

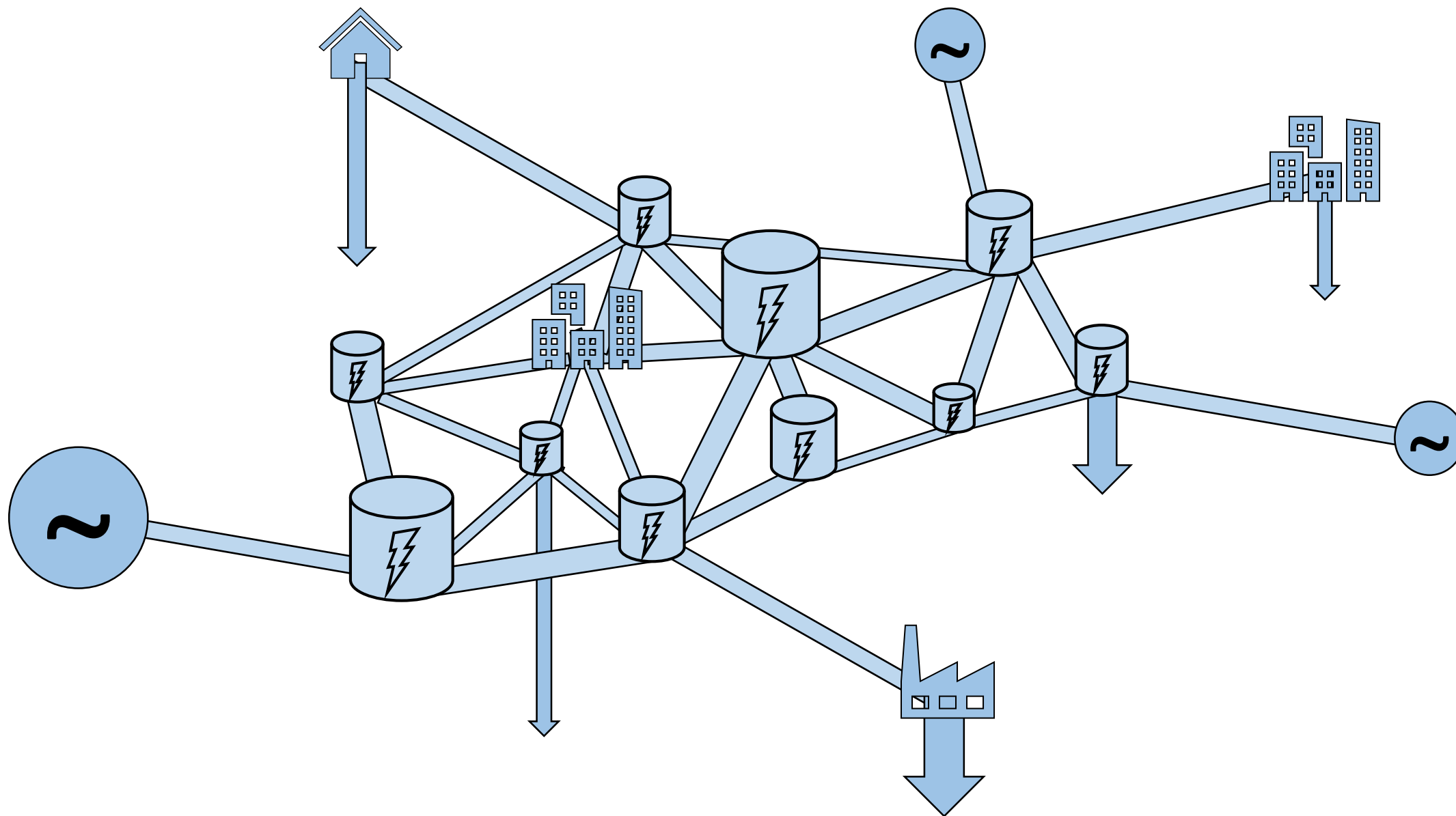
Optimized power flows in microgrid with and without distributed energy storage systems

