Evaluation of Customer-Oriented Power Supply Risk with Distributed PV-Storage Energy Systems

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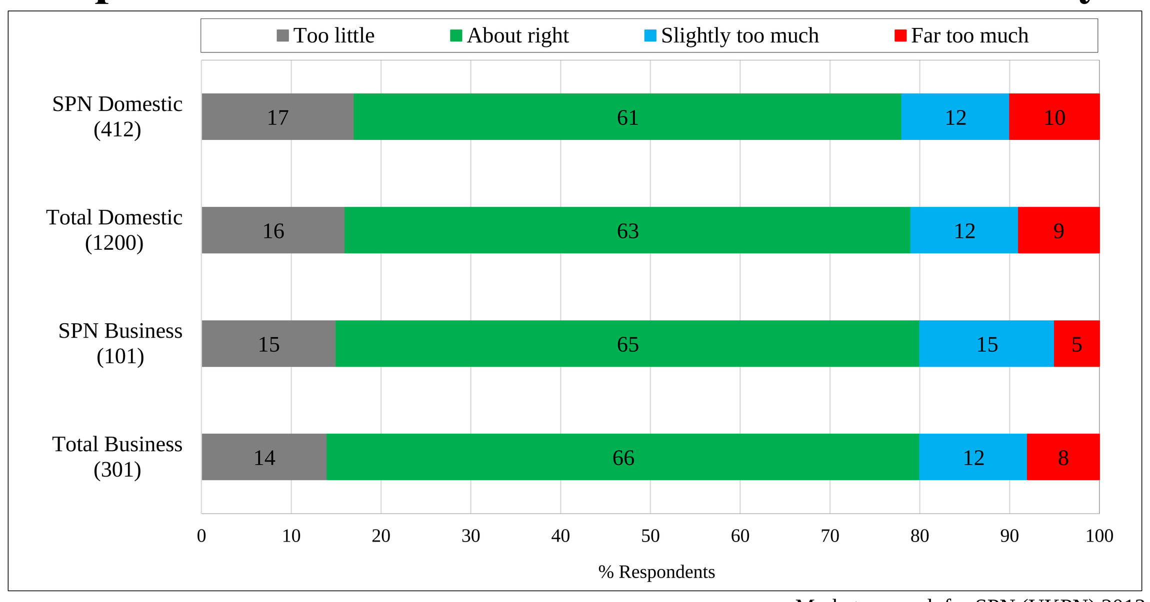
Customer Priorities in a Climate of Rising Energy Prices

- **Accurate** reliability evaluation raises customer WTP.
- **System-oriented** evaluation masks poor reliability performance.
- Different customer **perceptions** of DNO services' value.

Perception of the DNO's 18% share of the electricity bill



Market research for SPN (UKPN) 2013

DNO services valued most highly are;

- Rapid supply **restoration.**
- Quicker **detection** of supply loss.
- **Carbon reduction** initiatives.

