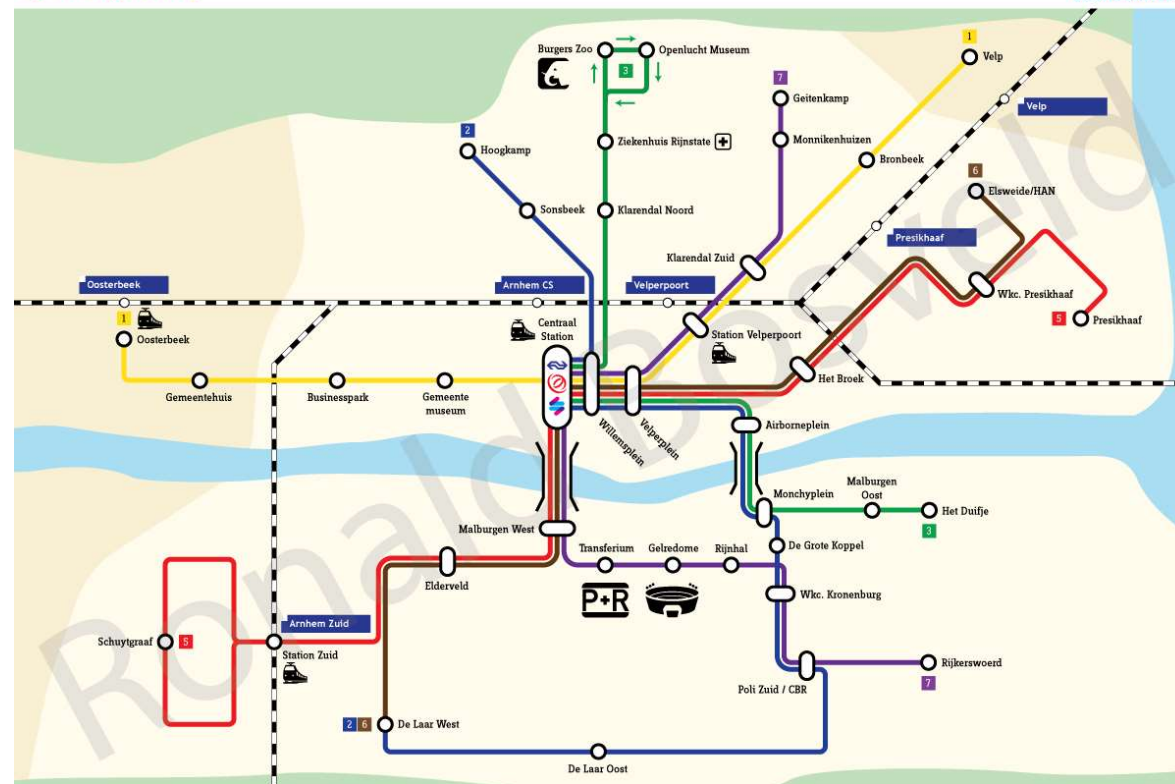


<https://www.stuff.co.nz/national/97509984/wellingtons-electric-trolley-bus-wires-to-start-coming-down-in-a-week>

Arnhem Trolley Grid



Trolley netwerk Arnhem vanaf December 2014
Ronald Bosveld



<https://wiki.ovinnederland.nl/wiki/Bestand:Trolley-net-Dec2014.png>

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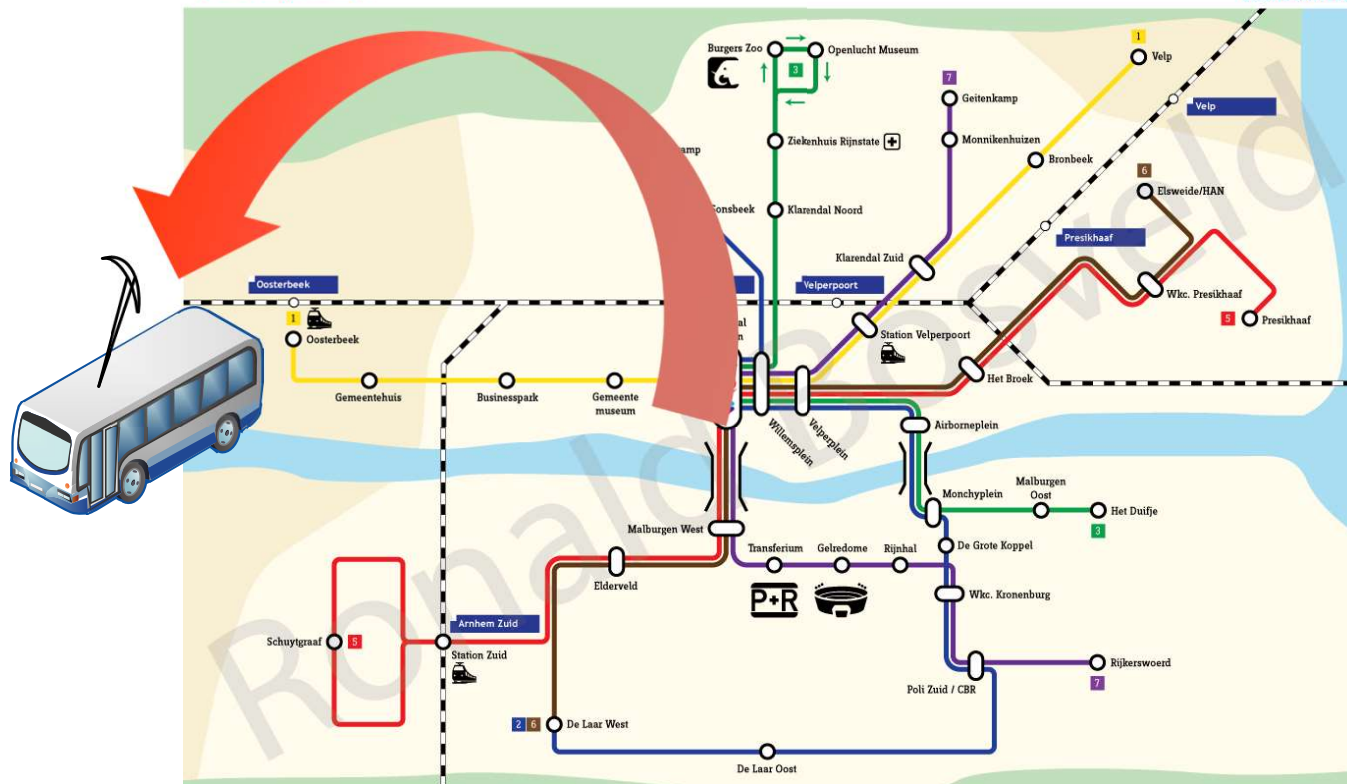
Storage

EV Charger

A Mono-functional Grid!

 brengtrolley

Trolley netwerk Arnhem vanaf December 2014
Ronald Bosveld



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 TU Delft

The Grid of the Future

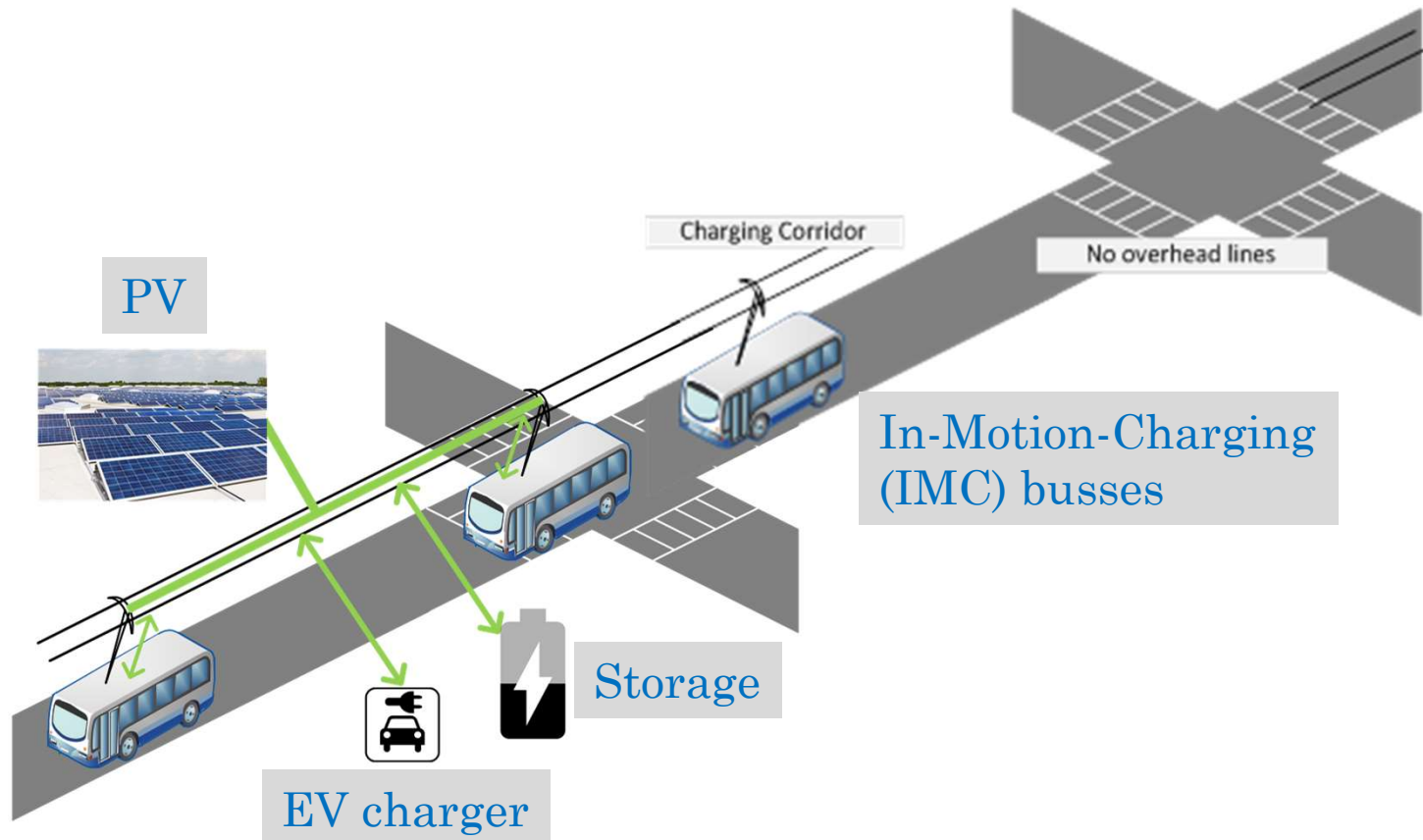
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The Grid of the Future

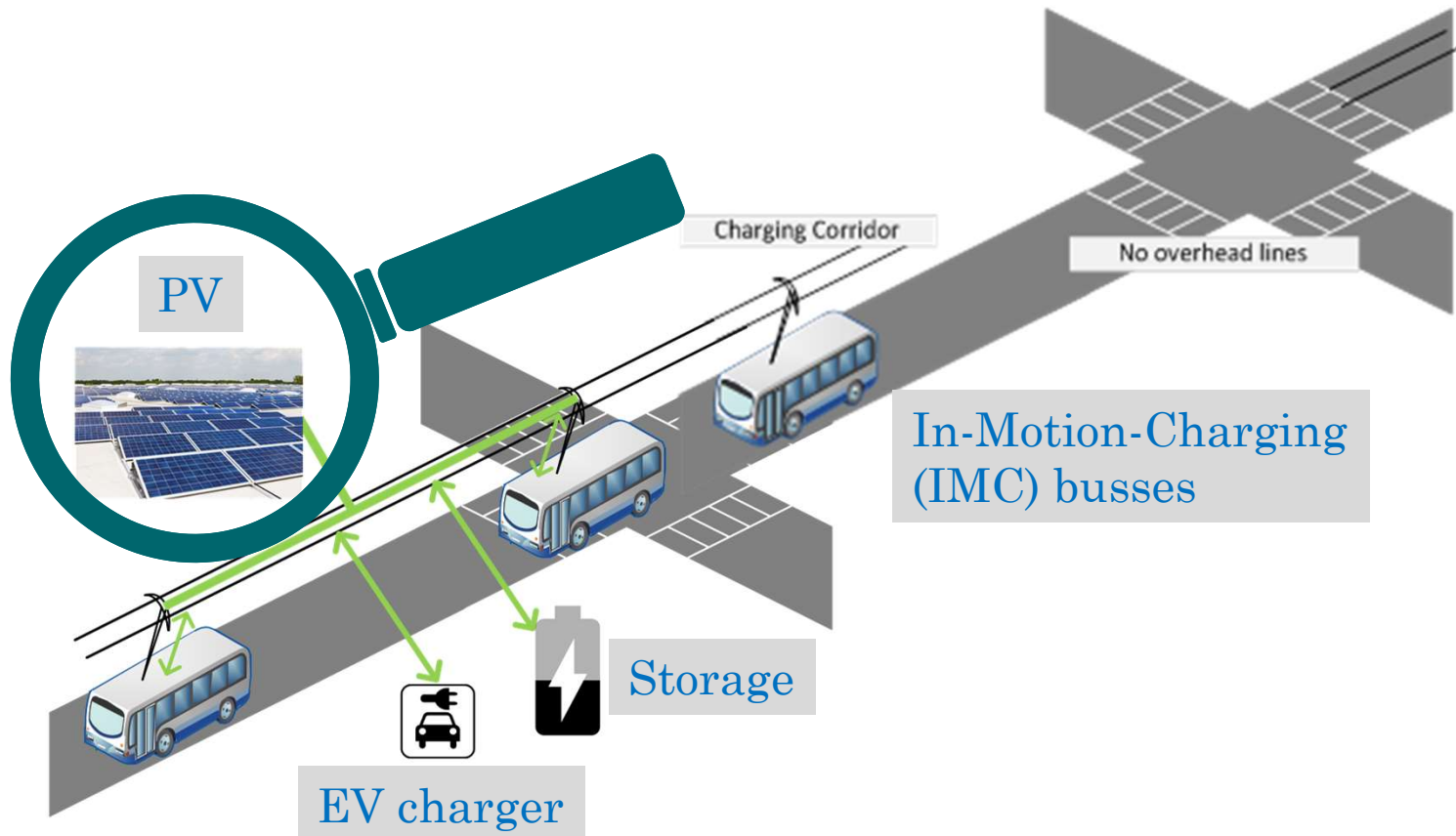
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PV Goal