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Model



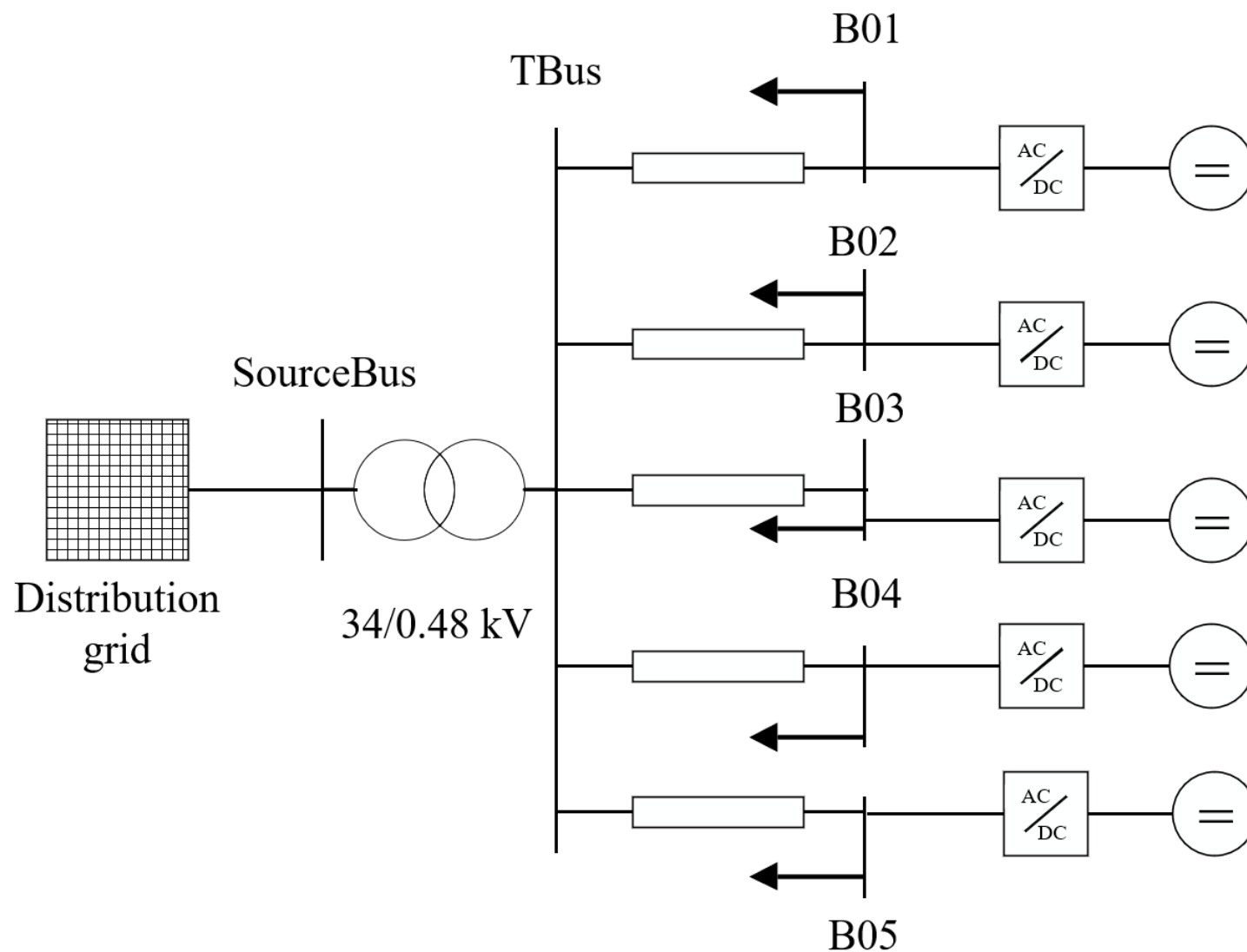


Radial network 0.48kV

- 5 loads
- 5 photovoltaic generators and inverters
- 5 power lines (cable)

