Assessing the impacts of higher PV Penetration in the distribution network on the DSO (Distribution System Operator)

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Overview

- Motivation
- Outline of research work

  > Technical impacts

  > Economic impacts
- Conclusion and future work

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Motivation

What are the factors that may impact DSO under increase PV penetration in low voltage public distribution network?

“DSOs are not public service entity!”

Motivation

What are the factors that may impact DSO under increase PV penetration in low voltage public distribution network?

"DSOs are not non-profit entity!"

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Technical impacts

Impacts on the feeder characteristics

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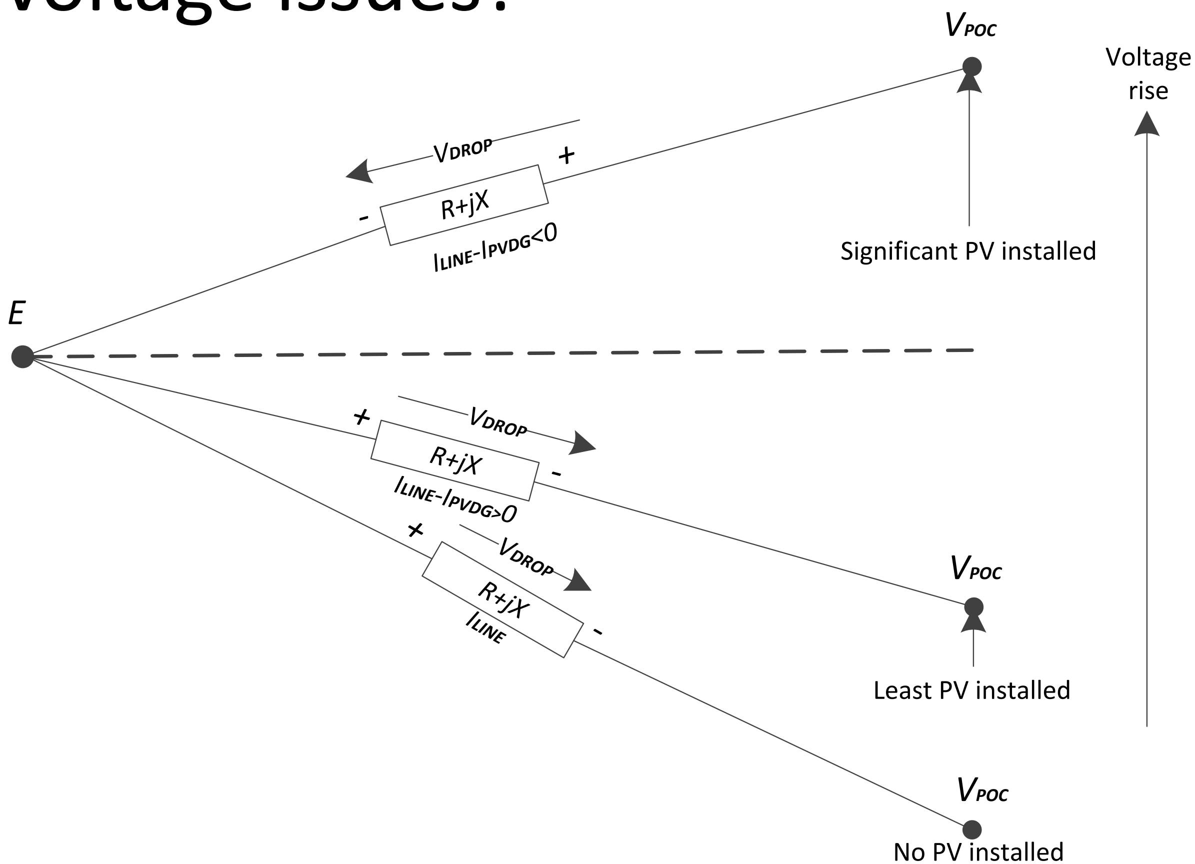
Increase PV penetration may affect in one of the following basic feeder characteristics.

