2021 Grid of the Future

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Studies of Distribution Locational Marginal Pricing Methodology Based on Bronzeville Community Microgrid

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Outline

- Introduction
- DLMP Methodology and Modelling for Microgrid-Level Transactive Energy Market
- Network Topology
- Scenarios and results
- Conclusions
- Demo (5min Opus-one: Optional)

Introduction

- Modern distribution systems are experiencing transformative change due to a growing penetration of distributed energy resources (DERs)
- A market-based approach to energy market transaction is needed for managing various DERs efficiently and economically
- ComEd is collaborating with Opus One to design, develop and evaluate an energy transaction platform of running a **Shadow Energy Exchange for DER (SEEDER)**
- The solution focused on energy trade from **dispatchable DERs in microgrid settings** considering day-ahead and real-time markets
- The main difference between the wholesale transmission market and retail distribution market: unbalanced phase loading, islanded/grid-connected operation, and flexible operation modes of DERs

Introduction

- ComEd is validating the energy exchange platform in two stages:

- Stage 1: A non-real time simulation focusing on power system and economic analysis to demonstrate various scenarios in which energy exchange is optimized (the focus of this paper)

- Stage 2: A real-time simulation focusing on integration with a real-time digital simulator (RTDS) for the field readiness demonstration

DLMP Methodology and Modelling

- DLMP Methodology

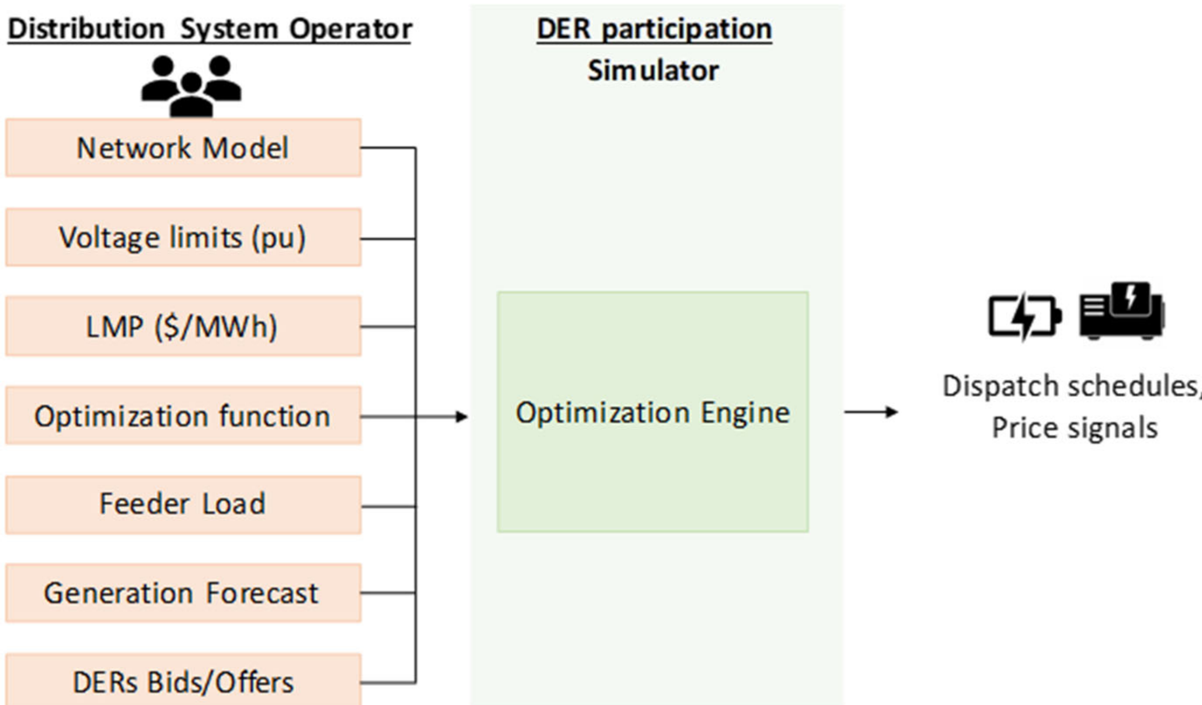
- **Distribution Locational Marginal Price (DLMP)** is defined as the price to serve the next unit of energy at a node on a distribution feeder
- Three components: **marginal energy price**, **marginal congestion price**, and **residual price** representing the remaining marginal components

$$\lambda_{DLMP}(t,i) = \lambda_{Energy}(t,i) + \lambda_{Congestion}(t,i) + \lambda_{Residual}(t,i) \qquad \forall i \in N_R, \forall t$$

- The optimal dispatch for all participating DER resources is obtained by running a time-series constrained AC unbalanced optimization with the objective of minimizing operating cost while respecting the thermal and voltage limits in all three phases;