- Make the grid 100% sustainable (**energy neutral**)
- Design a **decentralized** generation system
- Minimize use of (seasonal) **storage or the AC Grid**

Energy neutral:
$$\sum_t^{t=ye} P_{PV}(t) = \sum_t^{t=year} P_{bus}(t)$$

PV Integration Direction

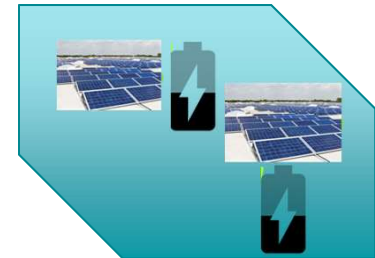
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PV(kW):100% Energy Neutral

Substation 1	129	Substation 11	331
Substation 2	265	Substation 12	224
Substation 3	1003	Substation 13	428
Substation 4	599	Substation 14	650
Substation 5	247	Substation 15	485
Substation 6	(SS 3)	Substation 16	240
Substation 7	99	Substation 17	174
Substation 8	271	Substation 18	83
Substation 9	(SS 4)	Substation 19	78
Substation 10	130	Substation 20	166

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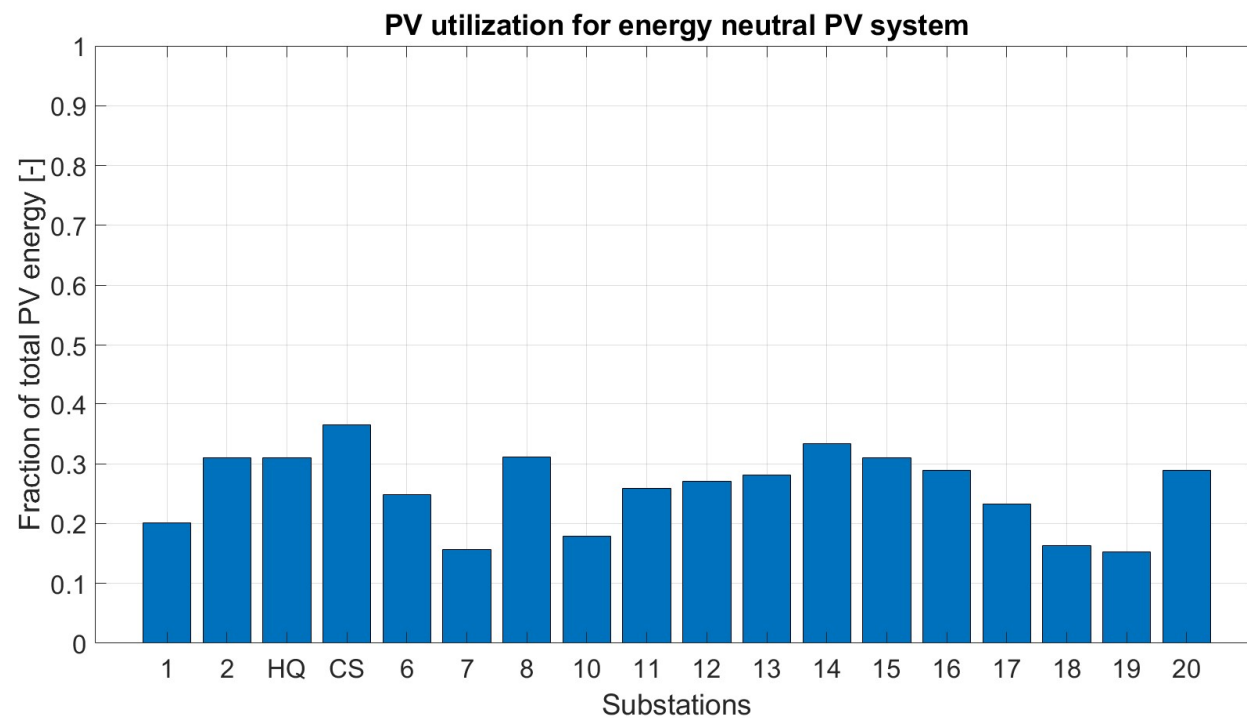
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Problem: PV Dump into AC Grid



One Reason: Traffic

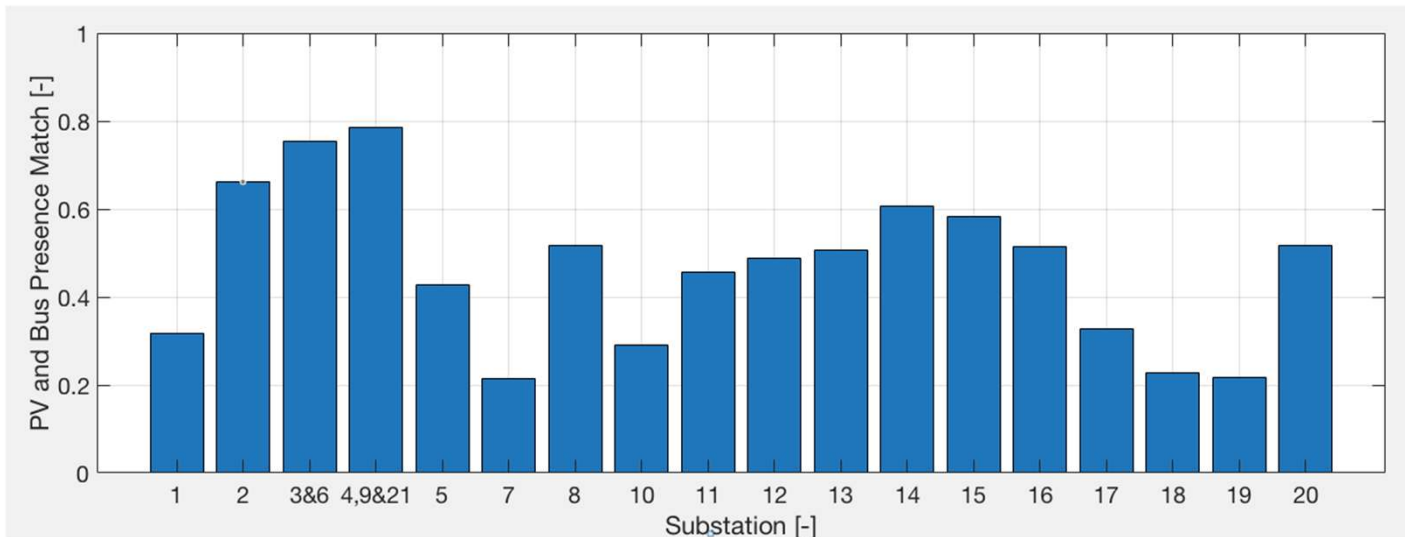
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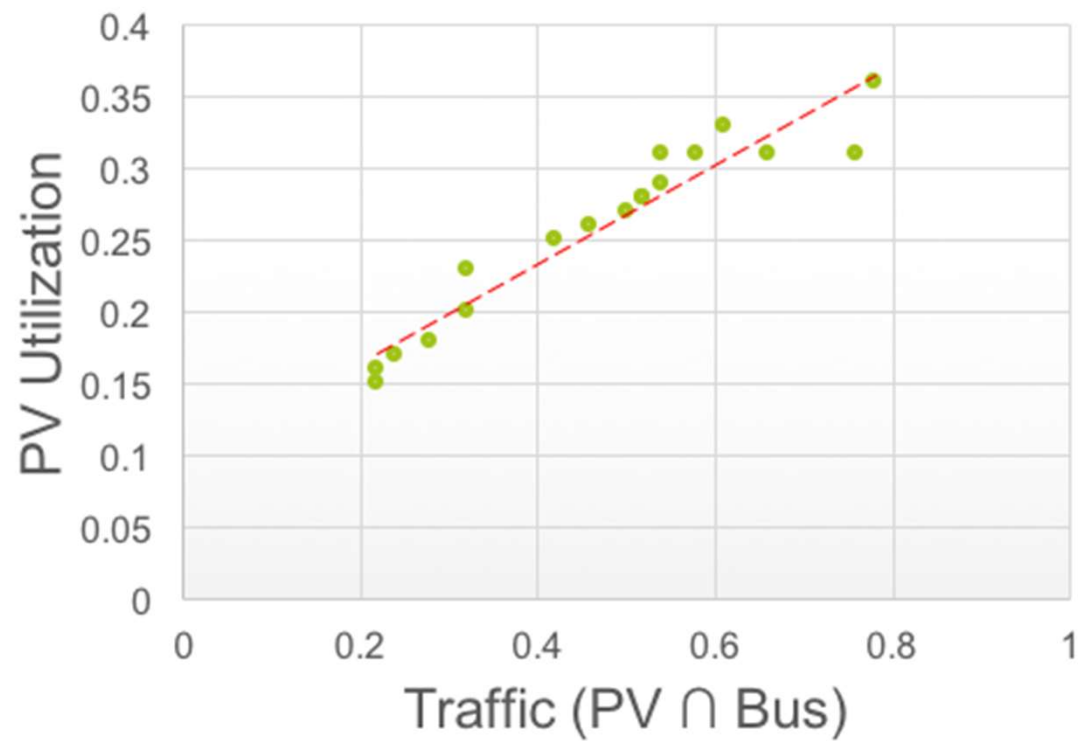
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Traffic and PV Utilization



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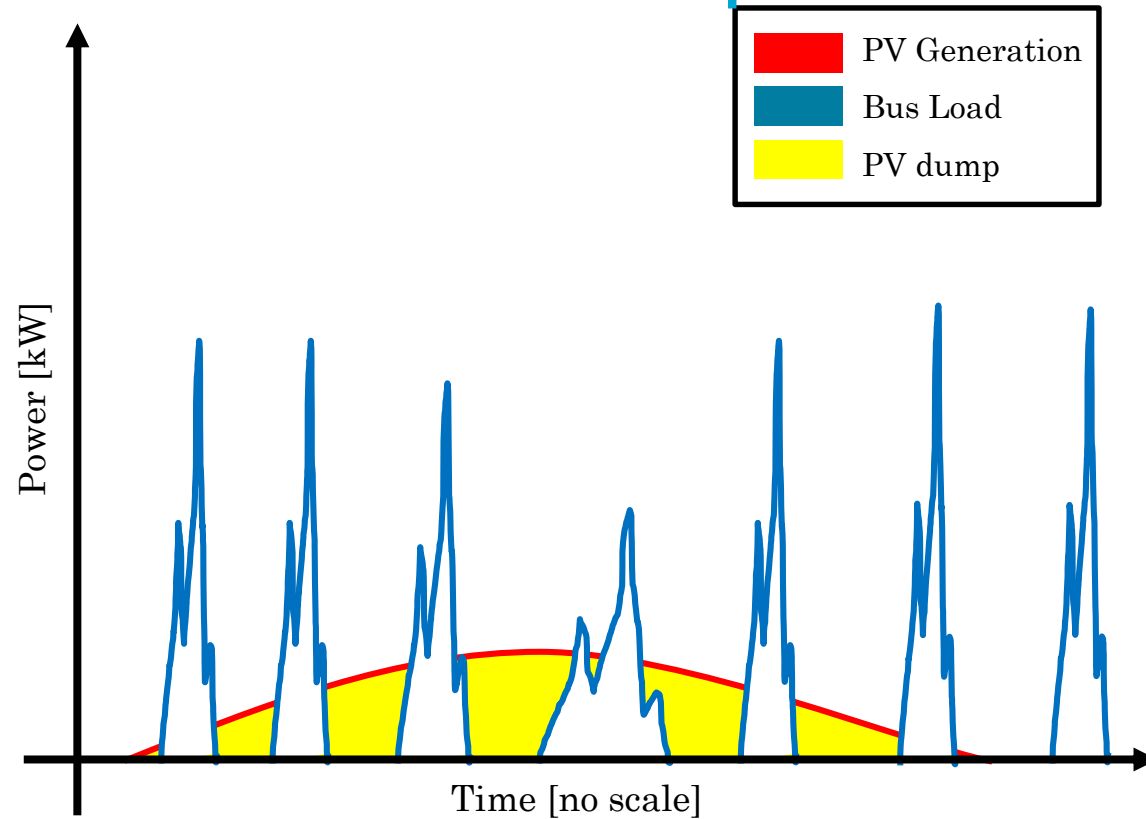
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Traffic Issue - Explained



