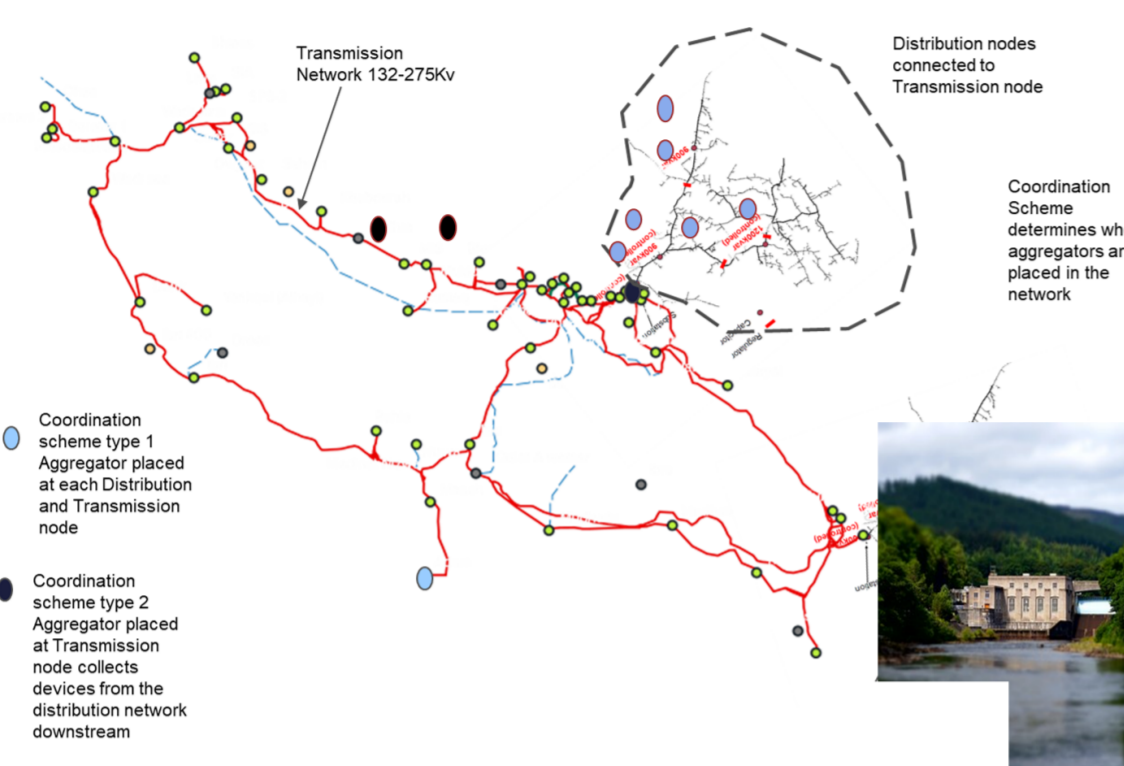


# Simulating a Commercial Power Aggregator at Scale Design and Lessons Learned

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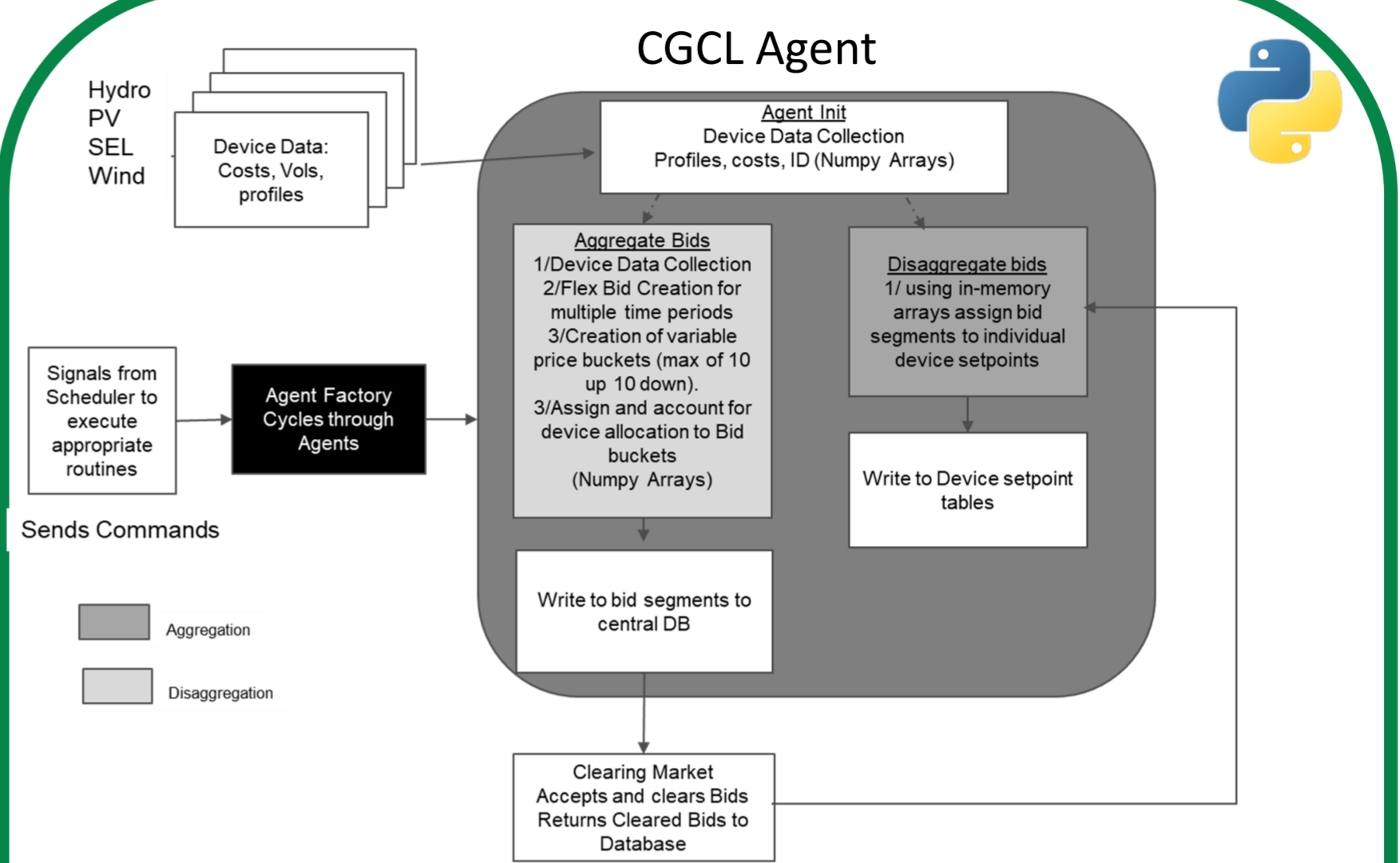
**Example transmission and distribution grid (Hypothetical).**  
Simulation used representation of actual Italian Danish and Spanish

Coordination scheme type 1: Aggregator placed at each Distribution and Transmission node  
Coordination scheme type 2: Aggregator placed at Transmission node collects devices from the distribution network downstream

- ❖ EU Horizon 2020 SmartNet project
- ❖ Compares different coordination approaches
- ❖ New approaches required because an increase in distributed energy resources affects transmission and distribution network operation as well as pricing in markets
- ❖ Focus is on design and implementation of one of the aggregation models, the Curtailable Generator / Curtailable Load (CGCL) aggregator (Marthinsen et al., 2017)

**TSO-DSO coordination schemes**

A. Centralized ancillary services market – balancing + congestion management services for TSO  
 B. Local Ancillary market – locally prioritized congestion management services for DSO  
 C. Shared balancing responsibility – separated balancing + congestion services for DSO/TSO  
 D. Common TSO-DSO ancillary services market model – unified balancing + congestion management for DSO/TSO