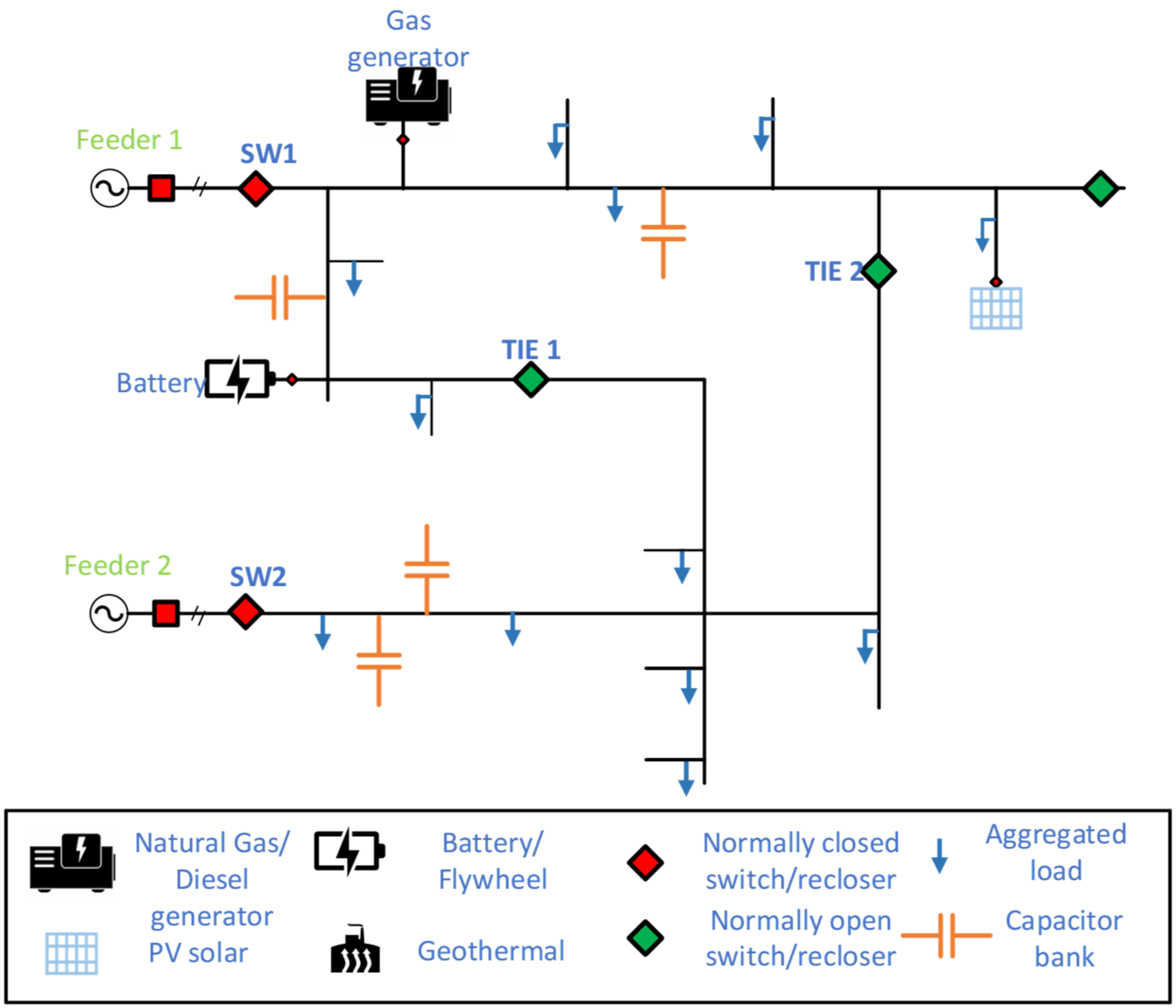
DLMP Methodology and Modelling

- Day-Ahead and Real-Time Electricity Market at a Microgrid Level



DLMP Methodology Inputs, Outputs and Key Components

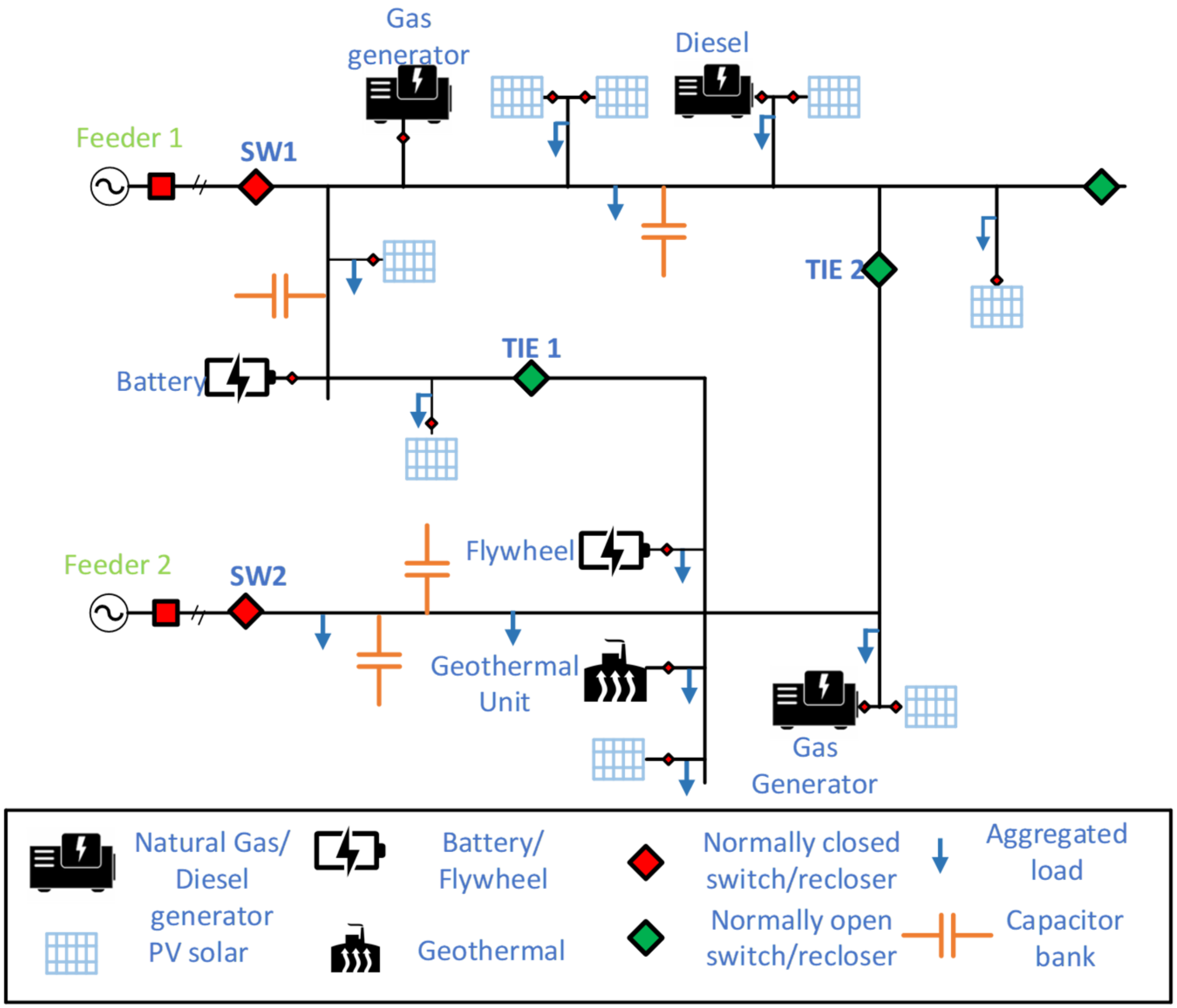
Network topology



Bronzeville Community Microgrid (BCM)

- 750 kW PV solar
- 500 kW/2000 kWh BESS