1. Voltage (**over/under/unbalance**)
2. Loading (**thermal loading in transformer/ line loading-> line losses**)
3. Protection (**in-correction operation**)
4. Power quality (**dips**, **swells**, **individual harmonics**, **THD, long interrupt**)
5. Control (**mal-functioning** of control techniques of **voltage regulator**, **capacitor switch banks** etc.)

Impacts on the feeder characteristics

Over voltage issues?



Impacts on the feeder characteristics

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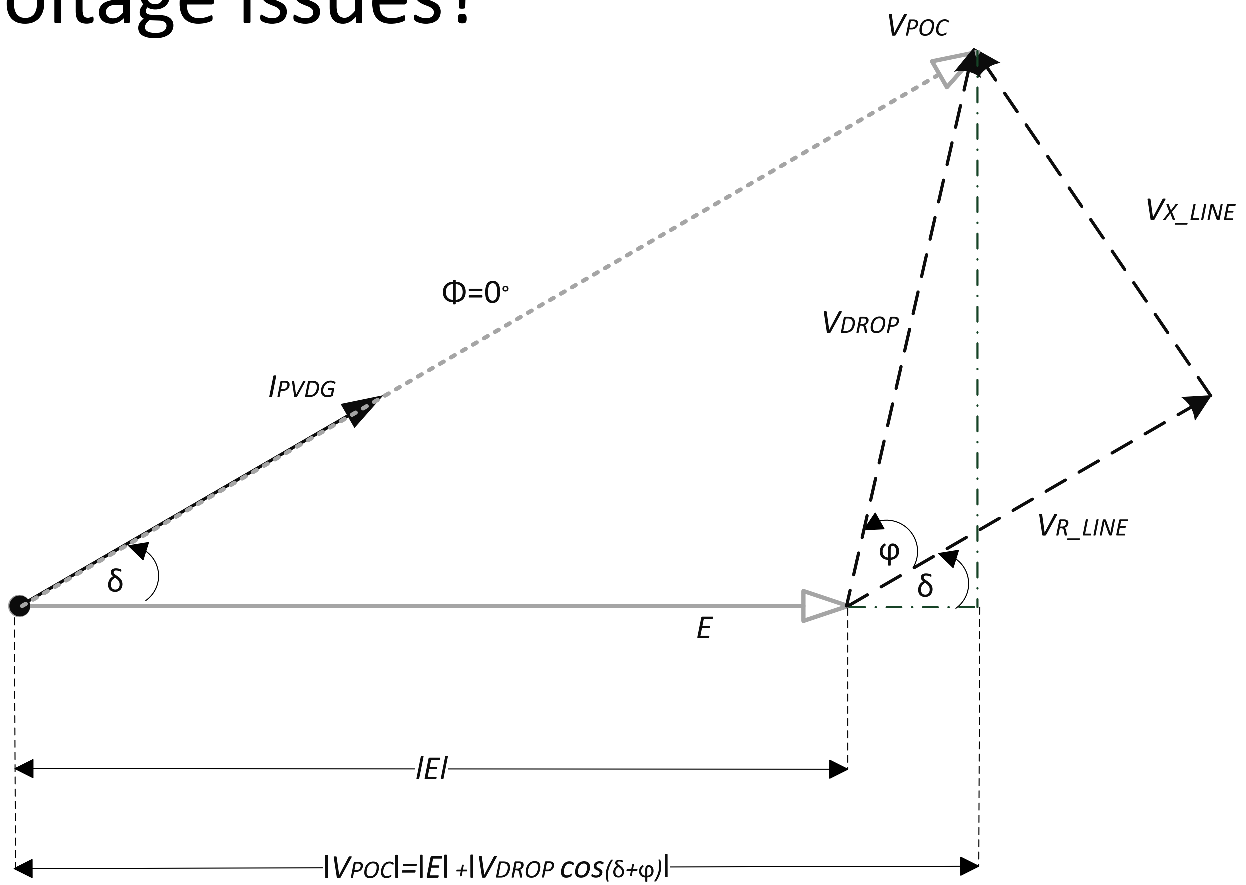

Impacts on the feeder characteristics

Over voltage issues?