**CGCL Agent**

Hydro, PV, SEL, Wind

Device Data: Costs, Vols, profiles

Agent Init: Device Data Collection, Profiles, costs, ID (Numpy Arrays)

Aggregate Bids: 1/Device Data Collection, 2/Flex Bid Creation for multiple time periods, 3/Creation of variable price buckets (max of 10 up 10 down), 3/Assign and account for device allocation to Bid buckets (Numpy Arrays)

Disaggregate bids: 1/using in-memory arrays assign bid segments to individual device setpoints

Write to Device setpoint tables

Write to bid segments to central DB

Clearing Market: Accepts and clears Bids, Returns Cleared Bids to Database

- ❖ CGCL - Curtailable Generation / Curtailable Load
- ❖ Aggregates bids from up to 300,000 devices of four different DER types (Solar, Hydro, Wind and Sheddable Loads) across 5 -10,000 power nodes.
- ❖ 5-10,000 CGCL agents

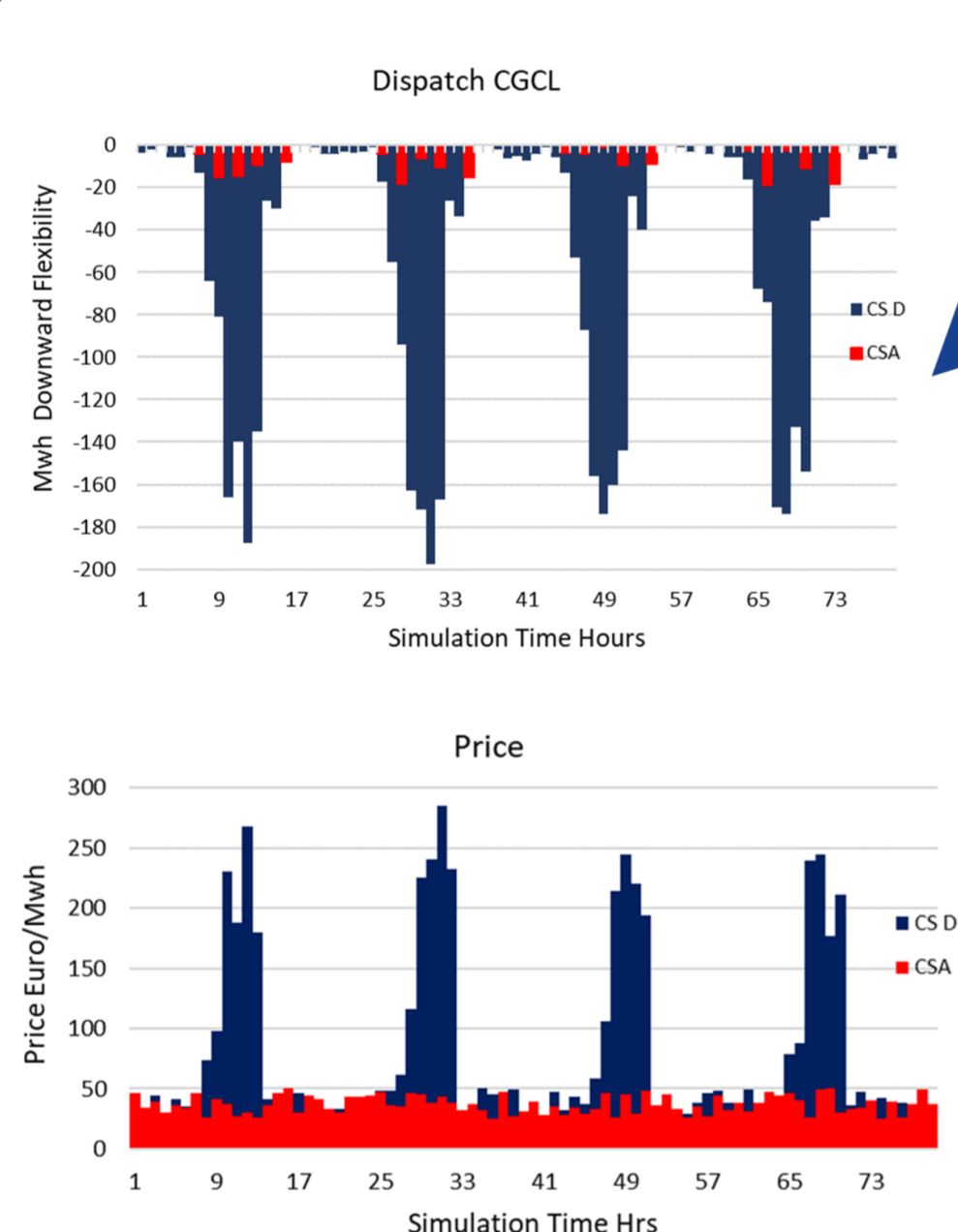
## Introduction

## Agent Design

## Agent Logic

## Results

## Challenges



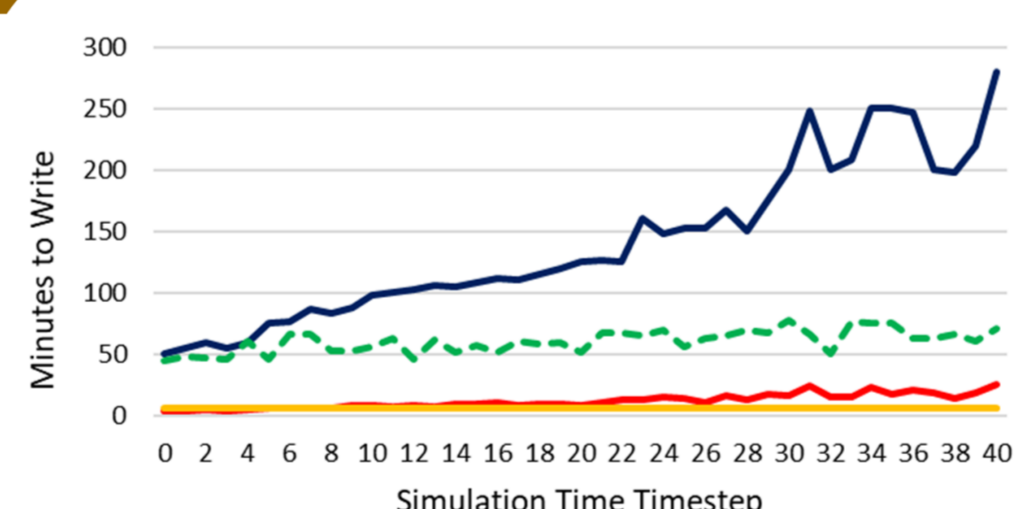
**Dispatch CGCL**

MWh Downward Flexibility vs Simulation Time Hours

**Price**

Price Euro/MWh vs Simulation Time Hrs

- ❖ Market clearing using OPF
- ❖ Coordination scheme CS-D results in much more downward flexibility than CS-A.
- ❖ Price patterns are node dependent. Only One node Shown