- 4.8 MW gas generator

Network topology



Bronzeville Community Microgrid (BCM)

- 750 kW PV solar
- 500 kW/2000 kWh BESS
- 4.8 MW gas generator

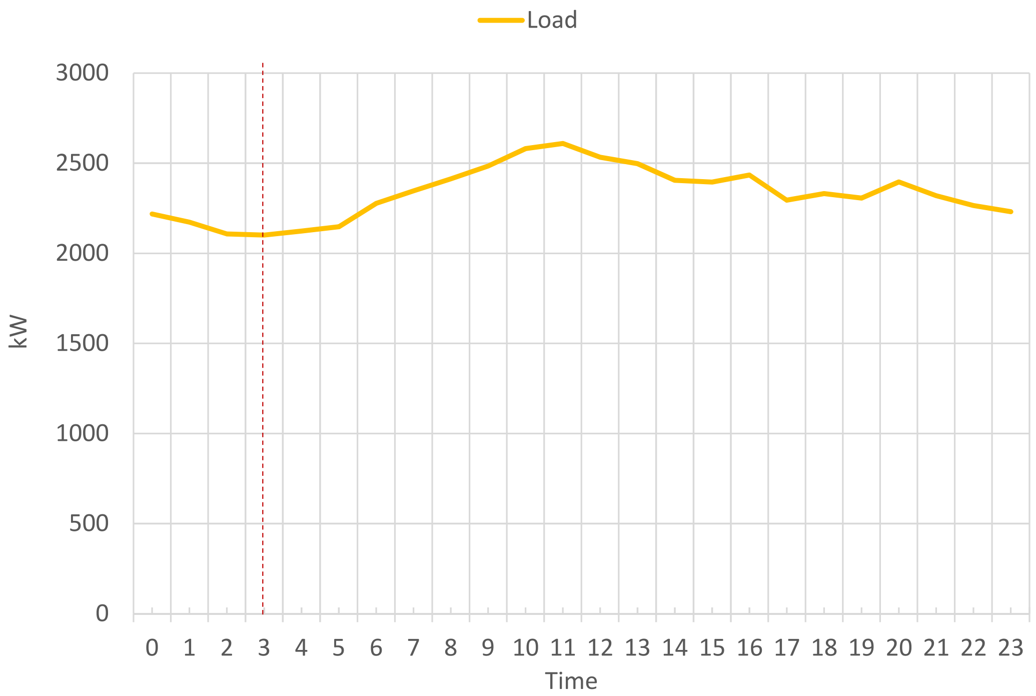
- Diesel generator
- Geothermal unit
- Gas generator
- BTM solar
- Flywheel

The DERs are all modeled as balanced three-phase devices.