Steady state calculation

- 1 hour interval
- 1 week total
- OPEN DSS software
- Gams optimization

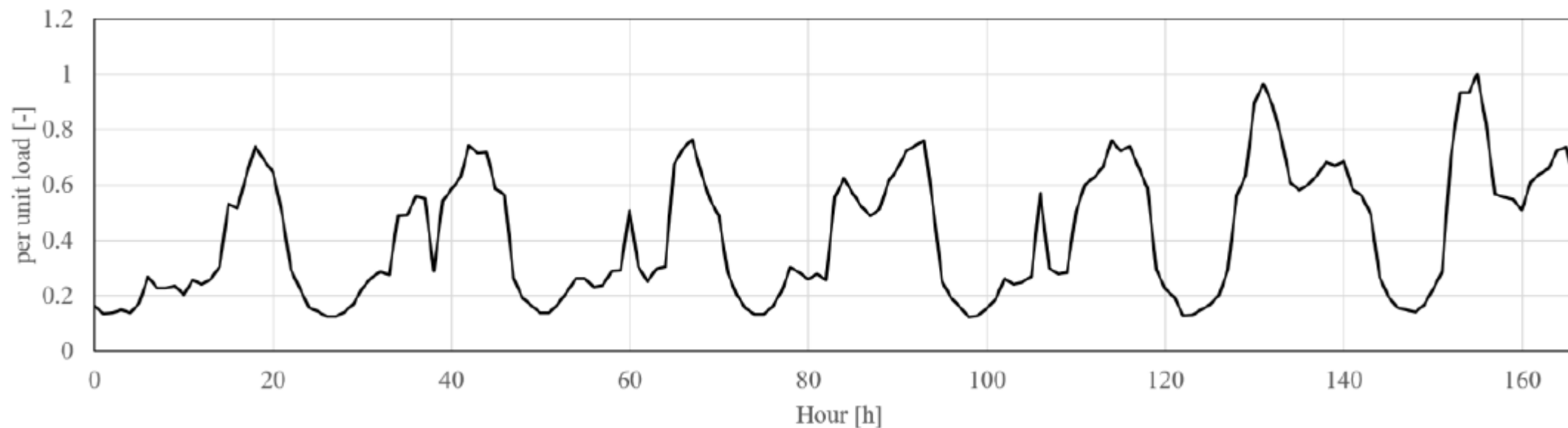




Load

$P = 90 \text{ kW}$

$P_f = 0.98$

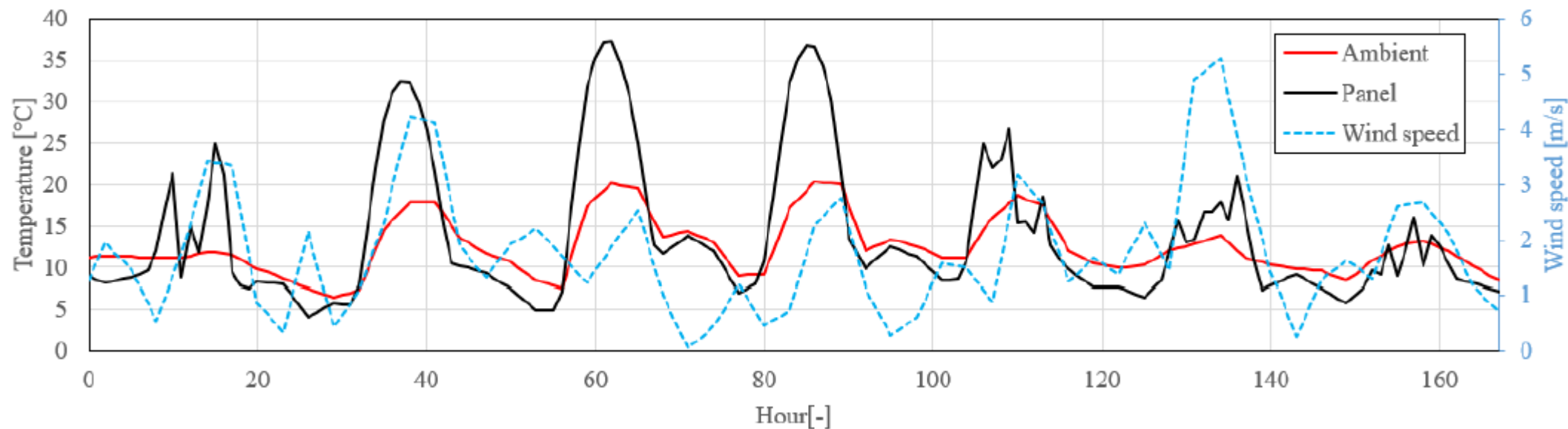




PV system

Meteorological data

Installed PV capacity [kWp]	Inverter rating [kVA]	Bus connection
20	25	B01
40	45	B02
60	65	B03
80	80	B04
100	105	B05