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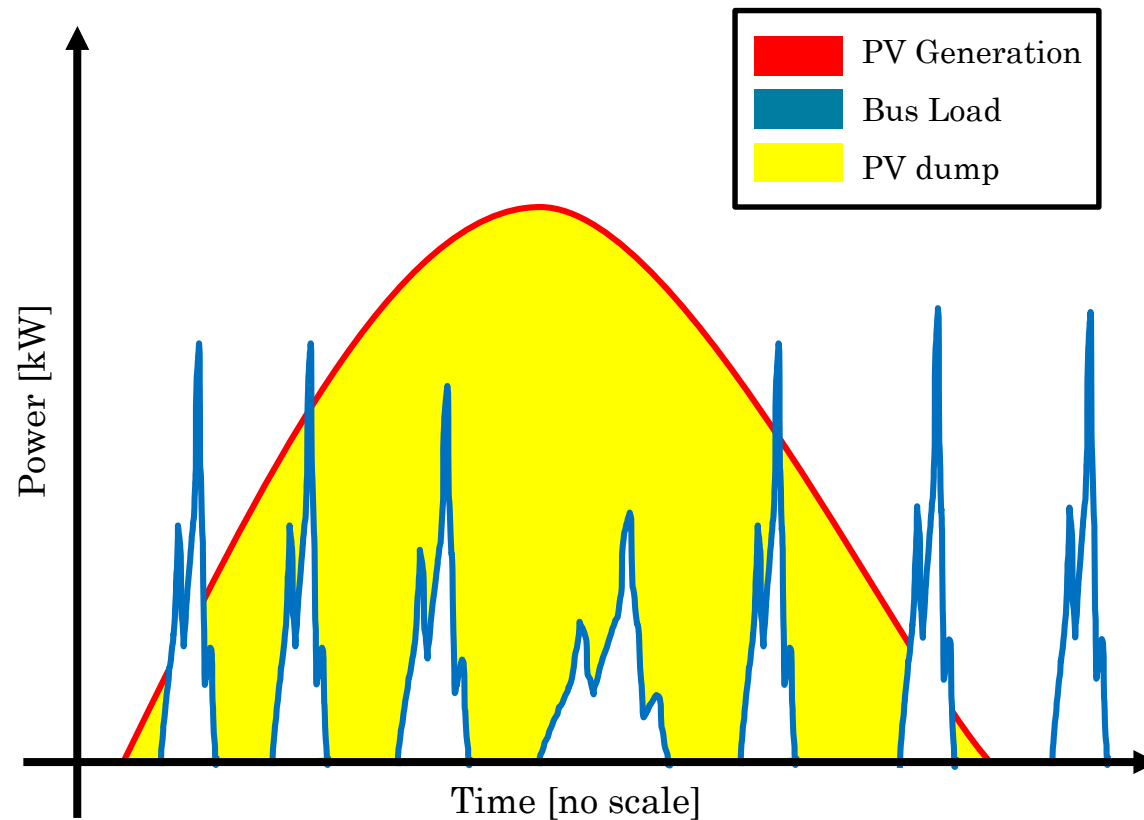
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Traffic Issue - Explained



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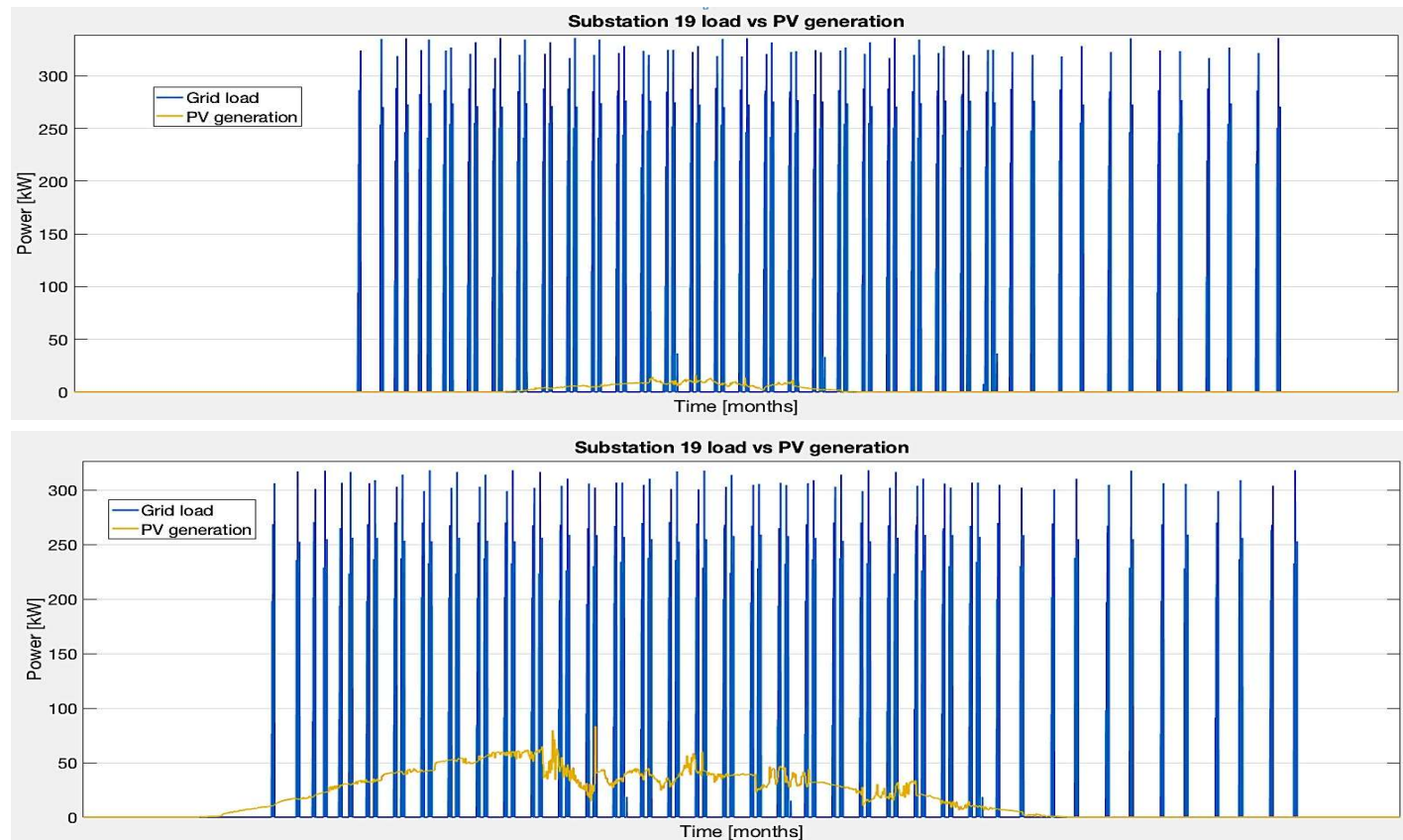
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Zoom in: Substation 19 (Model)



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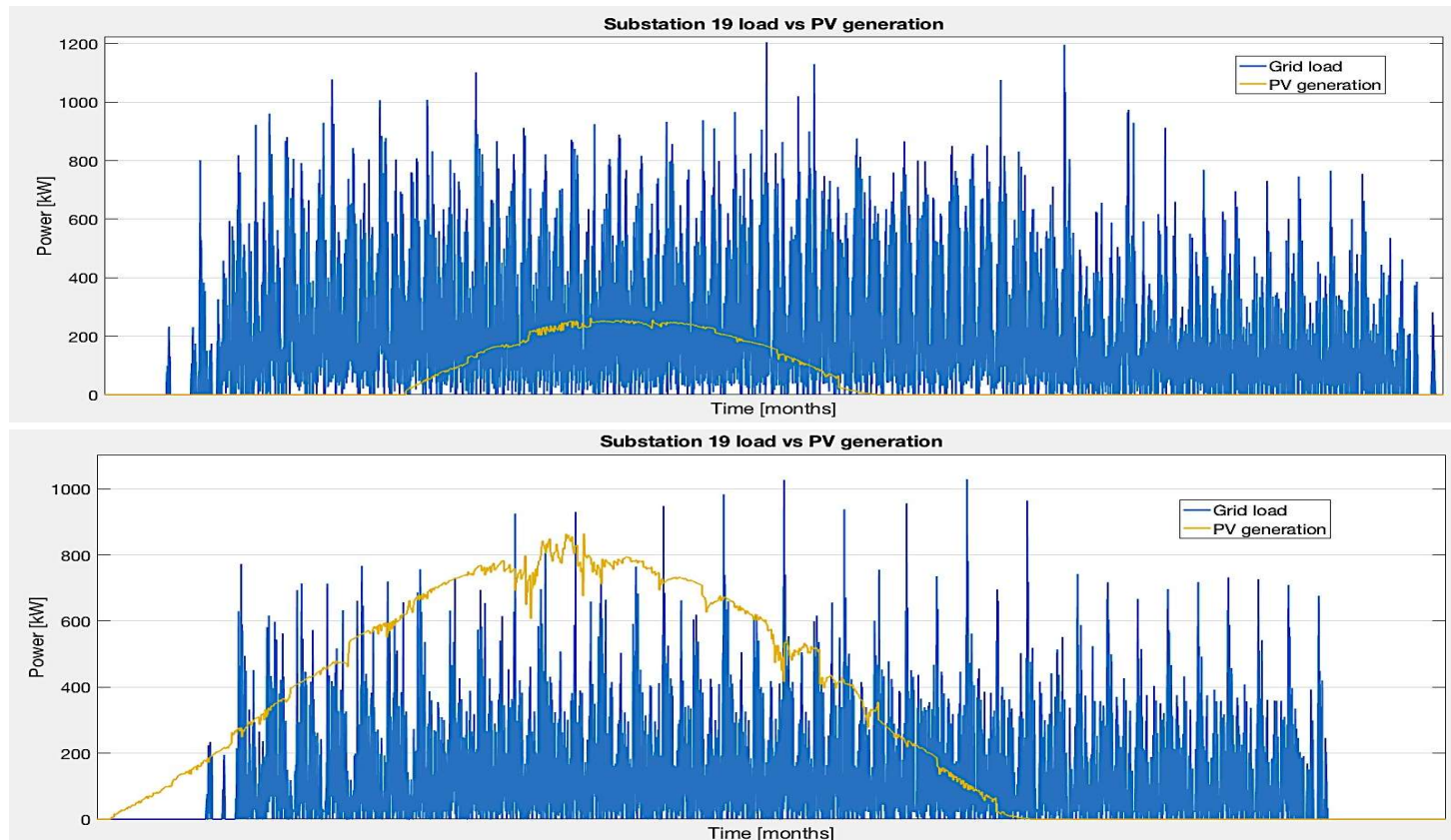
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Zoom in: Substation 4 (Model)