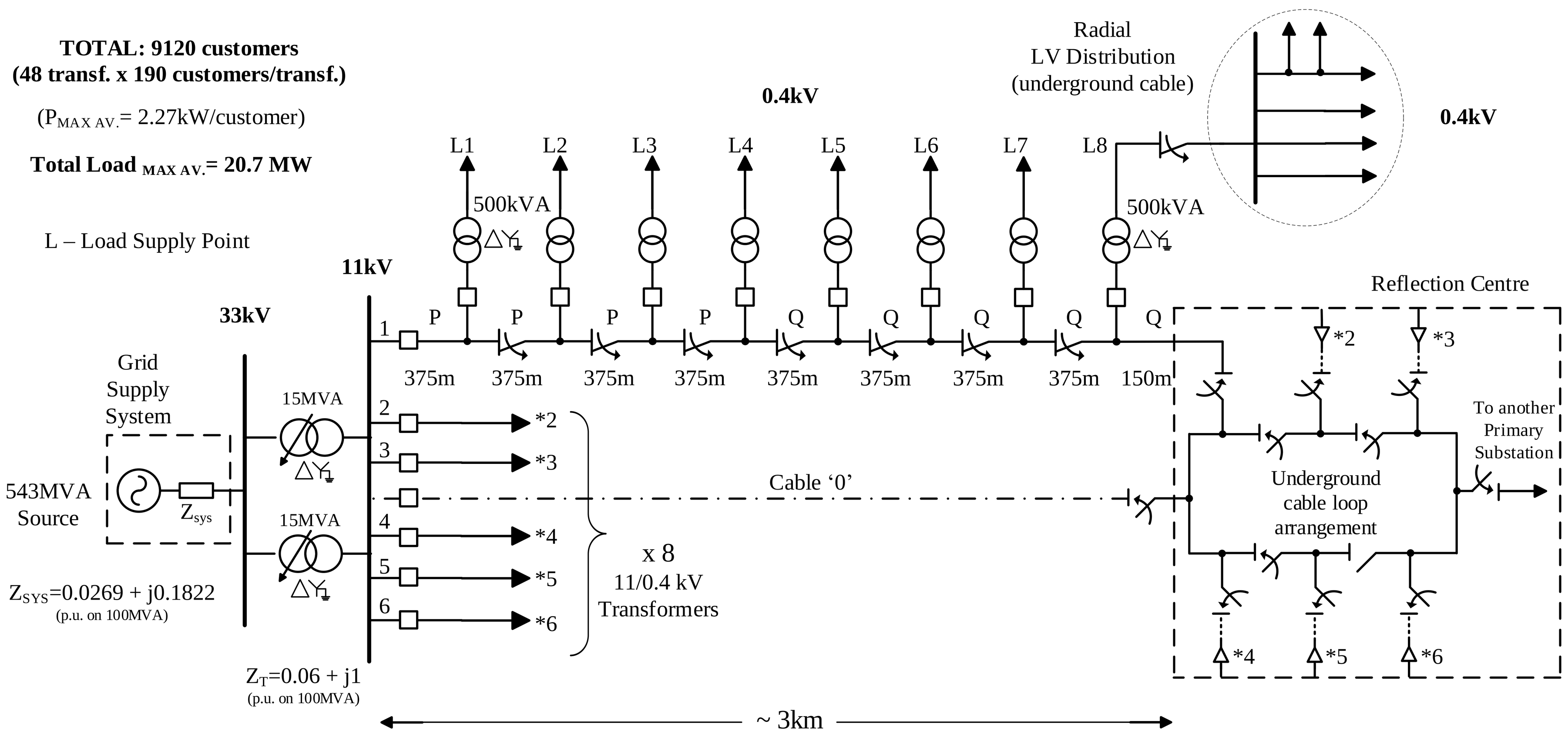
Customer WTP for increases in DNO service levels

Service Levels	WTP in % in 2023*	
	Domestic	Business
Cheaper and quicker connection of low carbon electricity generators	2.90	2.34
Investments enabling quicker detection of loss of supply	2.89	3.01
Investments supporting uptake of micro-generation technologies	1.96	1.94
Time to restore 80% of affected rural customers within 1 hour	1.30	1.33
Time to restore 80% of affected urban customers within 1 hour	-1.24	-1.37