Results – Case 1: Blue sky day

Total Load: 2.1 MW at **3:00 AM**

Asset	**Offer ($/MWh)**	**Capacity Offered (MWh)**
Natural Gas	13	1.5
Geothermal	20	2
Flywheel	0	0
LMP	16.72	-

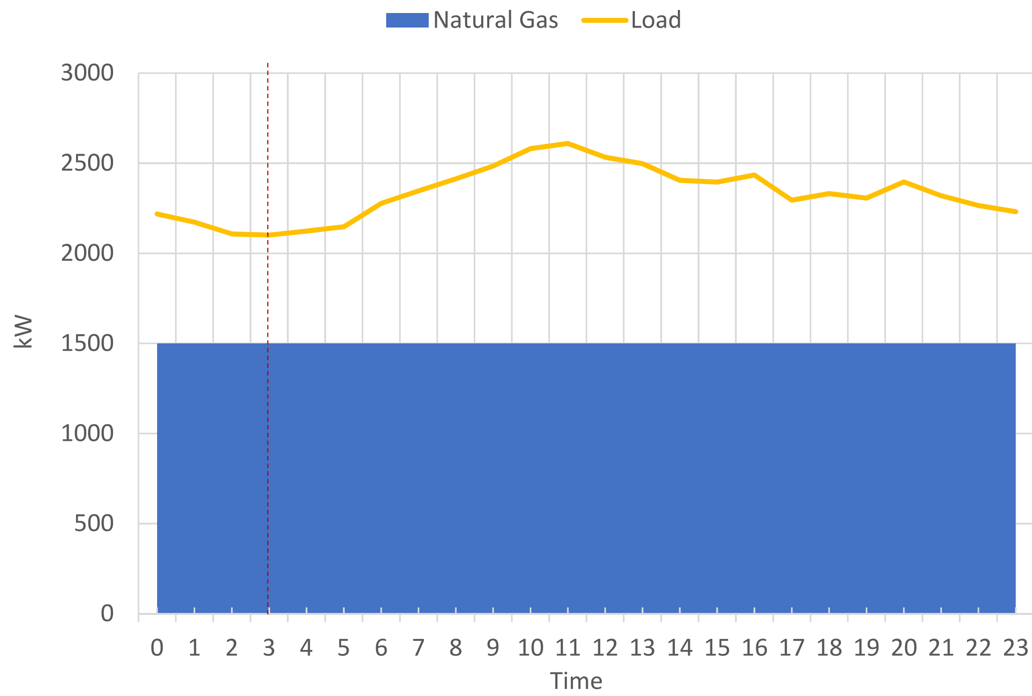


Results – Case 1: Blue sky day

Total Load: 2.1 MW at **3:00 AM**

Asset	Offer ($/MWh)	Capacity Offered (MWh)
Natural Gas	13	**1.5**
Geothermal	20	2
Flywheel	0	0
LMP	16.72	-

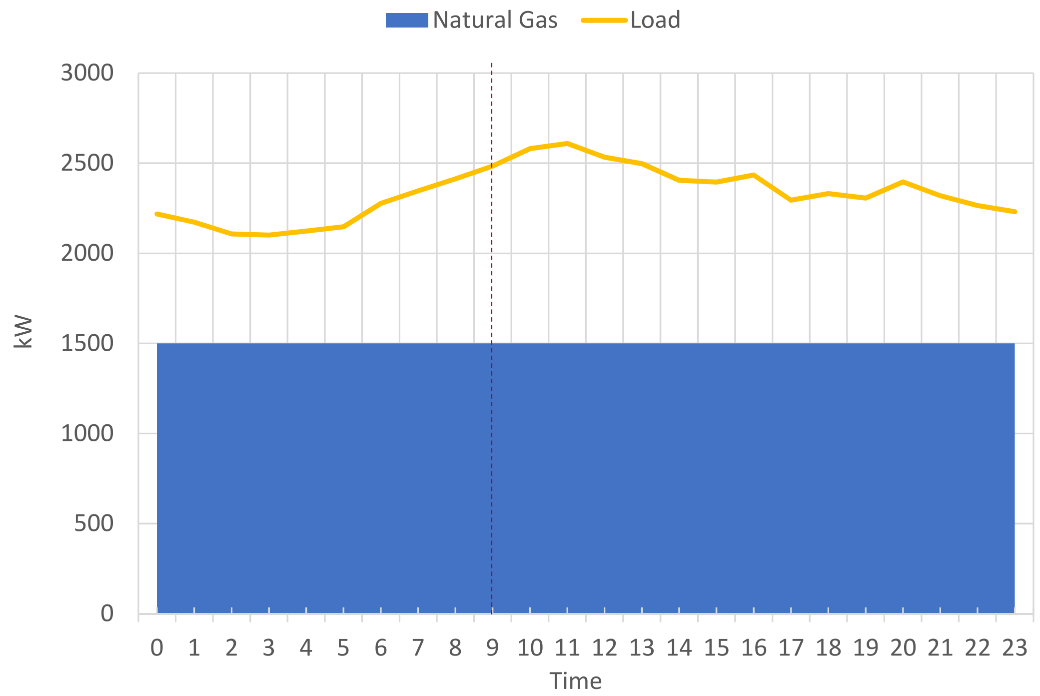
Asset	Optimal dispatch	DLMP ($/MWh)		
		Energy	*Congestion*	*Residual*
Natural Gas	**1.5**	16.72	0	-0.017
Geothermal	0	16.72	0	-0.006
Flywheel	0	16.72	0	0.003