PV Integration Direction

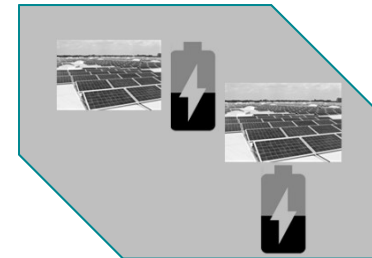
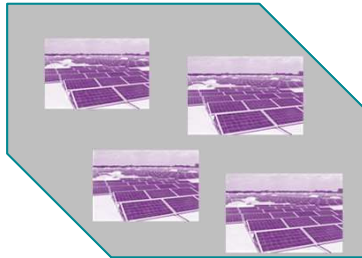
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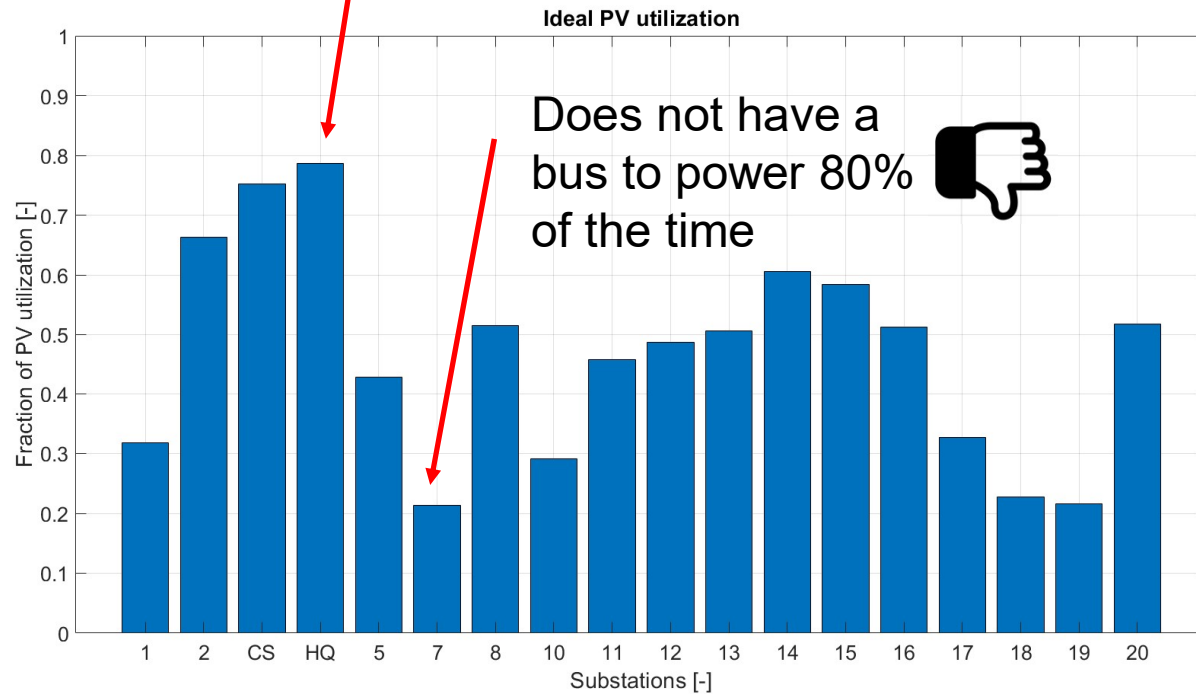


Traffic

Does have a bus
to power 80% of
the time



Does not have a
bus to power 80%
of the time



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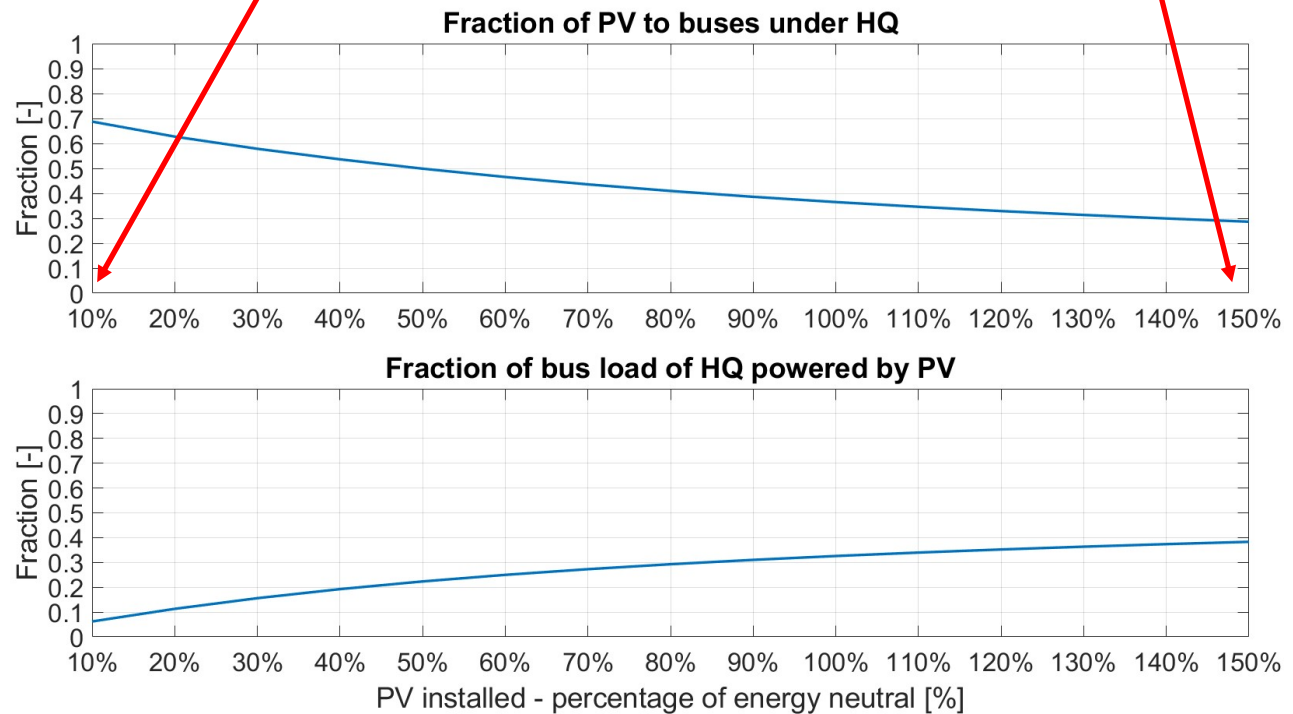
PV size



70% of PV to buses
5% of bus demand
with PV



30% of PV to buses
30% of bus demand
with PV



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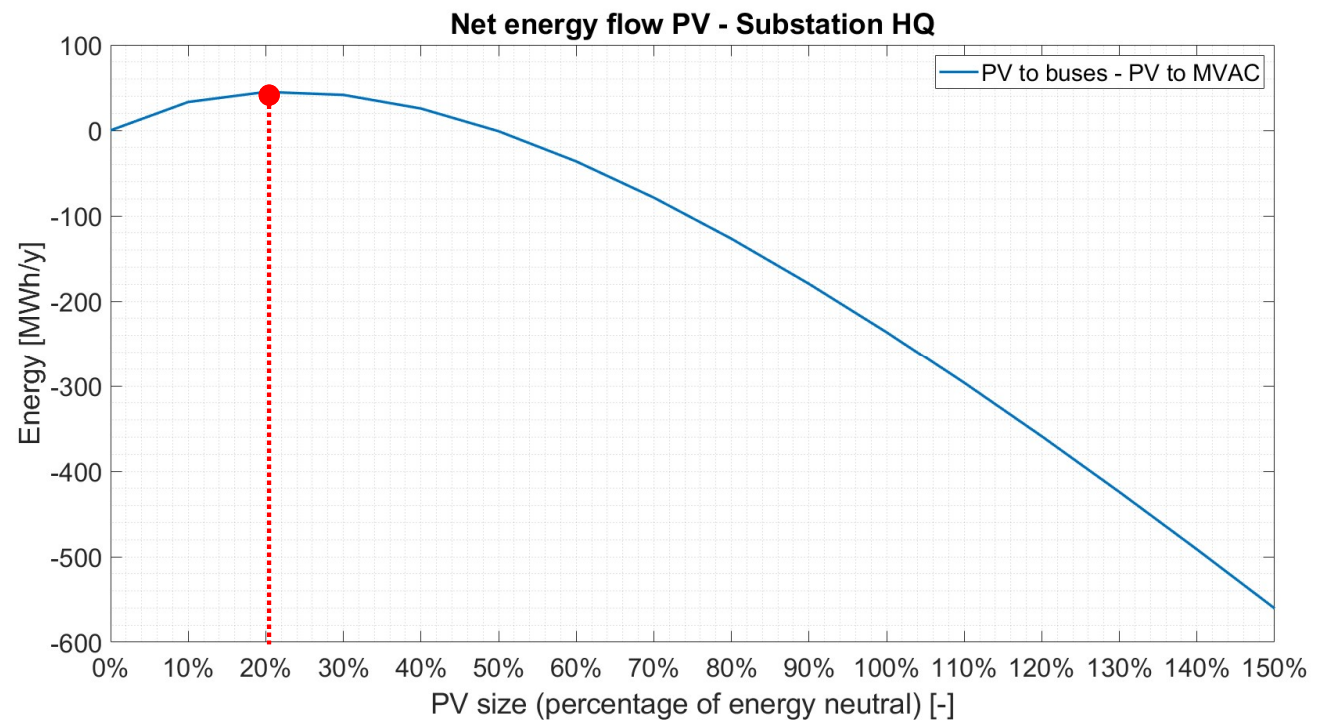
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PV: Maximum Benefit Point



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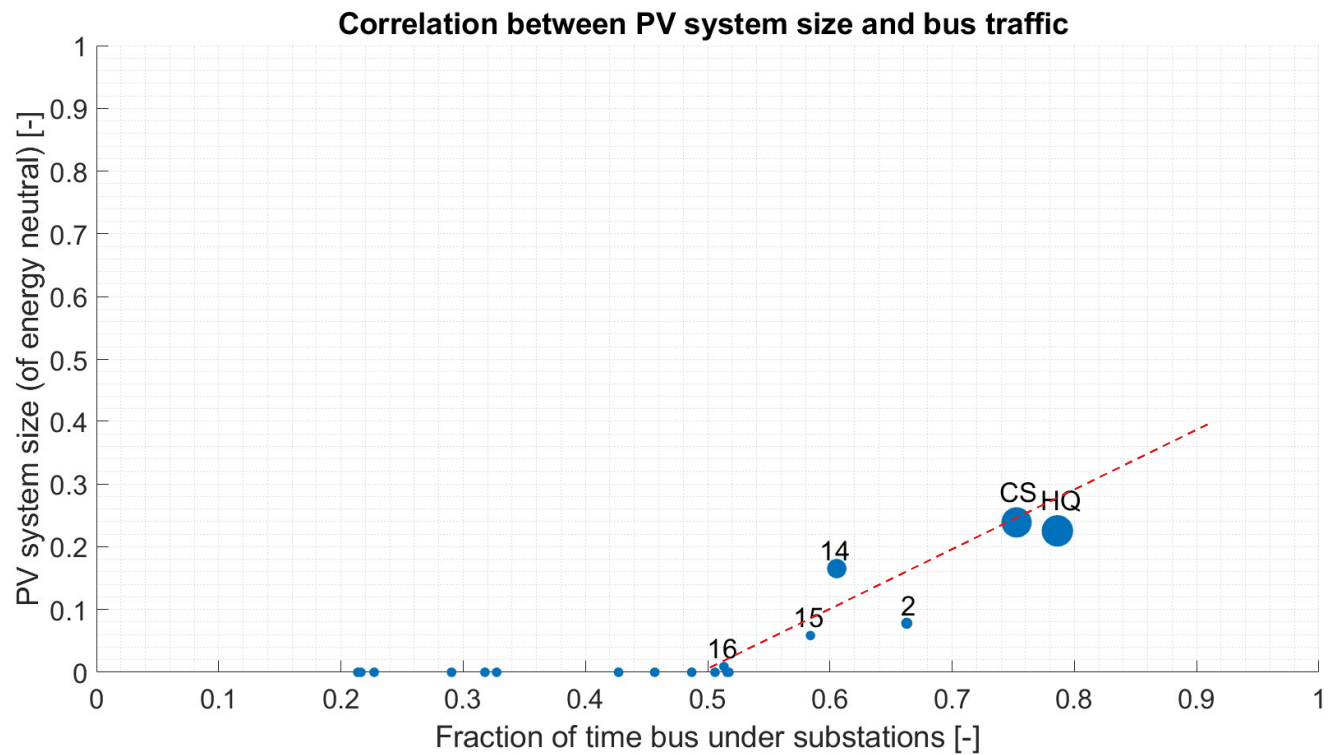
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Traffic and U_{PV} Correlation