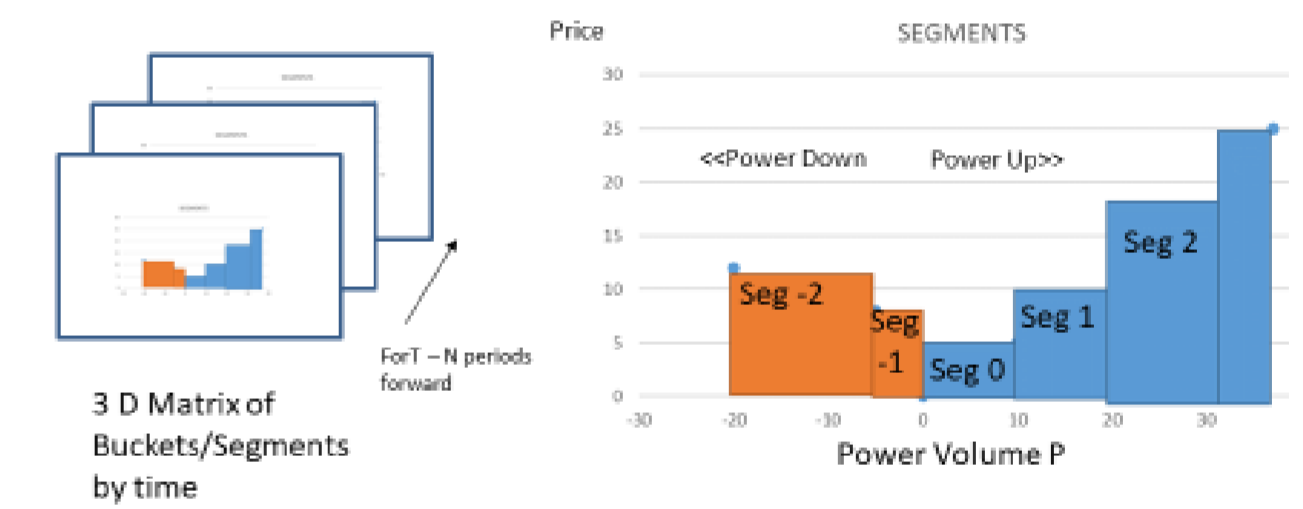
**Minutes to Write**

Minutes to Write vs Simulation Time Timestep

- ❖ Database write speed high
- ❖ Significant reduction in write times can be achieved with a different indexing strategy and using bulk SQL writes
- ❖ 5 Million writes per Tick (CGCL only)
- ❖ Solutions >> Database Sharding, Multi-threading/HPC/CUDA, Re-indexing, In-memory

**Flex Bids**

- Multiple Segments – 10 up 10 down max
- Depends on number of devices and cost spread



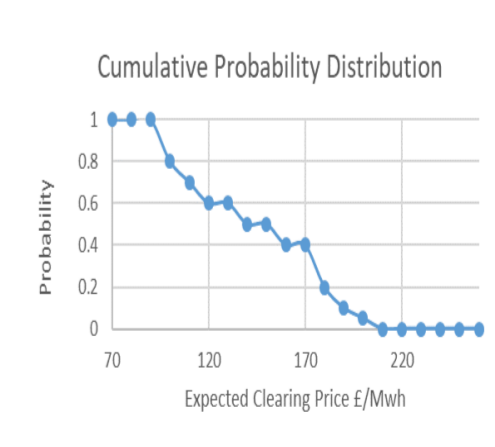
**Price Buckets**

		Buckets (price ranges)				
Lower Level	10	23	28	32	64	
Upper Level	23	25	32	64	102	
$p_{Upperj} = p_{Lowerj+1}$						
Vol Assigned MWh	100	26	5	123	21	
Price Bid	23	25	32	64	102	

- Example Bucket 1 – price range 10-23
- Variable size of buckets
- Choose bucket ranges to maximise profits

**Pseudo Code**

1. Choose price ranges associated with 10 buckets  $P_j \geq P_{j-1}$
2. Place devices in buckets where  $P_{j-1} \leq P_{device} < P_j$
3. Calculate bid price associated with bucket  $P_{bid}$  e.g.  $Price_{max}$
4. Estimate probability of clearing price
5. Profit  $\Pi$  is sum of Volume in Bucket \* Probability of clearing \* Price bid of bucket -  $\forall N$  buckets
6.  $\max_{P_1 \dots P_{N-1}} \Pi$  - Optimise ranges for N buckets ( $P_i$ )



### Future Work

- ❖ Database design/speed up
- ❖ Risk management & aggregator competition,
- ❖ strategic bidding, agent learning, congestion and portfolio management

### References

[1] Marthinsen, H., Plecas, M., Morch, A. Z., Kockar, I. & Džamarija, M. 2017. Aggregation model for curtailable generation and sheddable loads..