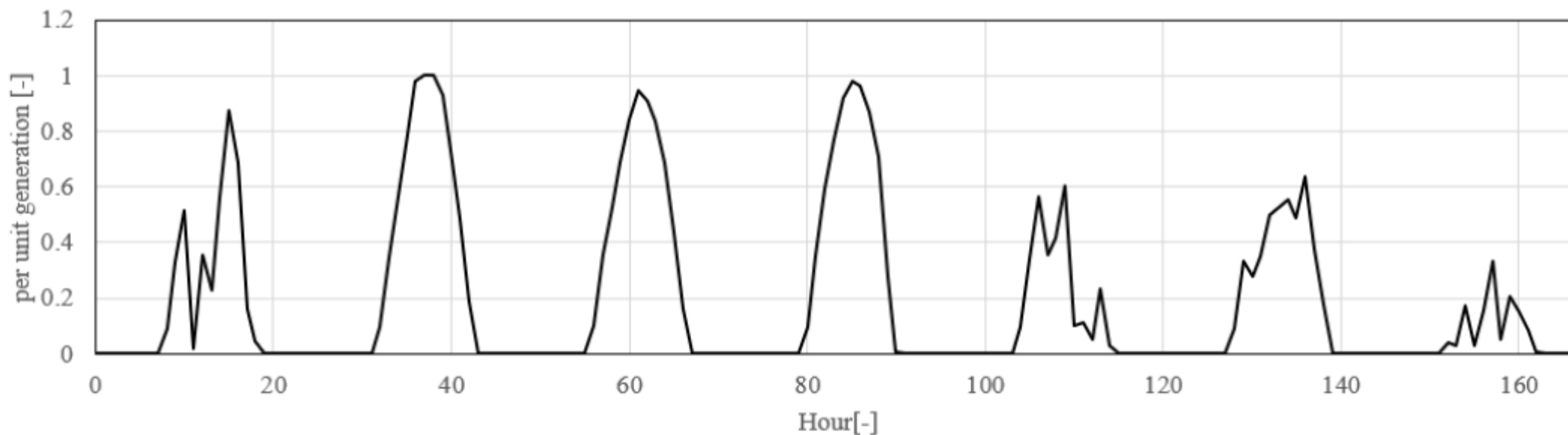




PV system

PV generation per unit

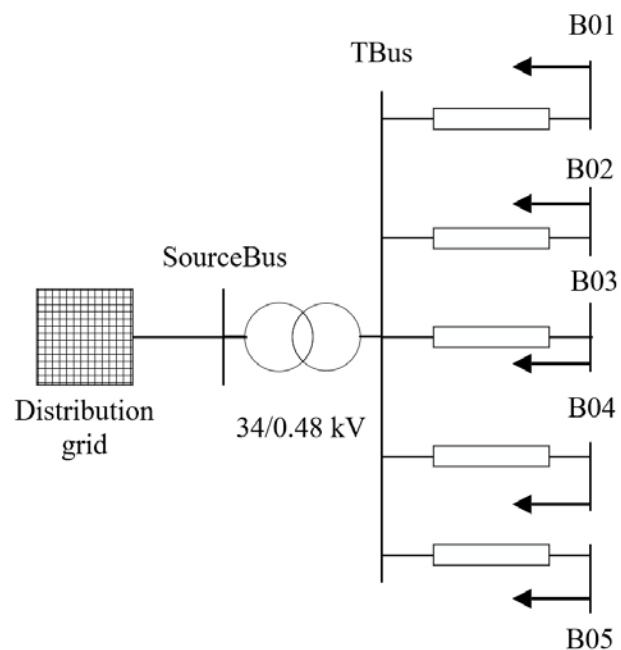