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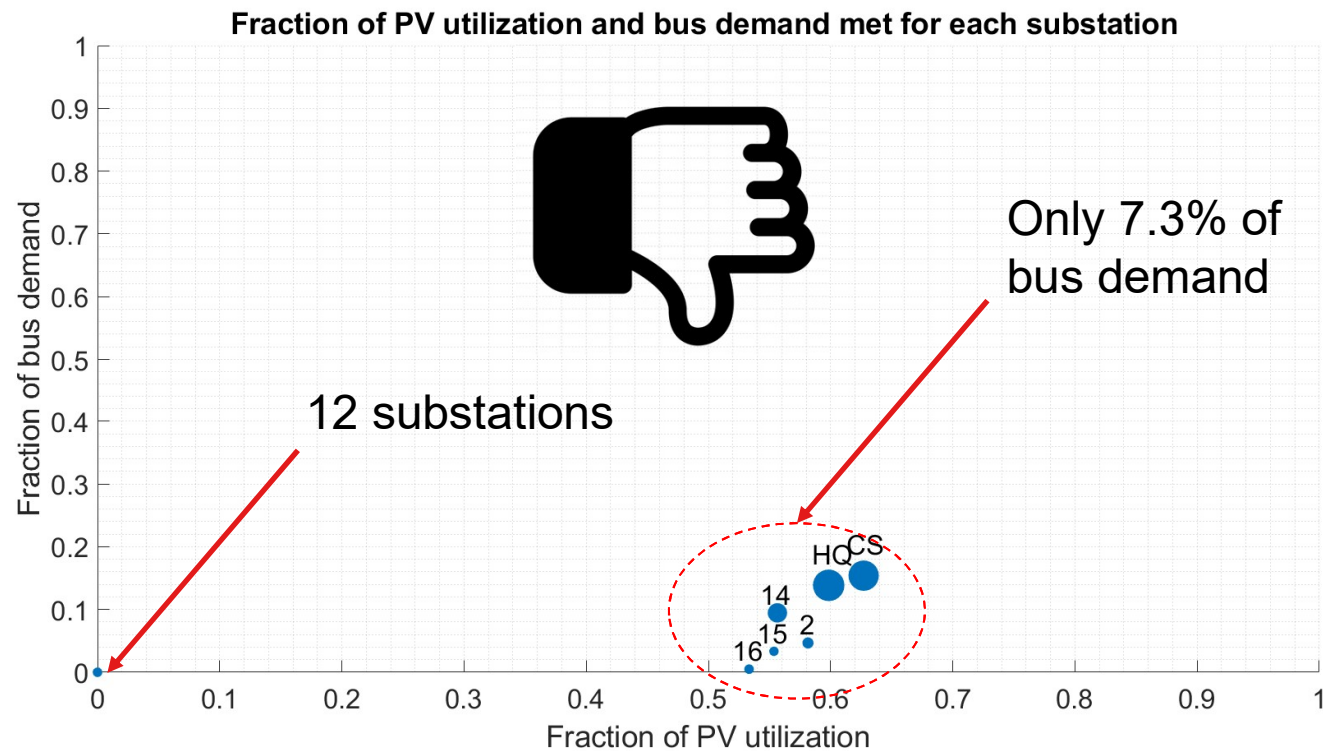
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The Problem with MSB Approach



The Grid of the Future

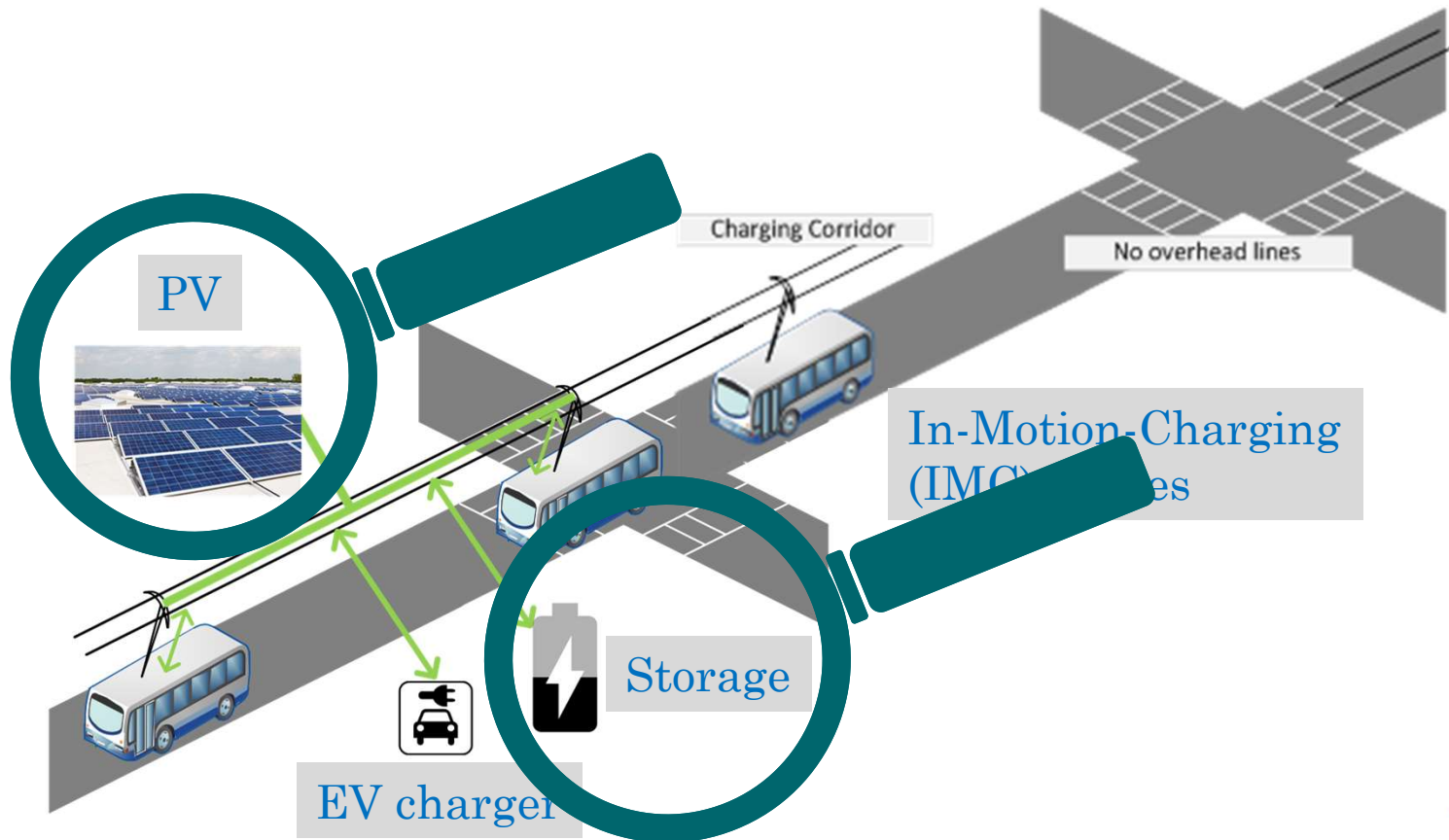
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PV Integration Direction

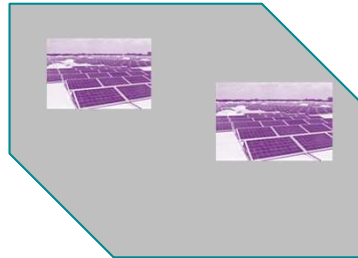
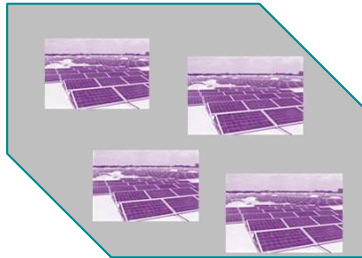
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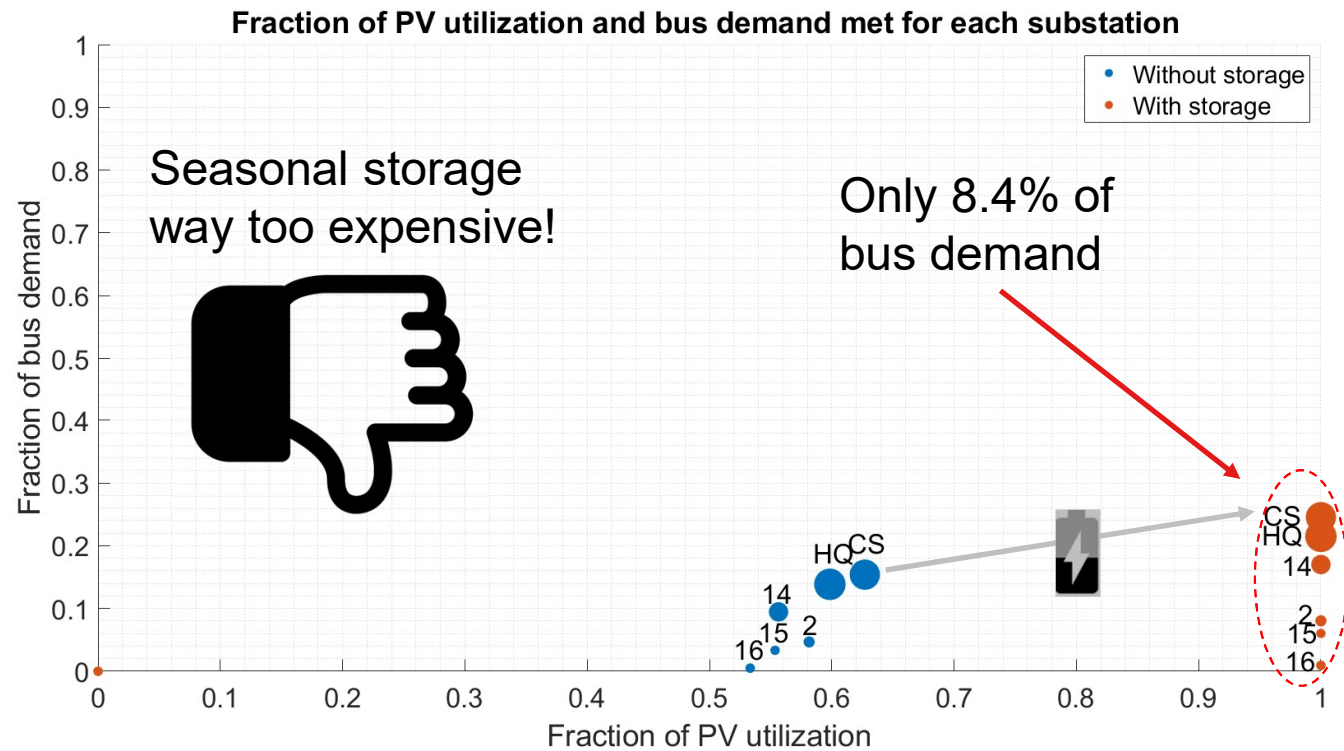
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Selective PV + Storage



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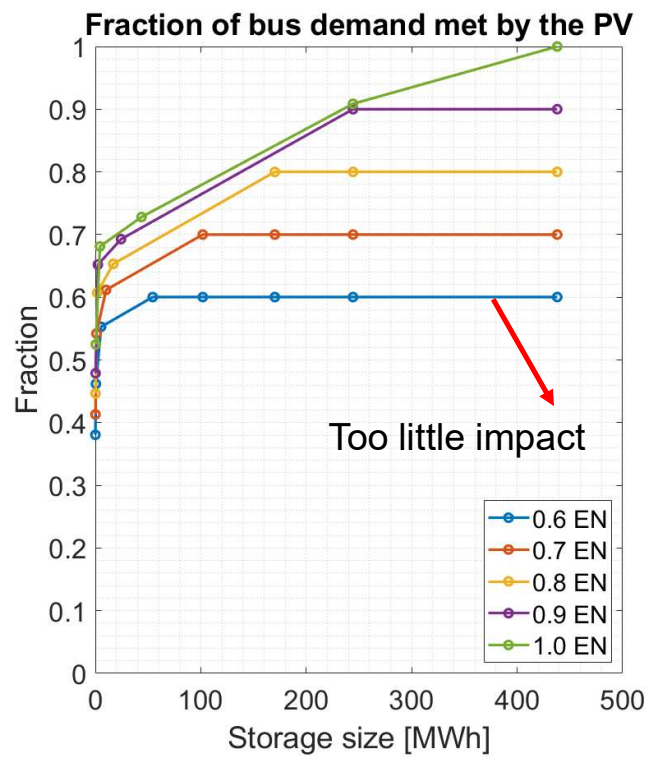
PV + Storage

Storage

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PV size

For substation CS



PV Integration Direction

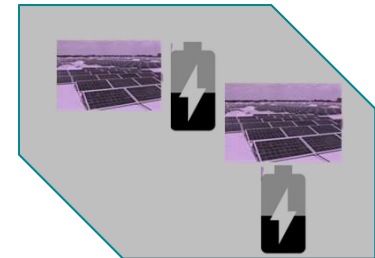
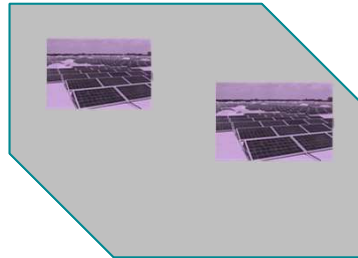
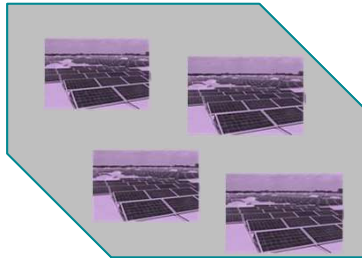
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Next Steps: Wind?