Results – Case 1: Blue sky day

Total Load: 2.5 MW at **9:00 AM**

Asset	Offer ($/MWh)	Capacity Offered (MWh)
Natural Gas	13	1.5
Geothermal	20	2
Flywheel	19	0.25
LMP	22.02	-



Results – Case 1: Blue sky day

Total Load: 2.5 MW at **9:00 AM**

Asset	Offer ($/MWh)	Capacity Offered (MWh)
Natural Gas	13	1.5
Geothermal	20	2
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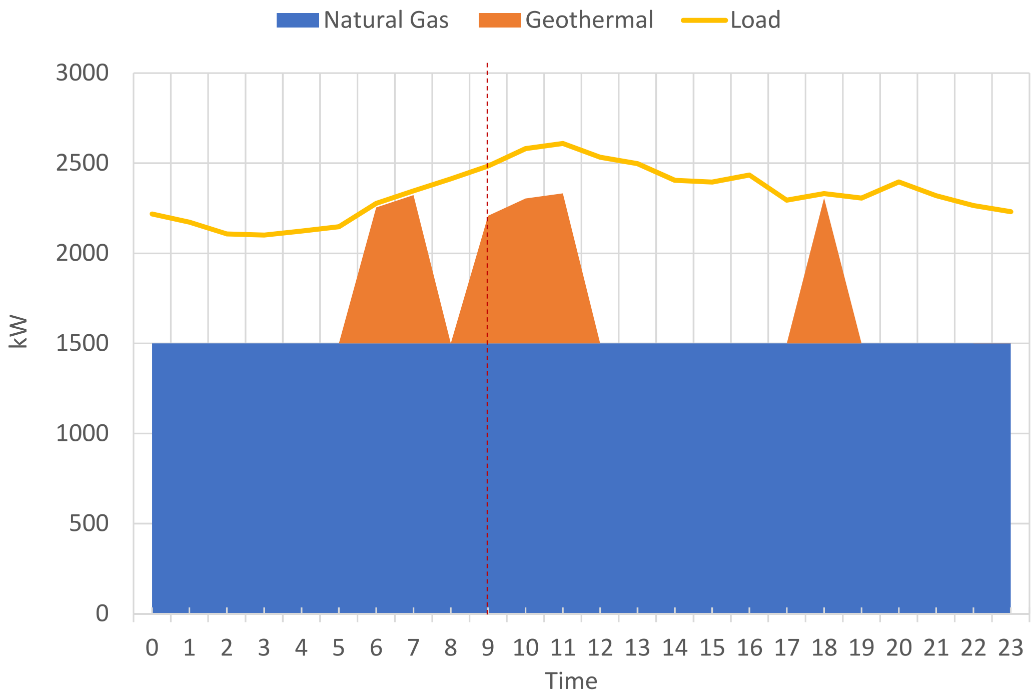