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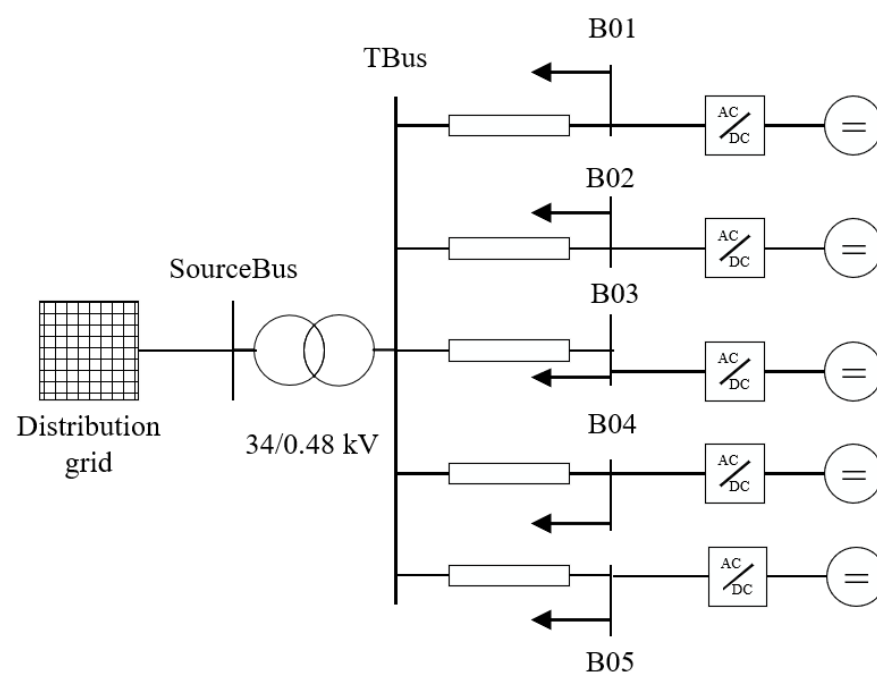


Model cases

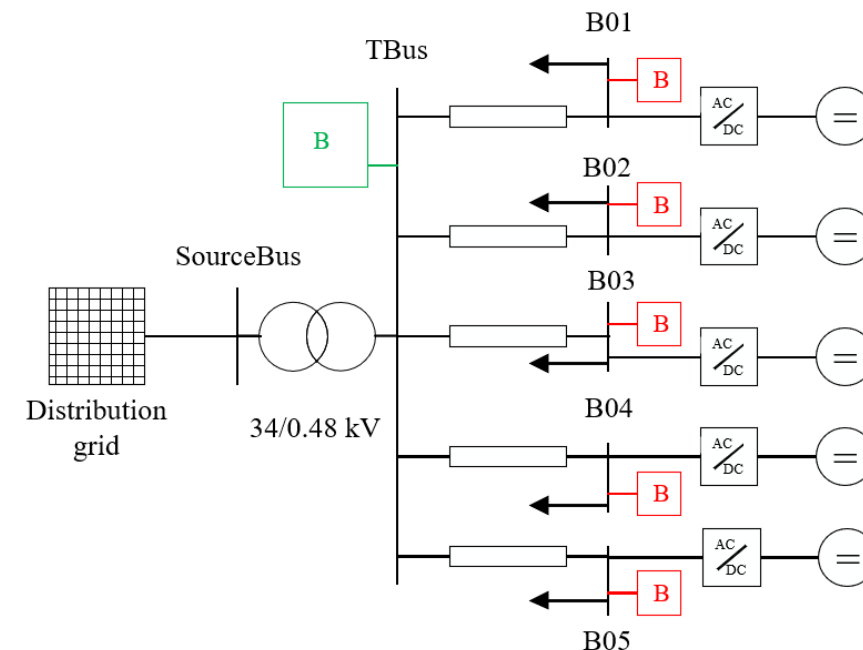
A)