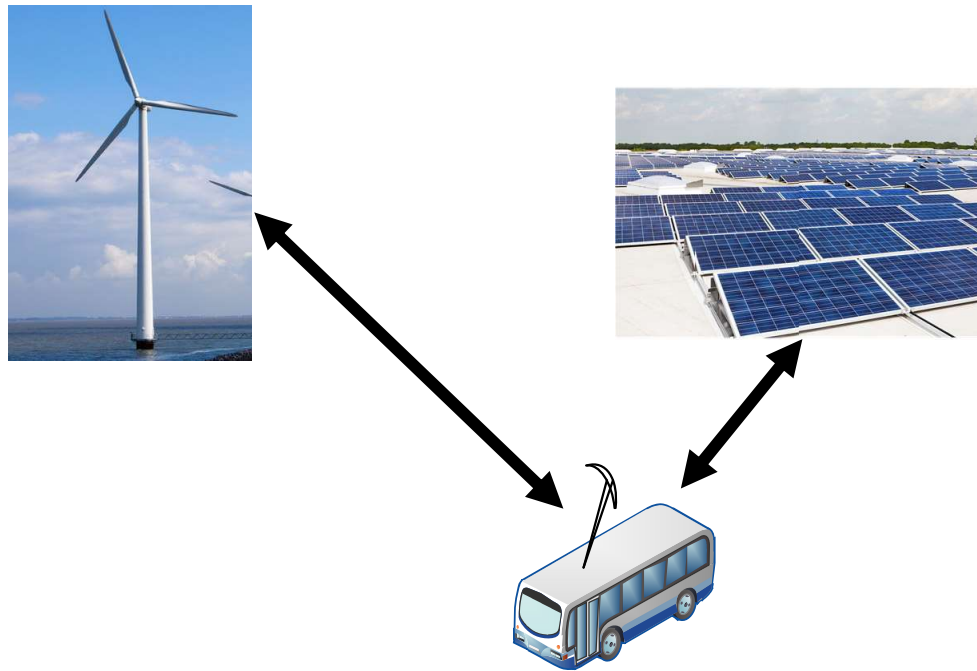
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Wind Motive: PV and Bus (Arnhem)

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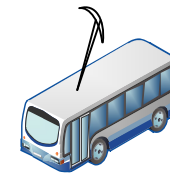
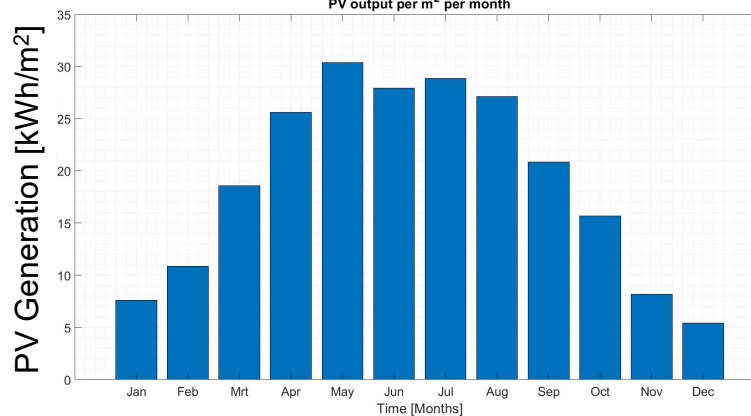
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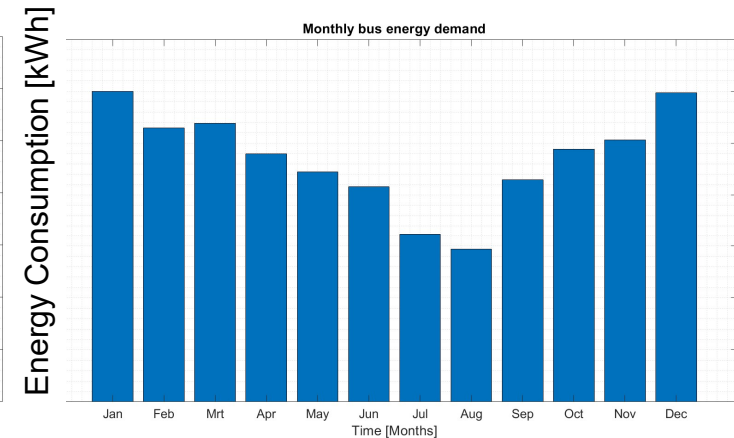
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PV output per m² per month



Monthly bus energy demand



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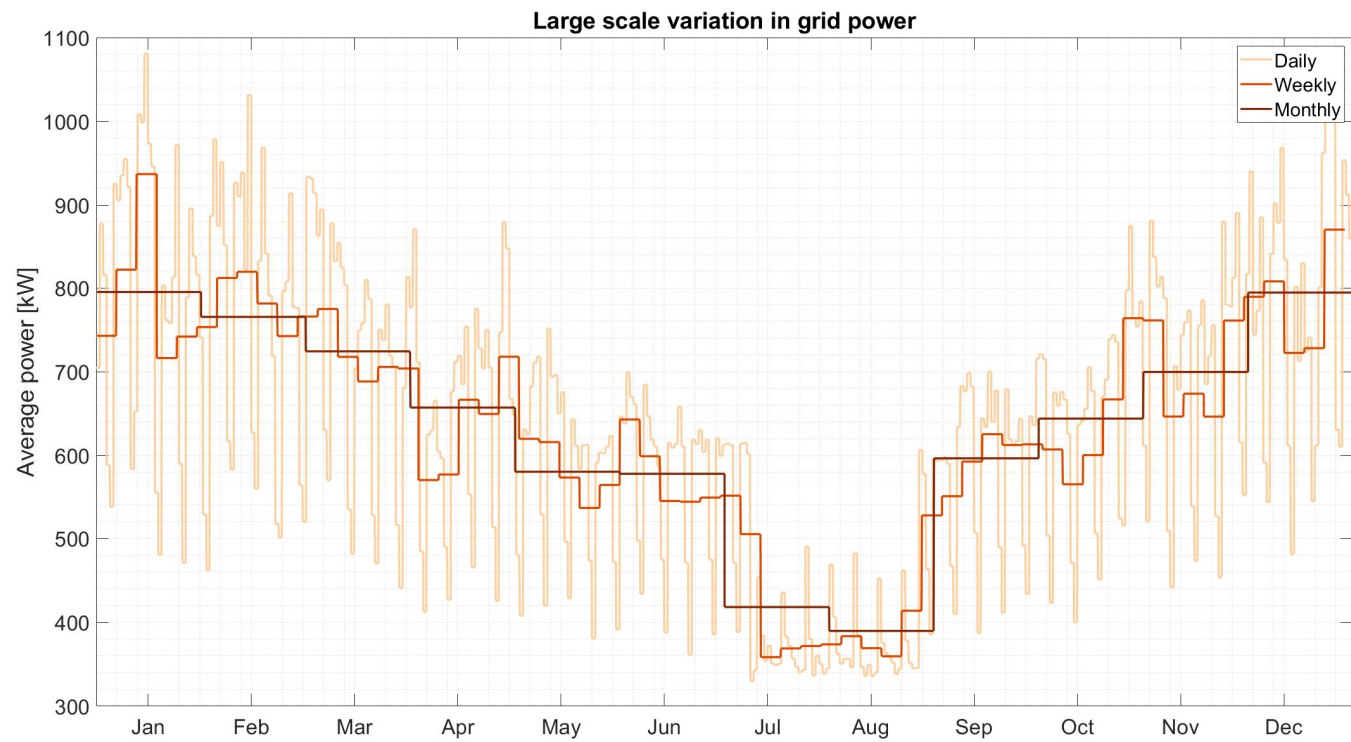
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Wind Motive: Seasonal



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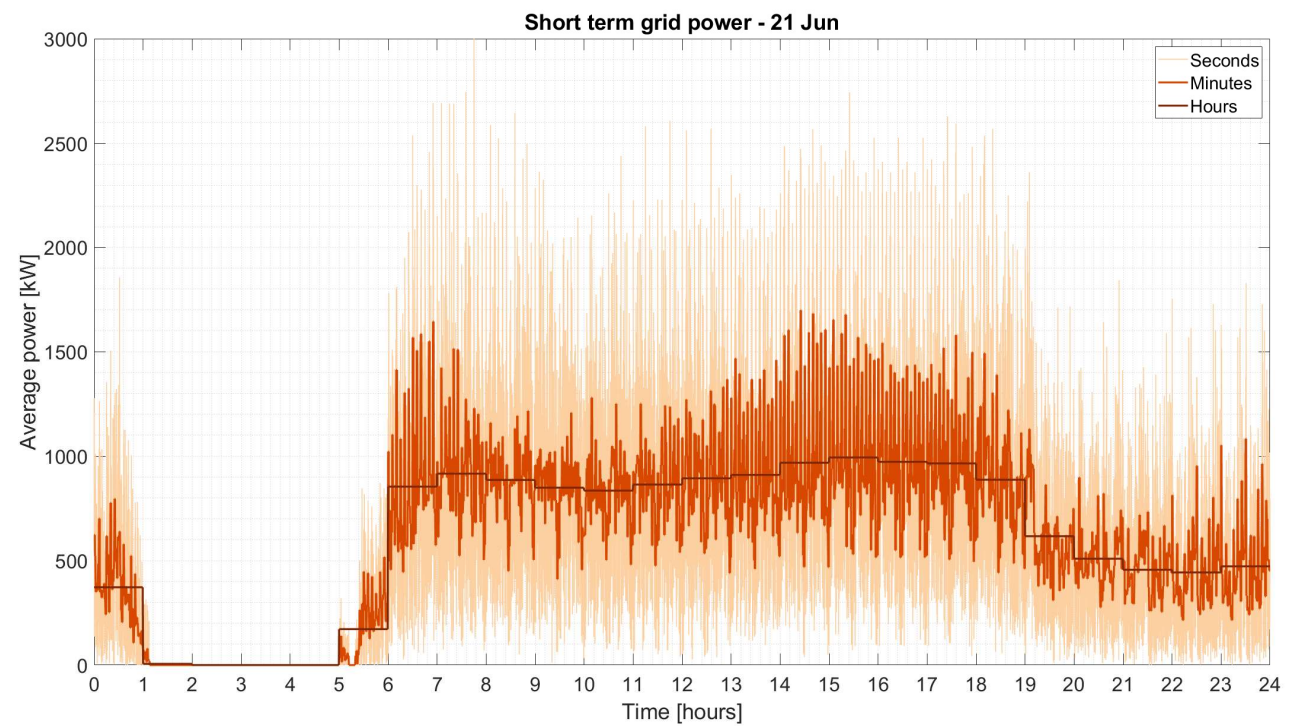
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PV motive: Daily