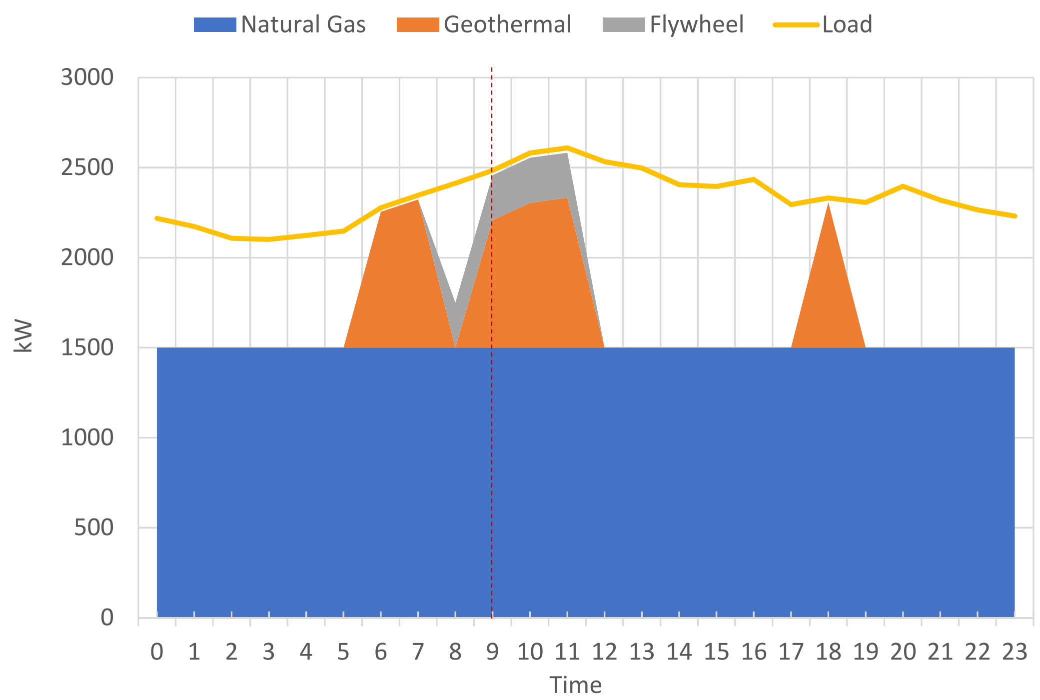
Results – Case 1: Blue sky day

Total Load: 2.5 MW at **9:00 AM**

Asset	Offer ($/MWh)	Capacity Offered (MWh)
Natural Gas	13	1.5
Geothermal	20	2
Flywheel	19	0.25
LMP	22.02	-

Result at Geothermal location

Phase	DLMP ($/MWh)		
	Energy	*Congestion*	*Residual*
ABC	20.025	0	-0.025
A	22.02	0	-0.021
B	22.02	0	-0.032
C	16.035	0	-0.022



Constraints

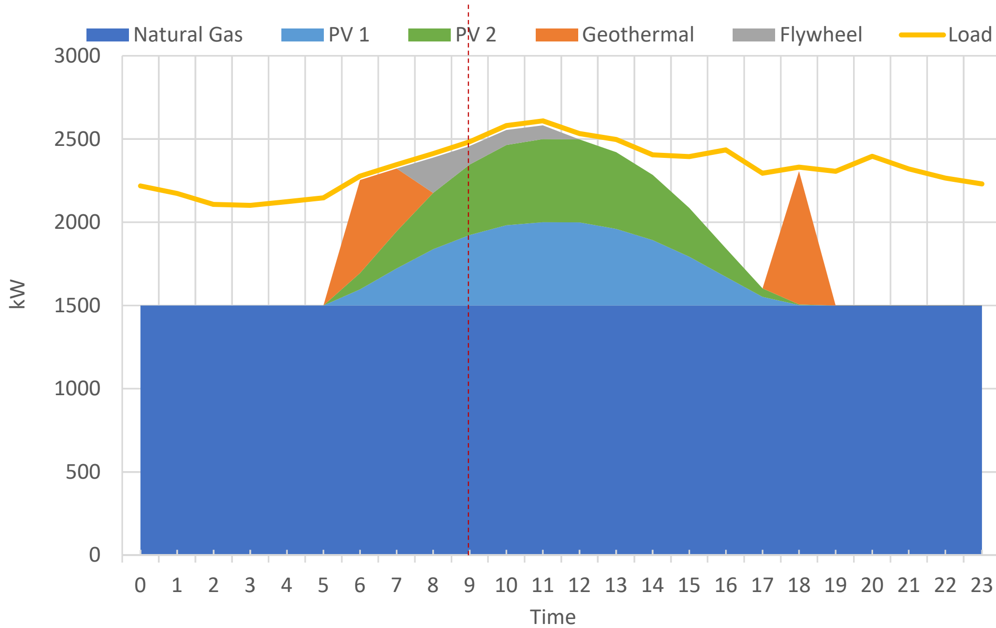
- No real power back-feed
- DERs are 3ph-balanced generators

Generators that output unique amounts of power per phase might have more value

Results – Case 2: Blue sky day with PV

Asset	Offer ($/MWh)	Capacity Offered (MWh)
Natural Gas	13	1.5
Geothermal	20	2
Flywheel	19	0.25
PV1	0	0.4235
PV2	0	0.4235
LMP	22.02	-

Asset	Capacity cleared (MW)	DLMP ($/MWh)		
		Energy	*Congestion*	*Residual*
Natural Gas	1.5	19.004	0	-0.036
Geothermal	0	19.004	0	-0.018
Flywheel	0.1114	19.004	0	-0.004
PV 1	0.4235	19.004	0	-0.003
PV 2	0.4235	19.004	0	-0.036