*SPN 2013; WTP = Willingness to Pay

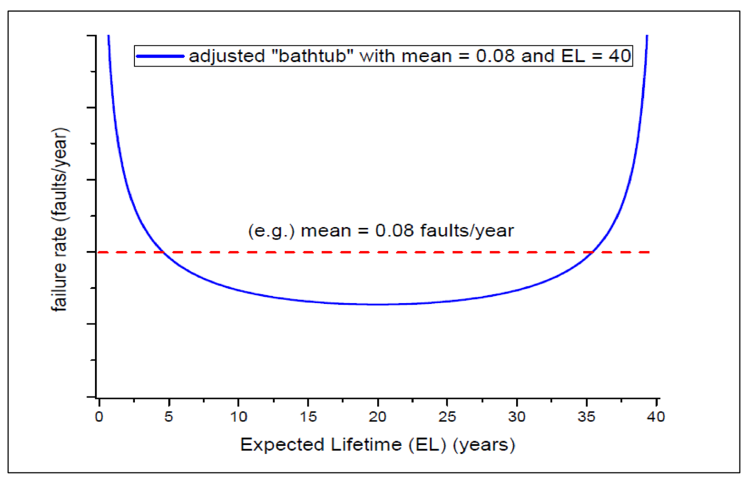
Integrated Quality of Supply Analysis

Urban MV Network

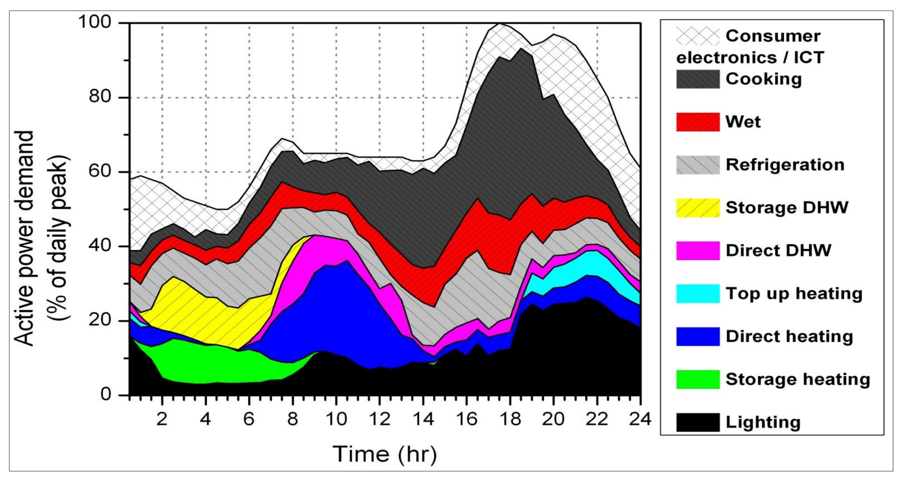


- After Diversity Maximum Demand: 2.27kW/customer
- LV aggregate networks with reliability equivalents

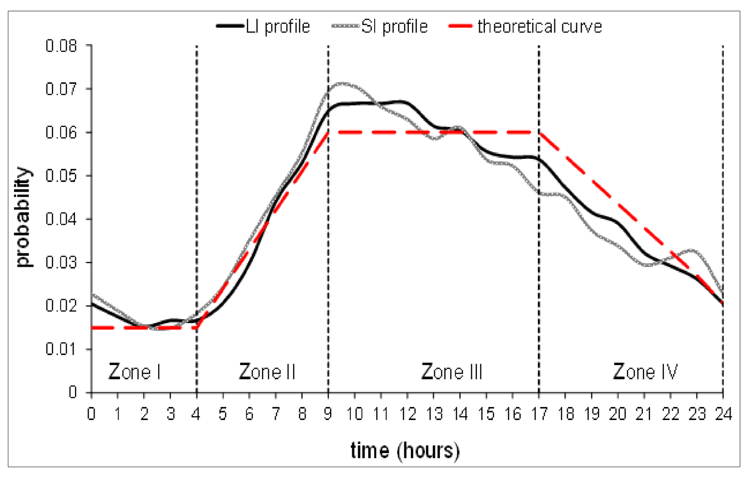
Monte-Carlo simulation enhanced by including:



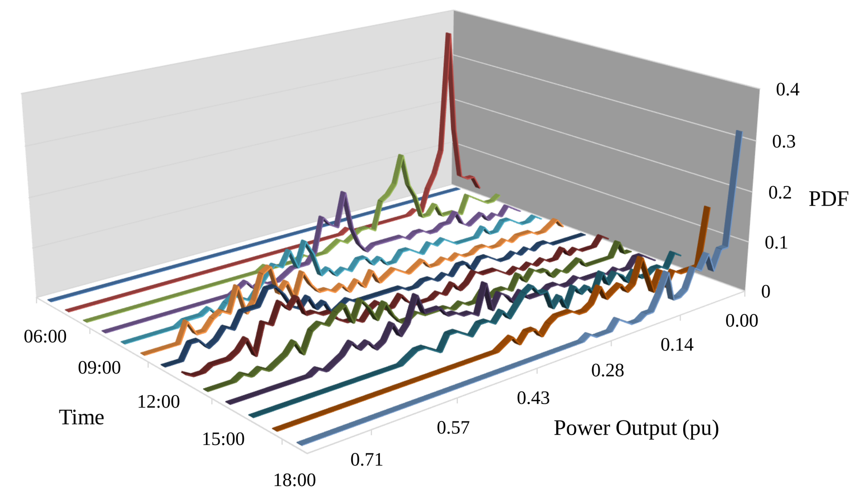
- Time-varying component failure rates.



- Time-varying demand profiles.



- Daily probabilities of long/short interruptions.



- Spatial-temporal variation of PV.

Customer-Oriented Reliability Evaluation

Reliability Enhancement

1) PV+DSR - Uncontrolled solar photovoltaic (PV) energy with a 50% overall network penetration, and demand-side response (DSR) designed for reliability improvement through load reductions during periods with high fault-probability.