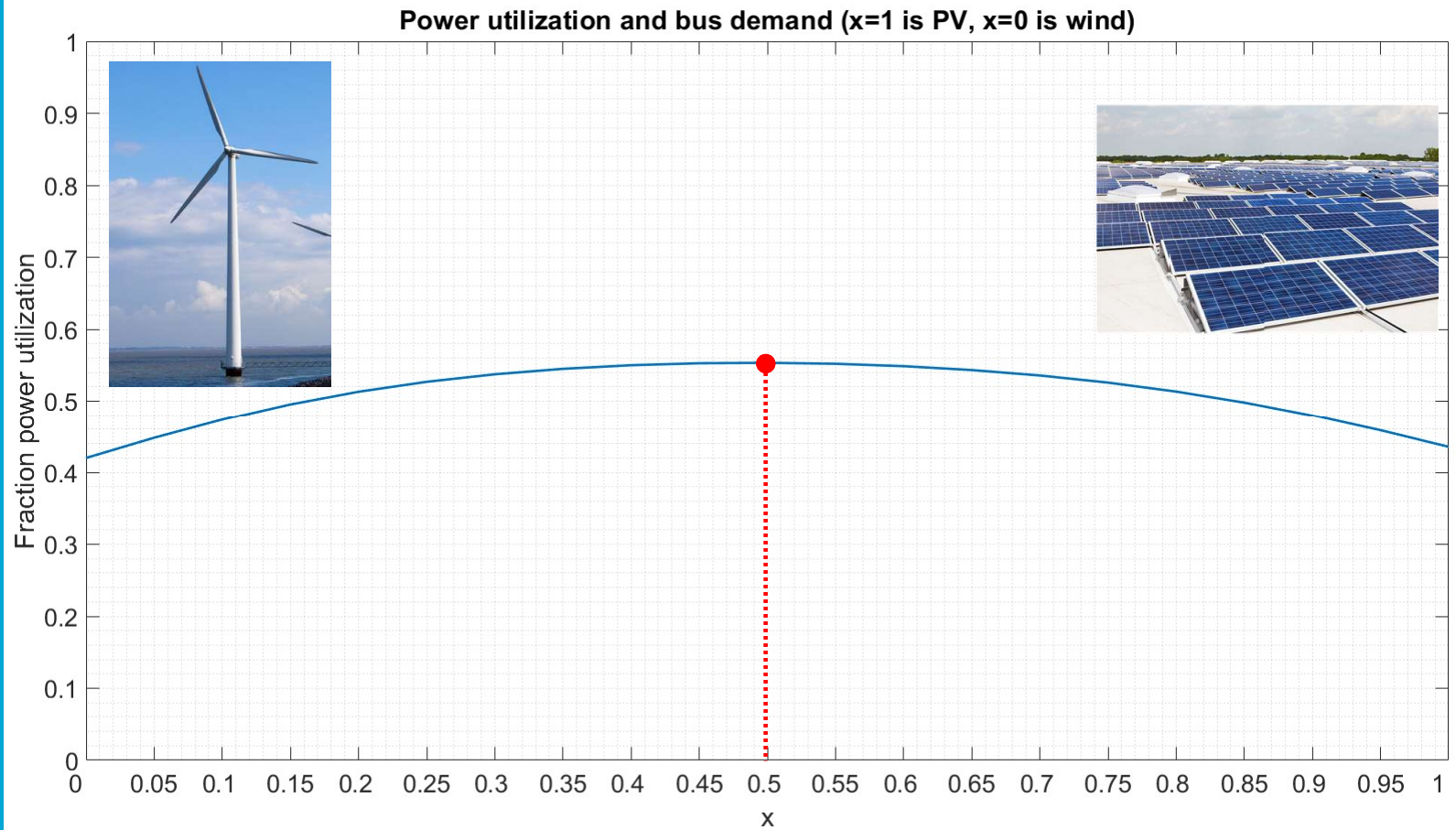
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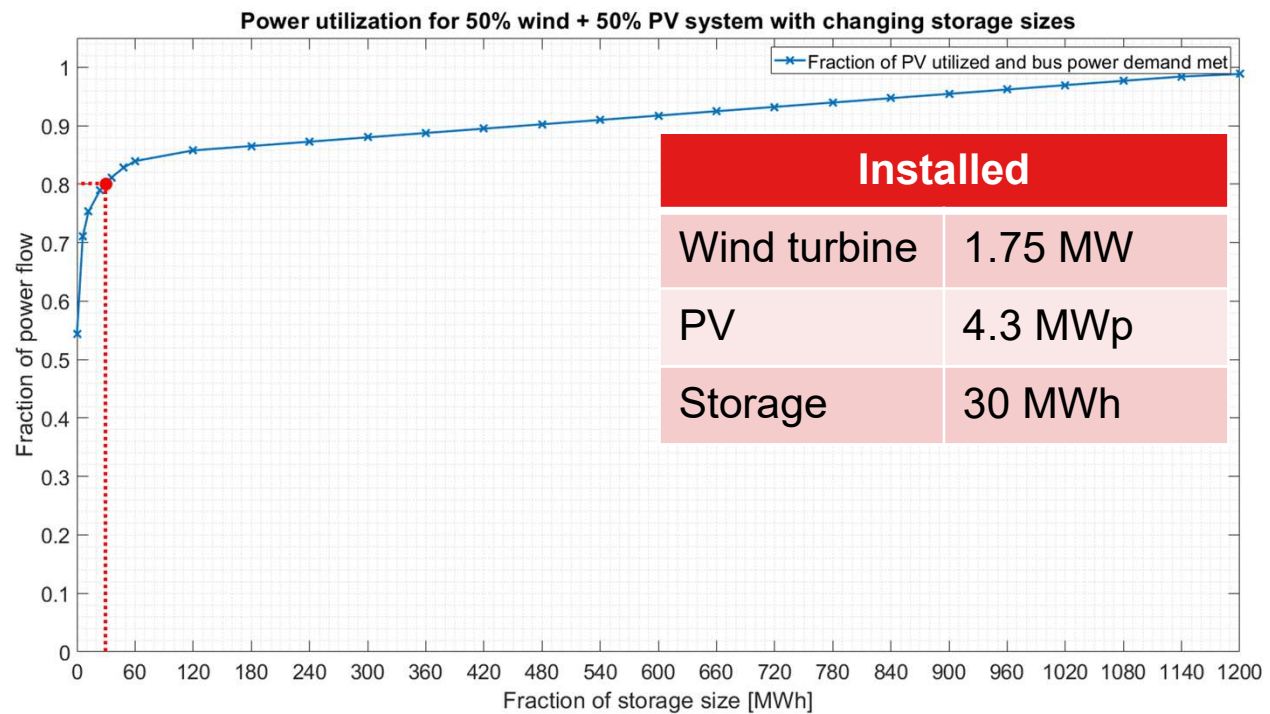
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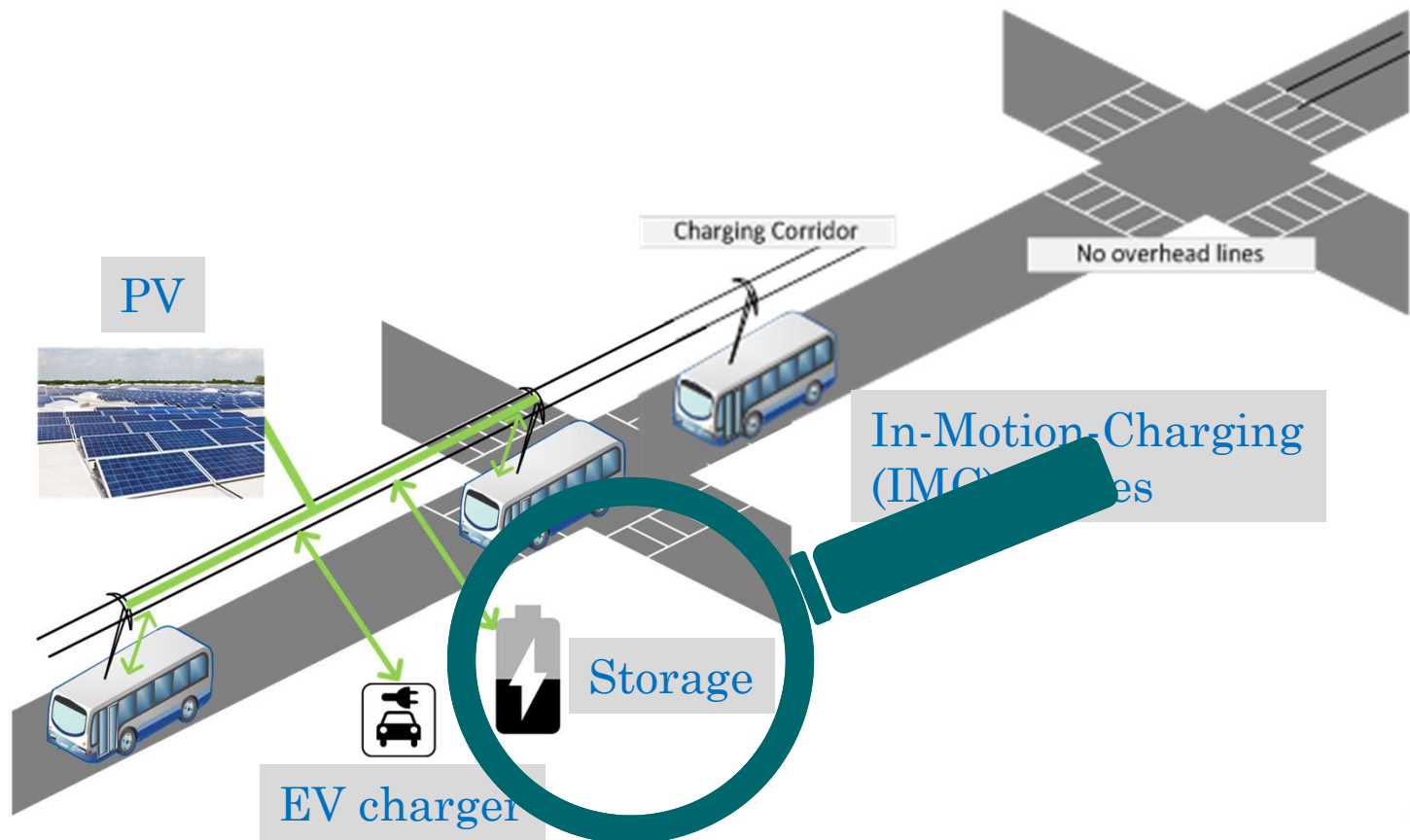
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The Grid of the Future



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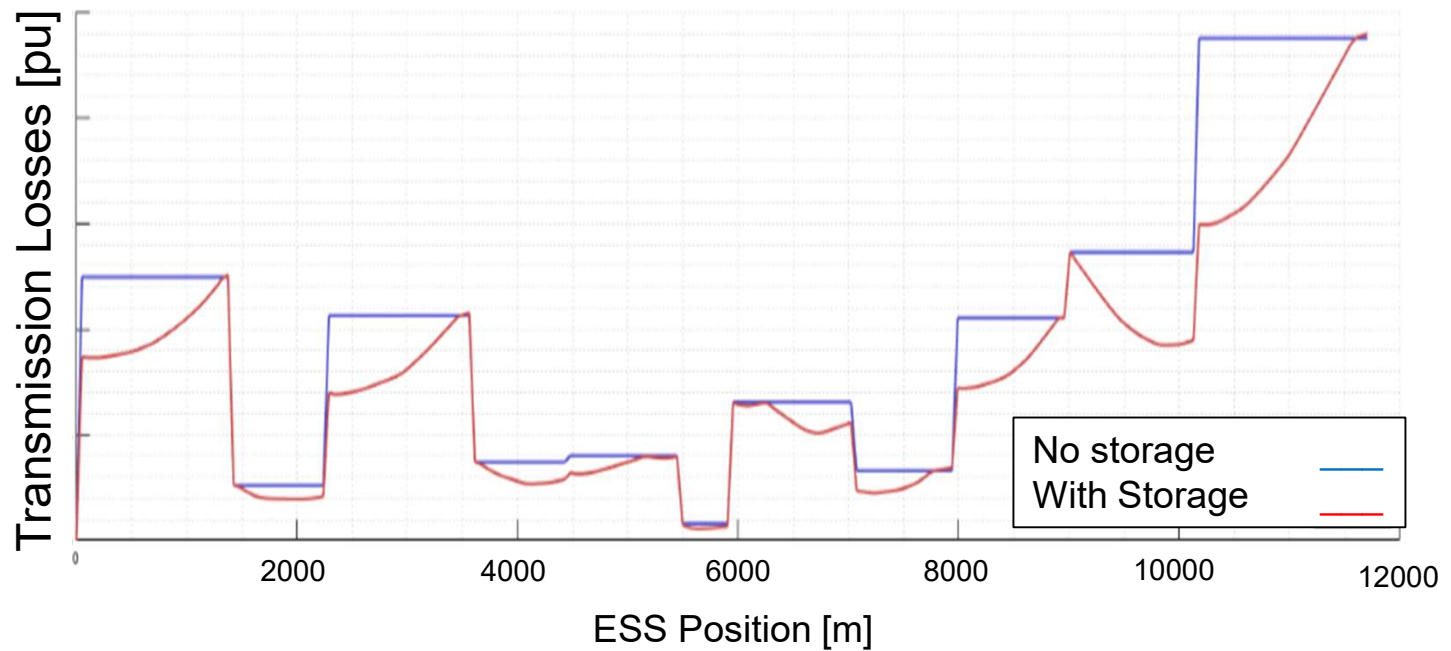
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Reduction of Transmission Losses