Solved by optimally co-ordinating the solar inverter [1].

Able to increase the PV penetration 35.65% to 66.7% of distribution transformer.

[1] S. Pukhrem, M. Basu and M. F. Conlon, “Enhanced network voltage management techniques under the proliferation of rooftop solar PV installation in low voltage distribution network,” IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. pp, no. 99, pp. 1-1, 2016.

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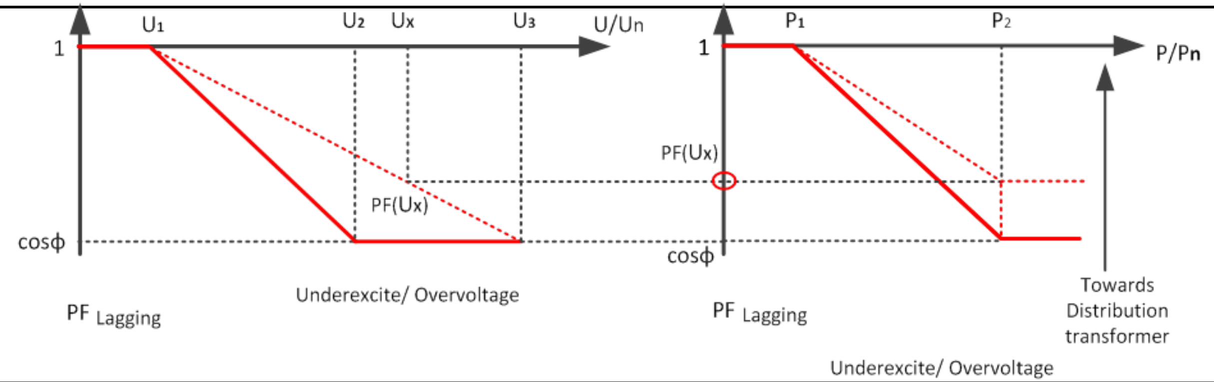