Cost Optimization Constraints

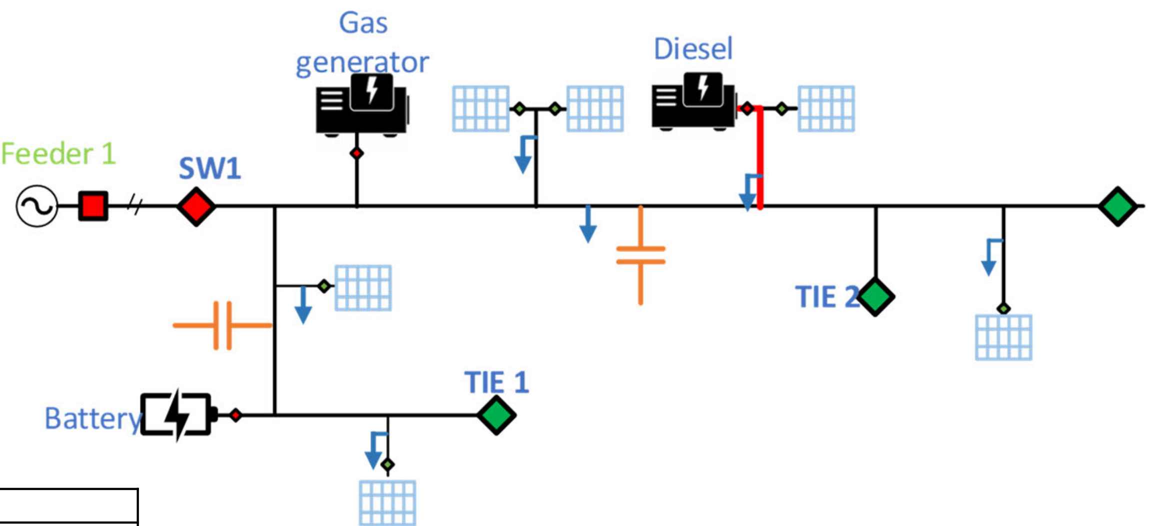
- No real power back-feed
- DERs are 3ph-balanced generators

Solar can reduce the DLMP but also it can increase total system costs.

Results – Case 3: Negative congestion

At 12:00 PM, the load is **5.27 MW**

Asset	Offer ($/MWh)	Capacity offered (MW)
Diesel	10	3
BESS	20	0.78
Natural Gas	0	0
LMP	23.33	-



Asset	Capacity cleared (MW)	DLMP ($/MWh)		
		Energy	*Congestion*	*Residual*
Diesel	2.49	23.33	-13.601	0.271
BESS	0.78	23.33	0	0.304
Natural Gas	0	23.33	0	0.313

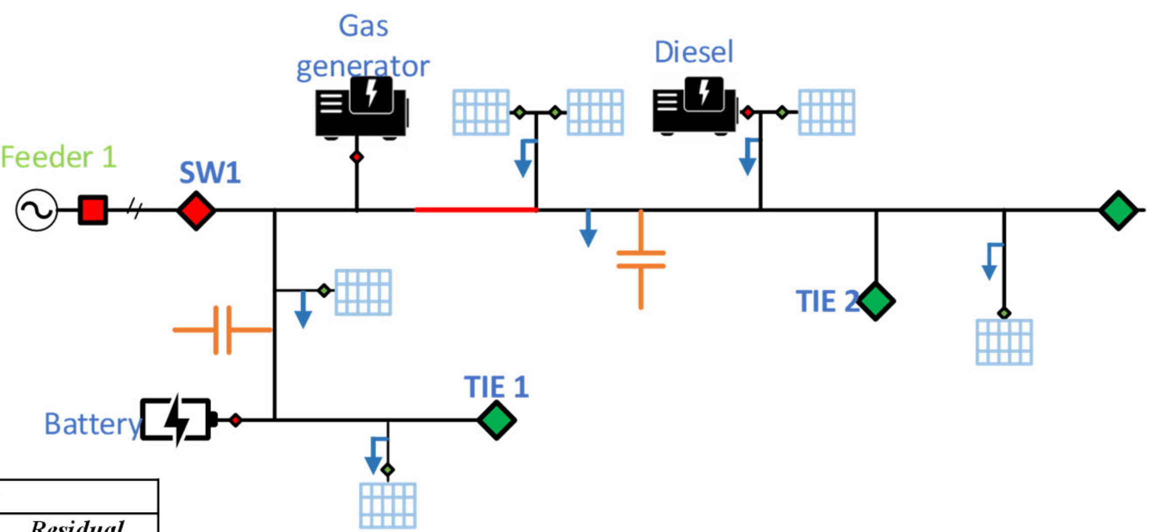
Results – Case 4: Positive congestion

At 12:00 PM, the load is **8.27 MW**

Asset	Offer ($/MWh)	Capacity offered (MW)
Diesel	25	2
BESS	0	0
Natural Gas	13	8.4
LMP	17.08	-