Reduction of Transmission Losses

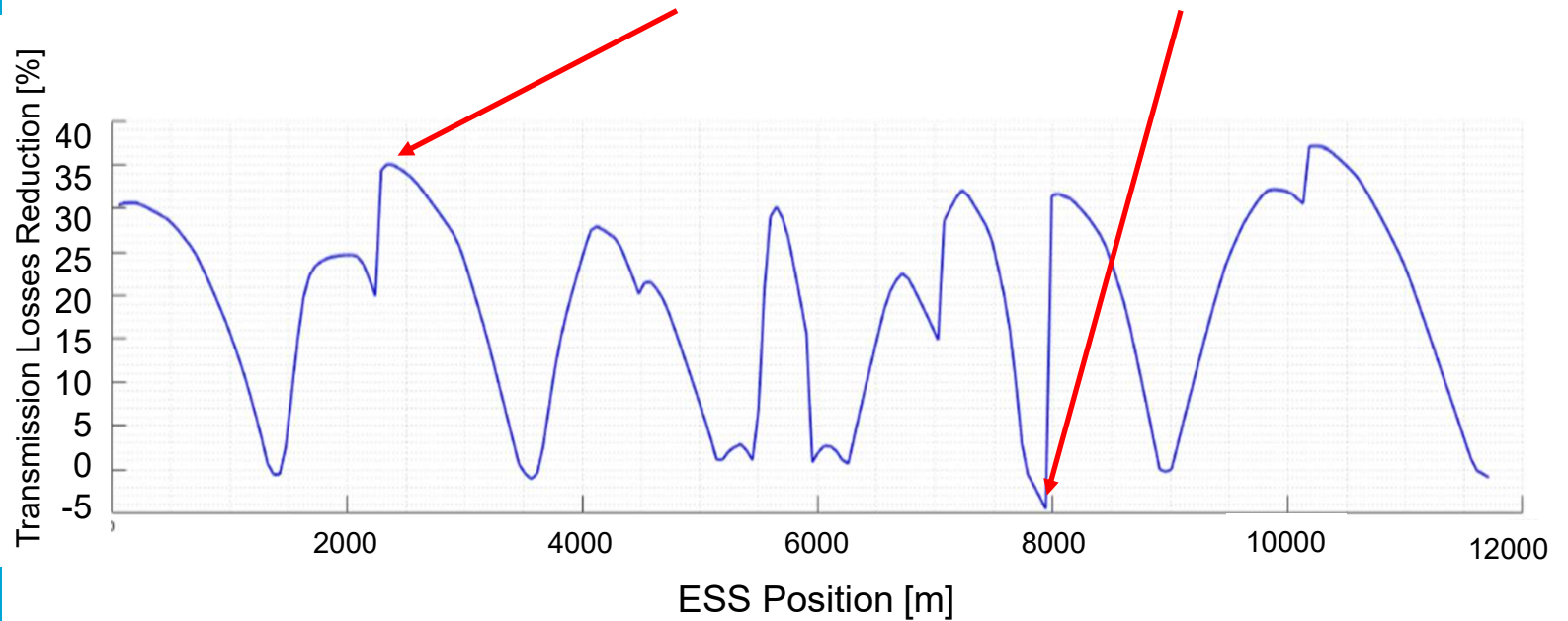
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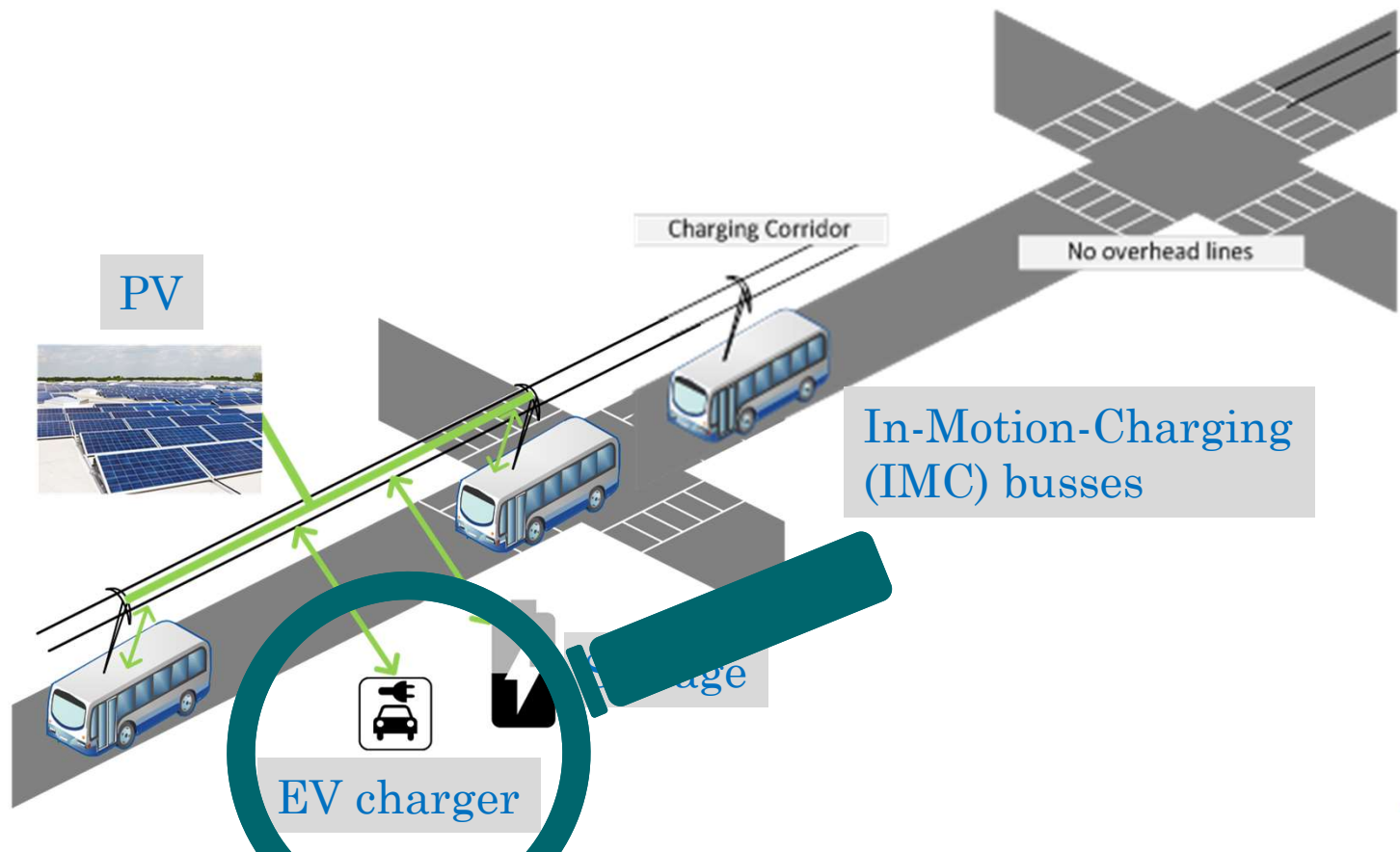
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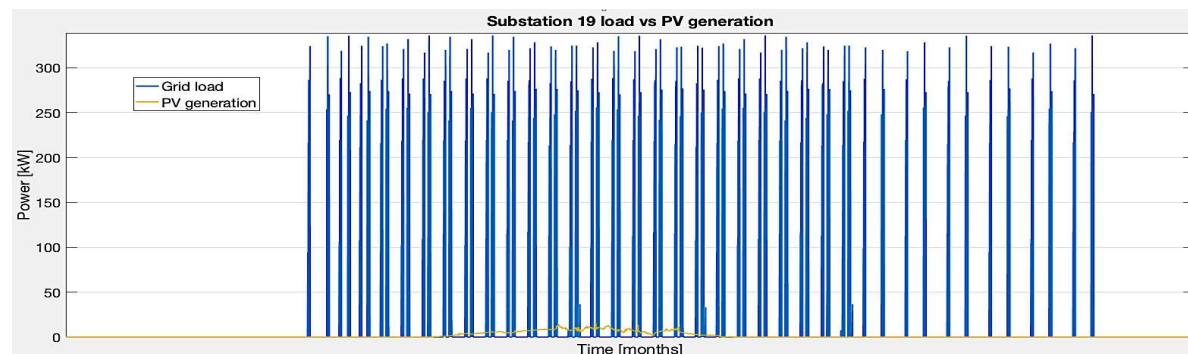
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The Grid of the Future



EV Integration

- Trolleygrids are (over-)sized for peak demand which occurs infrequently
- Bidirectional EV Chargers can be active players in the trolleygrid



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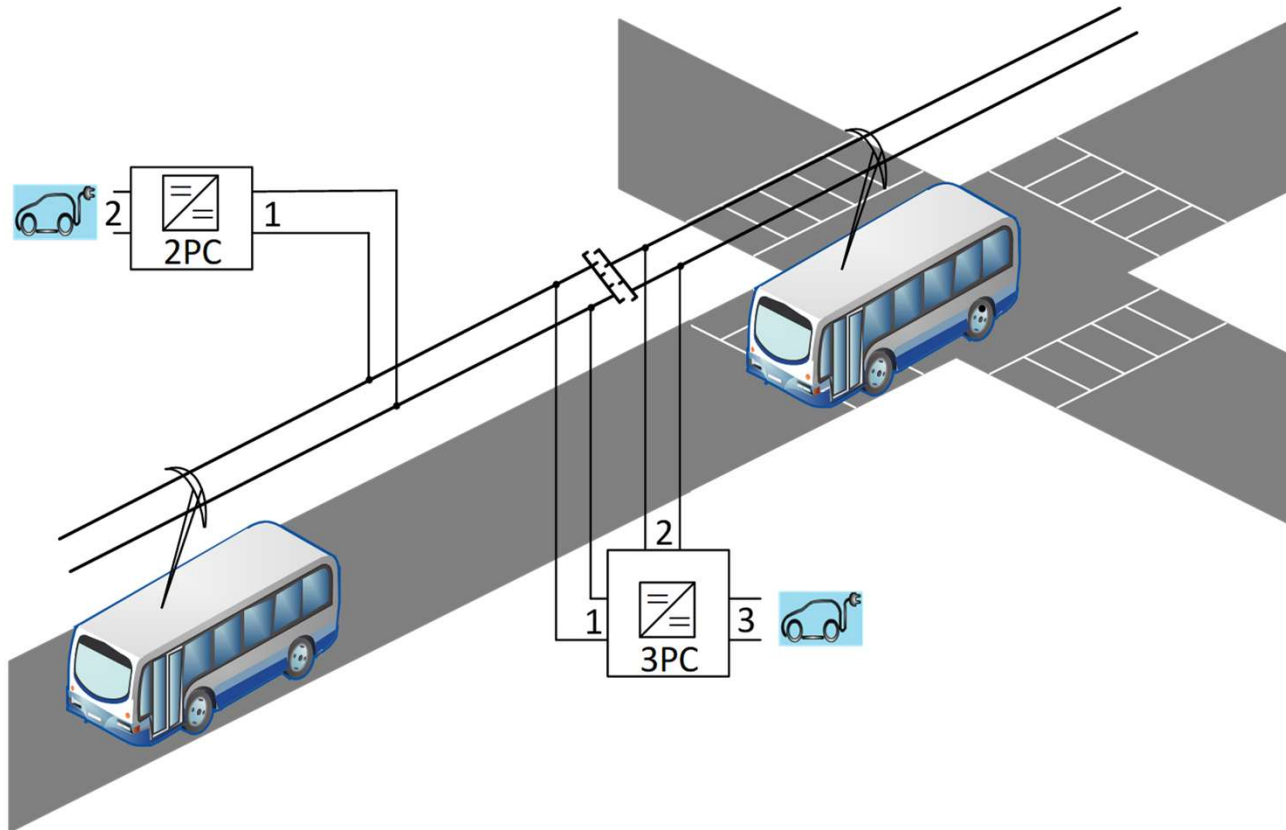
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EVCh: Method of Connection



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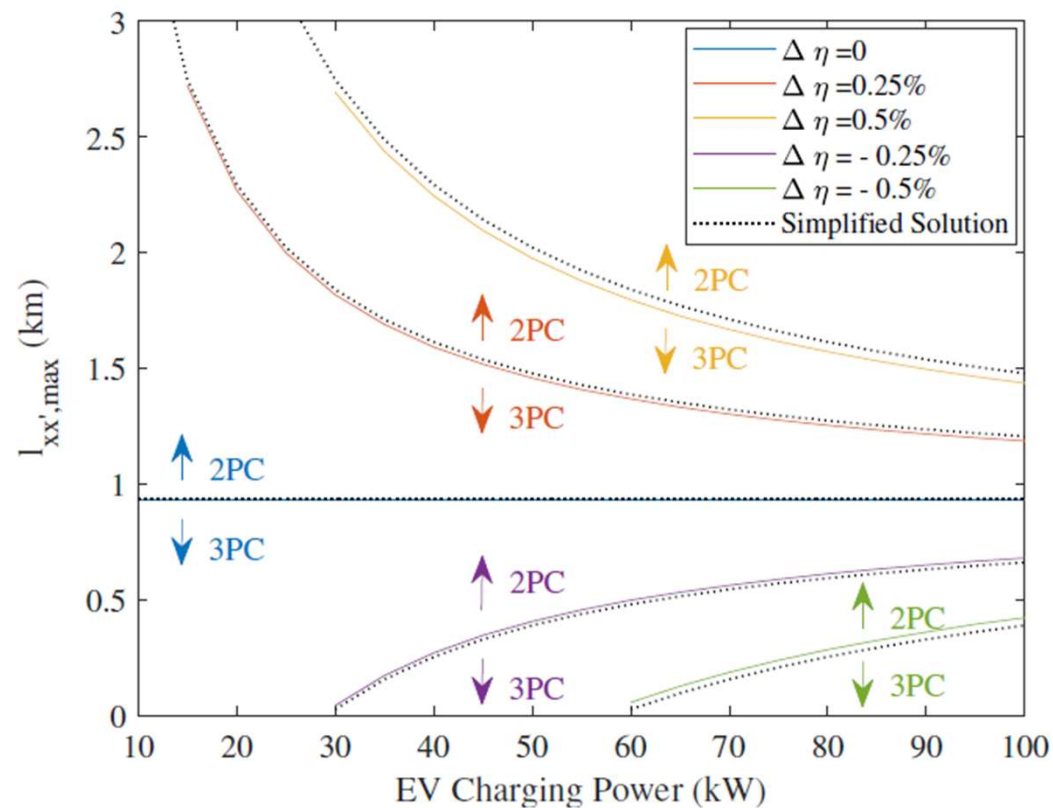
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2PC or 3PC? - First Results



Questions?