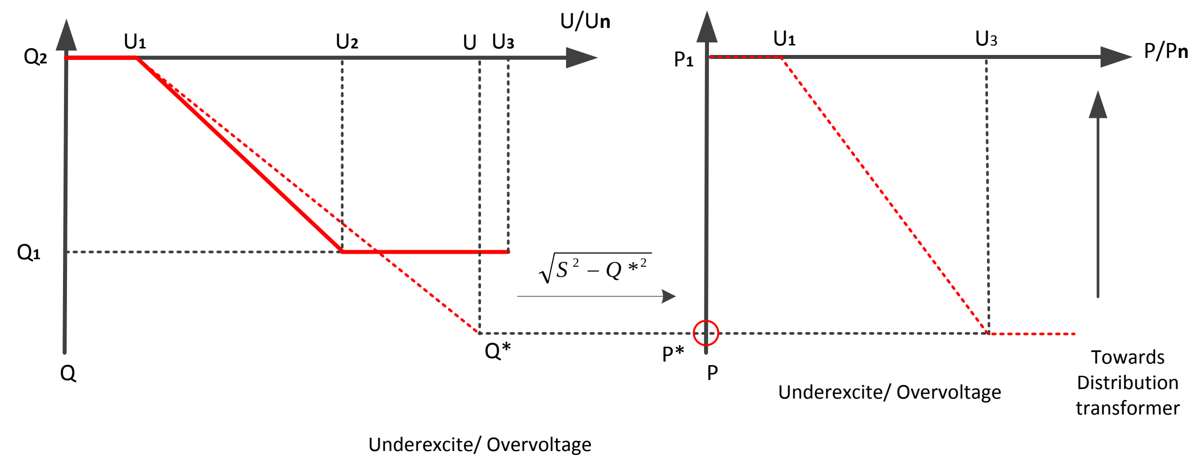
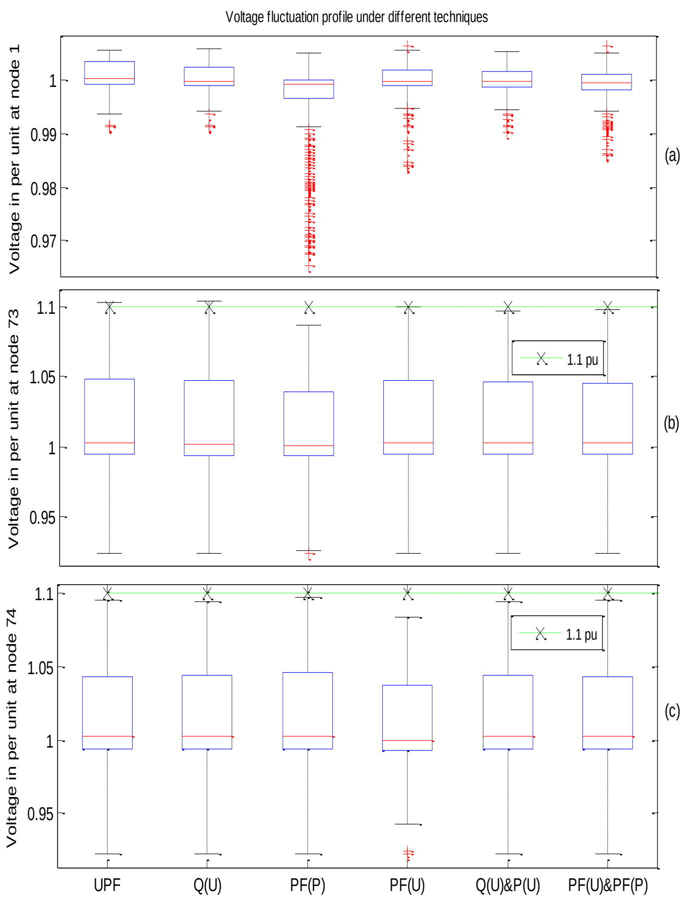
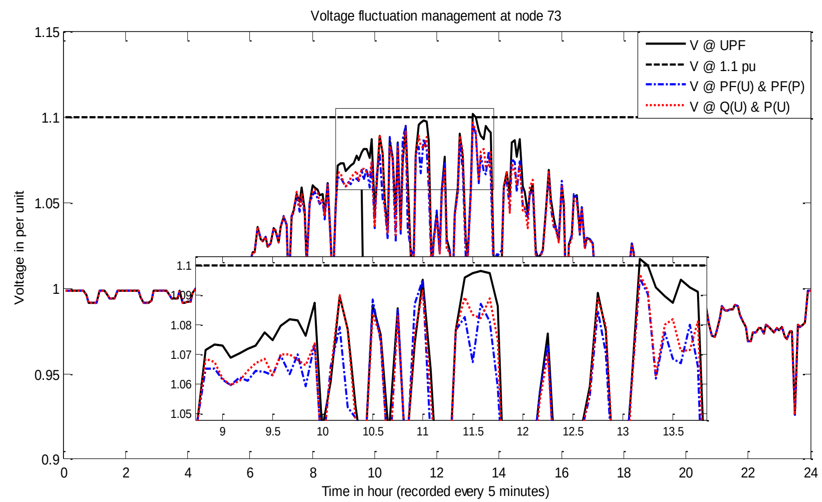
Co-ordinating algorithm

Techniques	Droop curve
PF(U) & PF(P)	
Q(U) & P(U)	

Voltage profiles





Technical impacts

1. But, why should DSO take risk in integrating such intermittent sources? -> Climate issue
2. Does the Regulator incentivised to motivate DSO in accommodating such intermittent sources in their network?