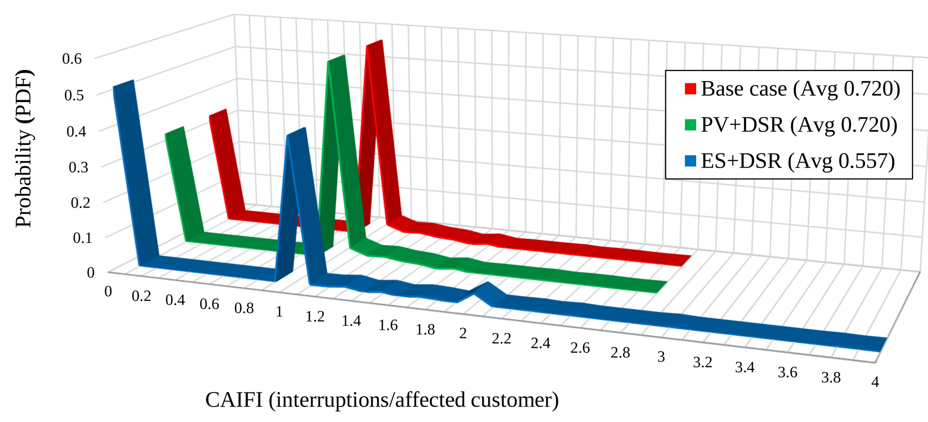
2) ES + DSR – Energy Storage (ES) where daily Microgeneration output is controlled by an energy management system to provide a backup capability of 3.67 kWh per customer per fault, coupled with DSR.

Comprehensive Reliability Assessment

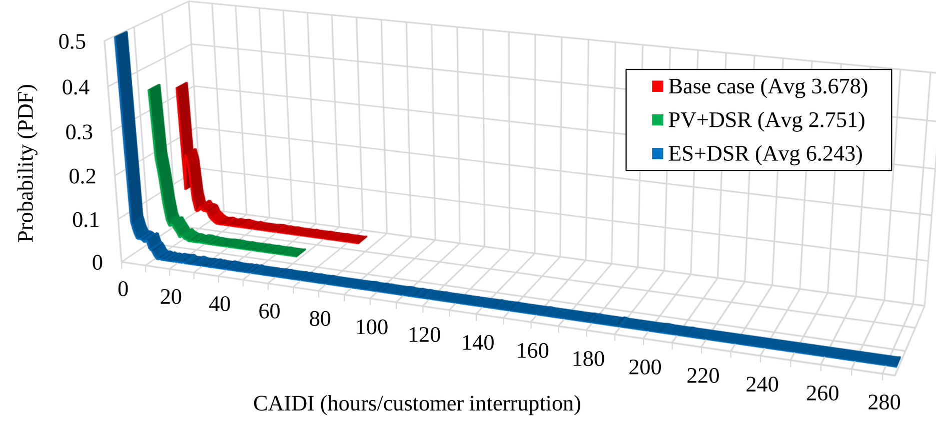
- Each customer index is significantly larger than its system equivalent.
- ES+DSR significantly alleviates impacts of long interruptions but
- Has negligible impact on short interruptions.

Parameter	Index	Base Case	PV+DSR	ES+DSR
Duration of Long Interruptions	CAIDI (hours/aff. cust.)	3.678	2.751	6.243
	SAIDI (hours/cust./year)	0.550	0.407	0.282
Frequency of Long Interruptions	CAIFI (ints/aff. cust.)	0.720	0.720	0.557
	SAIFI(ints/cust./year)	0.157	0.157	0.039
Frequency of Short Interruptions	CAMIFI (ints/aff. cust.)	0.797	0.797	0.819
	MAIFI (ints/cust./year)	0.208	0.208	0.216
Energy not supplied	ACCI (kWh/aff. cust.)	1090.41	828.99	1790.79
	ENS (kWh/cust./year)	146.37	110.63	85.21