Asset	Capacity cleared (MW)	DLMP ($/MWh)		
		Energy	*Congestion*	*Residual*
Diesel	1.51	12.824	12.103	0.073
BESS	0	12.824	0	0.177
Natural Gas	6.64	12.824	0	0.176

Asset	DLMP ($/MWh)
Diesel	25
BESS	13.001
Natural Gas	13

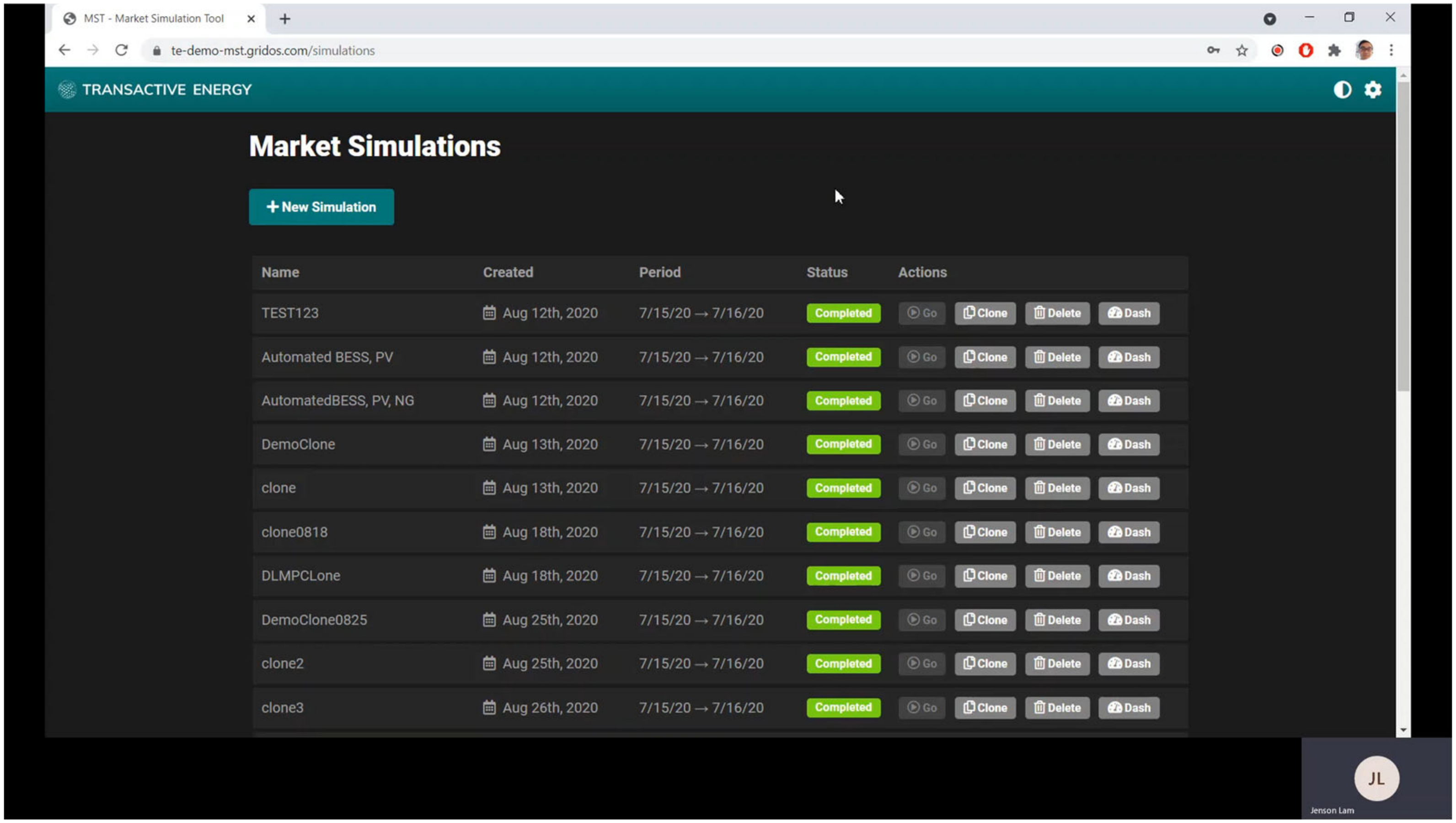


Conclusions

- Results demonstrate tool functions as expected
- DLMP is calculated per phase
- Generators capable of dispatching unique power on single-phase will potentially have more value than three-phase generators.
- An increased penetration of solar can also lead to smaller DLMP values. But, depending on the settlements, solar power curtailment can lead to an increase in system costs.

Thank You

Demo (5min)


MST - Market Simulation Tool
te-demo-mst.gridos.com/simulations
TRANSACTIVE ENERGY
Market Simulations
+ New Simulation
Name
Created
Period
Status
Actions
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Delete
Dash
Automated BESS, PV
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AutomatedBESS, PV, NG
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Jenson Lam