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Economic impacts

How does the DSO receive their revenue?

- Through the **settlement price** between the retailer and the DSO.
- The price is the electricity bill that we (consumers) pay to the retailer under a regulated distribution network tariff.

What is a distribution network tariff structure?

- This is the tariff structure that should respect the **network rate making principle**.
- So far, most of the EU countries **have volumetric type of network tariff structure** i.e. we pay in kWh of energy unit consumed.

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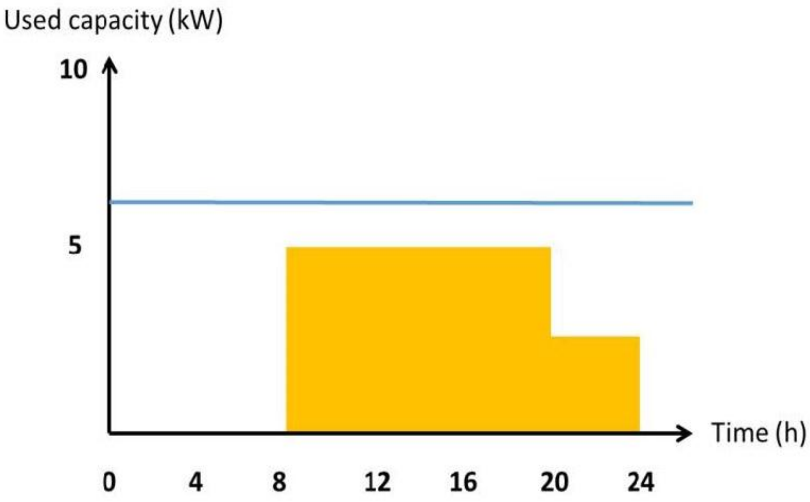
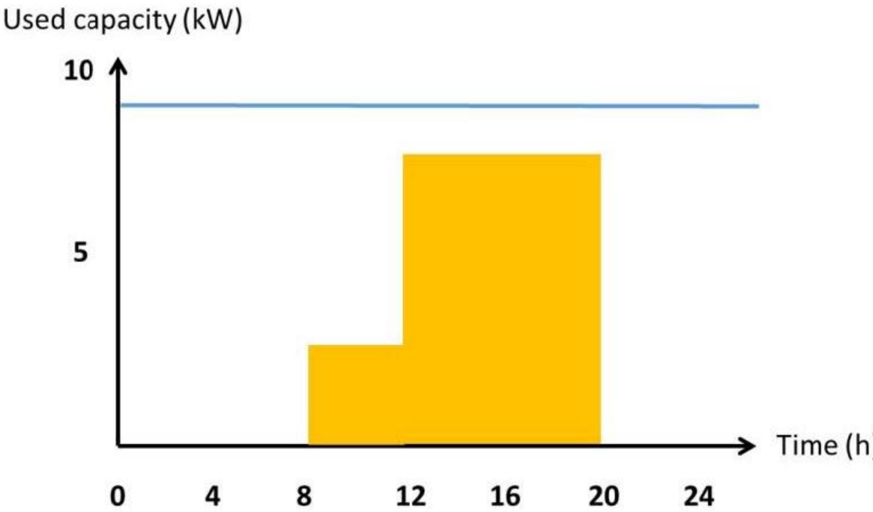
The network rate making principle

- ***Sustainability principles***
  - Guaranteed ***universal access*** to electricity to all the network users.
  - The entire ***cost recovery*** from the incurred cost of the network services.
- ***Economic efficiency principles***
  - ***Productivity efficiency*** is the least cost imposed to the network users for the network services provided by DNO.
  - ***Allocation efficiency*** is the cost imposed on the network users per how much they value the service they receive
  - ***Cost Causality*** is the type of charge that accurately accounts how much each network users contribute to the network costs.
  - ***Equity charge*** is the method of charging the same customer for the usage of same services.
- ***Customer protection principles***
  - ***Transparency*** avail all the network users the methods and results of the allocated network tariff through their respective electricity bills
  - ***Simplicity*** accredits the methods and the results from the allocated network tariff should be simple enough to understand by every network users.
  - ***Stability*** means reducing any regulatory uncertainty through stable short term network tariff and gradual changes towards long term network tariffing.