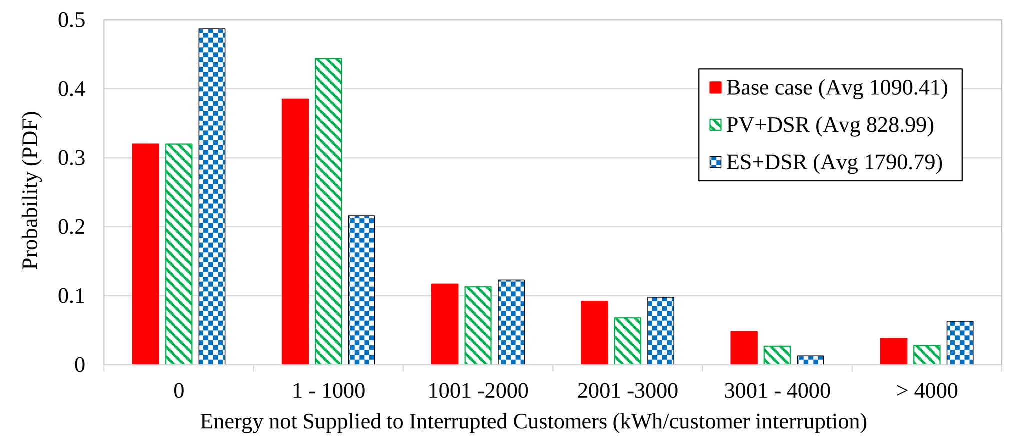
aff. cust. = affected customer; int = interruption



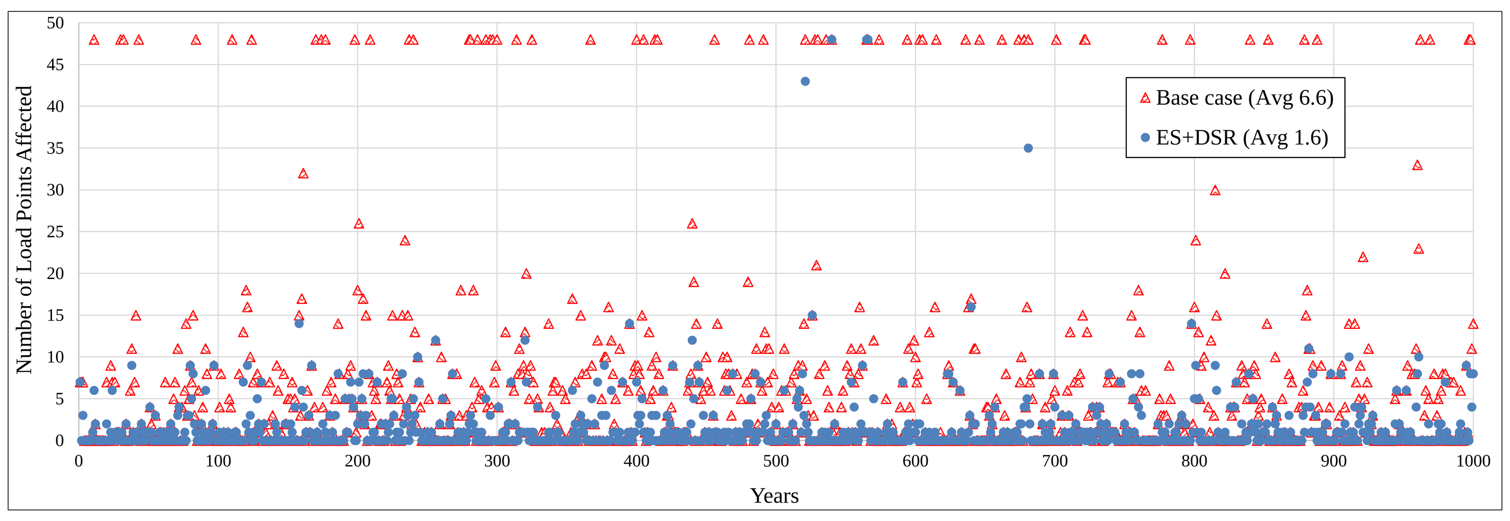
Impact of the frequency of long interruptions.



Impact of the duration of long interruptions.



Probability of ENS to interrupted customers.



Number of network load points affected by supply interruptions.

- **PV-storage** systems offer **reductions** in the average frequency and duration of interruptions, number of affected load points, and the subsequent ENS.
- **Customer WTP** is enhanced by customer-oriented reliability evaluation through:
  - More accurate quantification of perceived customer reliability.
  - Confidence in DNO-reporting on power delivery.
  - Supporting the uptake of distributed energy resources e.g. PV.
- **Reliability-based customer identification** enables DNOs to effect impactful network improvements, and consistently exceed regulator-set performance targets.

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