Volumetric type of network tariff structure



Case 1
Volume of energy consumed/generated: 70kWh
Contracted capacity (blue line): 6 kW
Maximum used capacity: **5 kW**



Case 2
Volume of energy consumed/generated: 70kWh
Contracted capacity (blue line): 9kW
Maximum used capacity: **7,5 kW**

Energy= 5kW X 12h + 2.5 kW X 4h =70kWh

Energy= 2.5kW X 4h + 7.5 kW X 8h =70kWh

Recalling the Distribution network cost

- The charging of the domestic customer is mainly through **high percentage of volumetric consumption** with **low fixed charge**.
- But, the **electric grid operation cost** is primarily defined by **high fixed charge** and **low variable charge**.
- **fixed charge** : long-run cost of operating the electric grid which includes **network losses**, **peak capacity of network**, **connection cost** and **network reliability**

Volumetric charges with net metering

- application of **net-metering system**, the volume of energy consumption reduces due to PV generation.
- this could reduce the **overall electricity bill** of the prosumers leading to decrease in DSO's network cost.

Results [2]

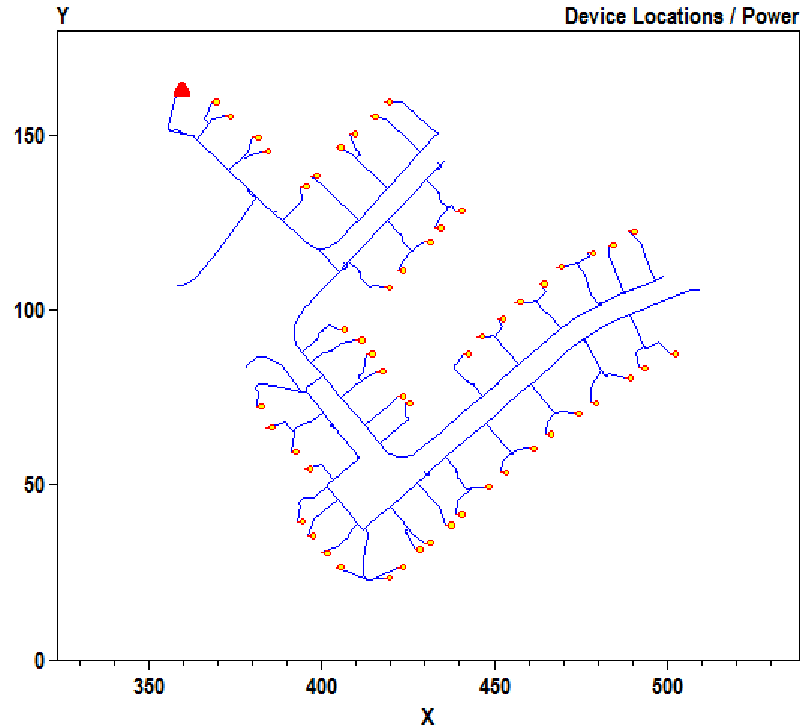
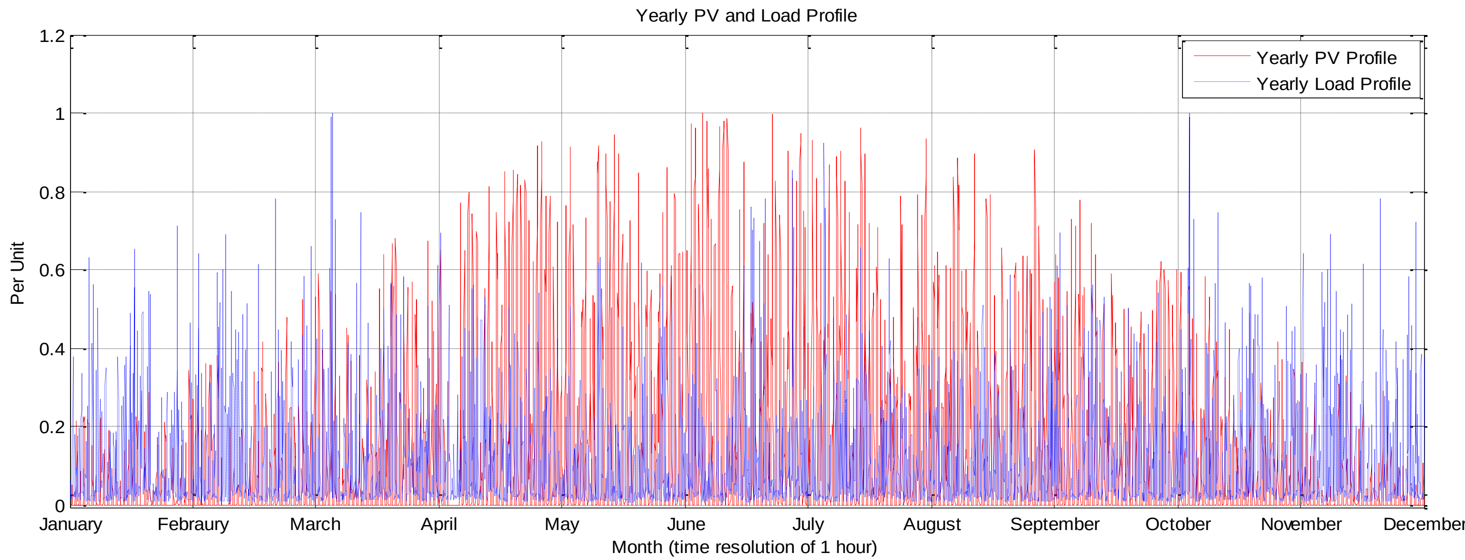


Table I: Three different combination of peak values of both PVDG and load demand

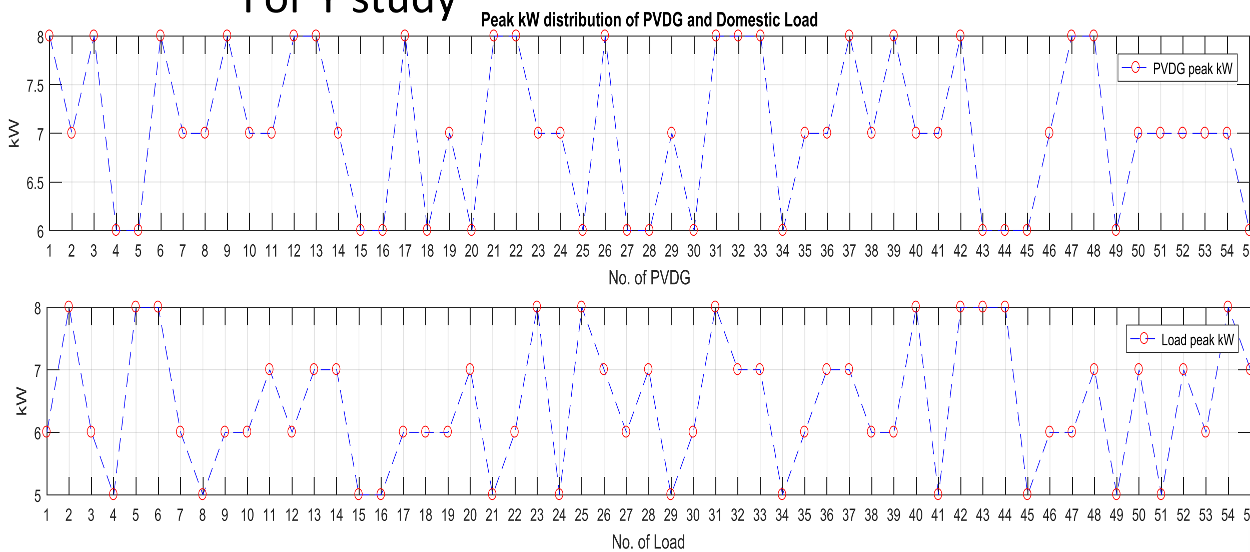
Designation	Range of peak value of PVDG in kW	Range of peak value of load in kW
X i.e. medium penetration	3-5	5-8
Y i.e. high penetration	6-8	5-8
Z i.e. No_PV	0	5-8

[2] S. Pukhrem, M. Basu and M. F. Conlon, "The relationship between PVDG technical impacts and DSO revenue: An approach to foster a higher share of non-firm PVDG integration ," CIGRE Symposium, Dublin,2017. (Submitted)

…contd Results



For Y study



...contd Results

Table II: Yearly comparative analysis of the three studies accounting 4 impact analyses

Study	Total annual energy flow to the load in kWh	Percentage of customer violating 1.1 pu voltage	Average network losses for a day		Percentage of peak loading with respect to the substation transformer rating i.e. 800 kVA	Percentage of reverse power flow with respect to the energy drawn from the utilities
			kW	kVAr		
Z	318355.77	0	0.821	0.305	51.67	0
X	233906.57	52.72	0.962	0.357	51.69	57.38
Y	217769.44	92.72	1.727	0.633	51.70	120.60

X and Y reduces by 20% and 30% of the reference value i.e. Z

…contd Results

Table III: Disaggregated price data for household consumers, 2015 (in EUR/kWh)

Composition of the electricity prices for household consumers (in EUR/kWh)					Share in price without taxes and levies (in %)	
Country	Total	Energy Supply	Network Cost	Taxes & Levies	Energy & Supply	Network cost
Denmark	0.304	0.038	0.056	0.210	40.6	59.4
Netherland	0.185	0.069	0.055	0.061	55.9	44.1
Ireland	0.245	0.133	0.066	0.046	66.6	33.4
UK	0.218	0.158	0.050	0.010	75.9	24.1

Table IV: 2015 annual share in price without taxes and levies for four different countries

Countries	**Energy Supply in EUR/kWh**			**Network cost in EUR/kWh**		
	"Z" i.e. Without PV	With PV		"Z" i.e. Without PV	With PV	
		"X"	"Y"		"X"	"Y"
Denmark	12098	8888	8275	17828	13099	12195
Netherland	21967	16140	15026	17510	12865	11977
Ireland	42341	31110	28963	21011	15438	14373
United Kingdom	50300	36957	34408	15918	11695	10888

...contd Results

- The revenue of DSO i.e**. the distribution cost reduces by 20% and 30%** of "Z" for the study "X" and "Y" respectively.
- This revenue was generated by considering a **volumetric tariff** in conjunction with **net-metering**.

...contd Consequence

- To sustain stable network cost, the **Regulator** may **impose higher charges per kWh consumed** by the network users (**both consumer and prosumer**) to balance the reduced charges from net-metering.
- Conversely, the normal consumers will end up paying the increase charges because of prosumer's activity leading to **cross subsidisation** between normal consumers and prosumers.

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- **Existing** distribution **network tariff structure** (**defined by the Regulator**) in conjunction with net-metering system **will worsen** the revenue generation of the **DSO**.
- DSO need **incentives** to carry out their **core activities** in presence of intermittent sources of generation.
- The **Regulators** need a **smarter regulation and policy** to **incentivise** the DSOs in meeting the new challenging mandates such as EU 20-20-20 targets.

Future Work

- To identify the potential **network cost drivers** under increase penetration of PV.
  - Connection, network capacity, reliability and distribution losses
- To **allocate** these costs by respecting **the network rate making principle**.

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Thank you for your time!