B)



C) D)





Optimization

Battery dispatch management - Algebraic optimization model in GAMS

Optimization of battery dispatching strategy in order to :

- Minimize cost of electricity (price arbitrage)
- Minimize peak demand charges

Model input data:

peak demand charges per year : 55 000 USD/MW/year

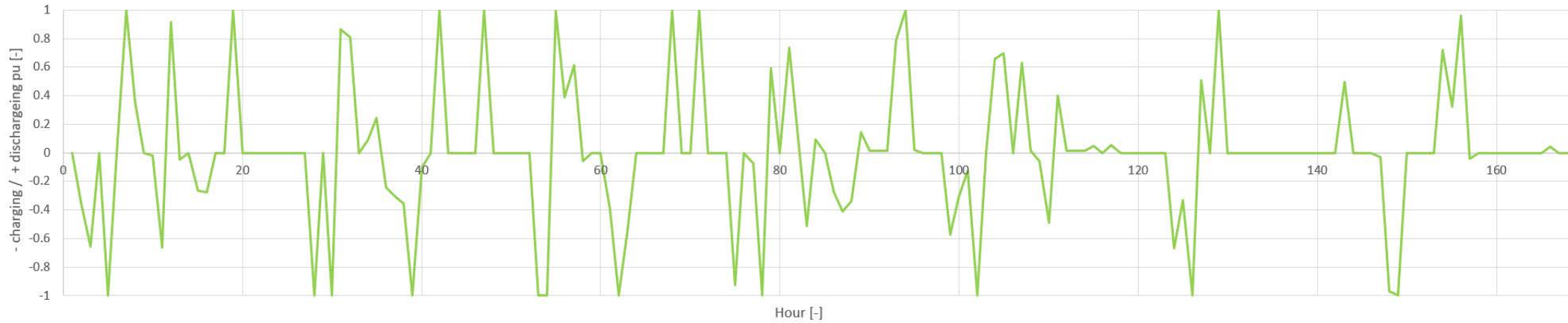
Electricity cost : 0.04245 USD/kWh (6am-12am) and 0.036 USD/kWh

Charging and discharging efficiency : 95%

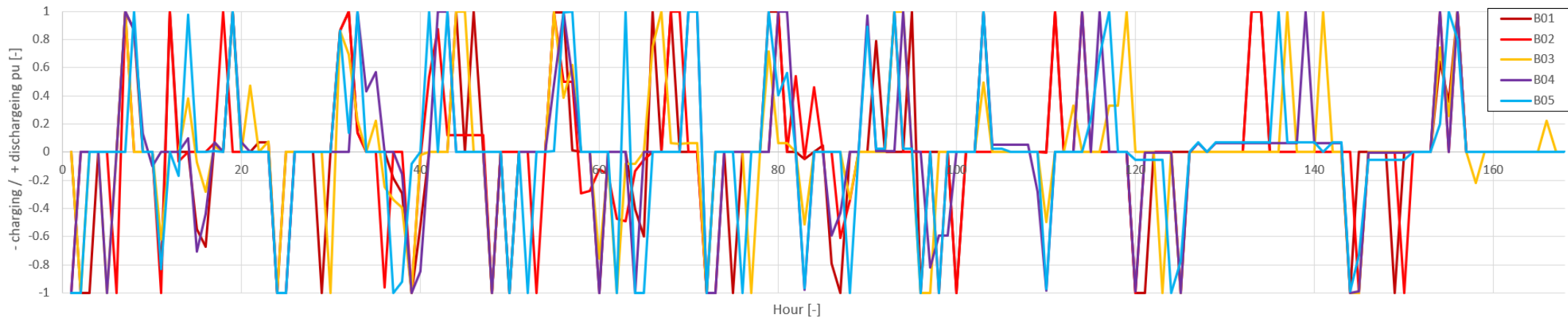




Optimal dispatch management for the single battery (battery pool)



Optimal dispatch management for distributed batteries

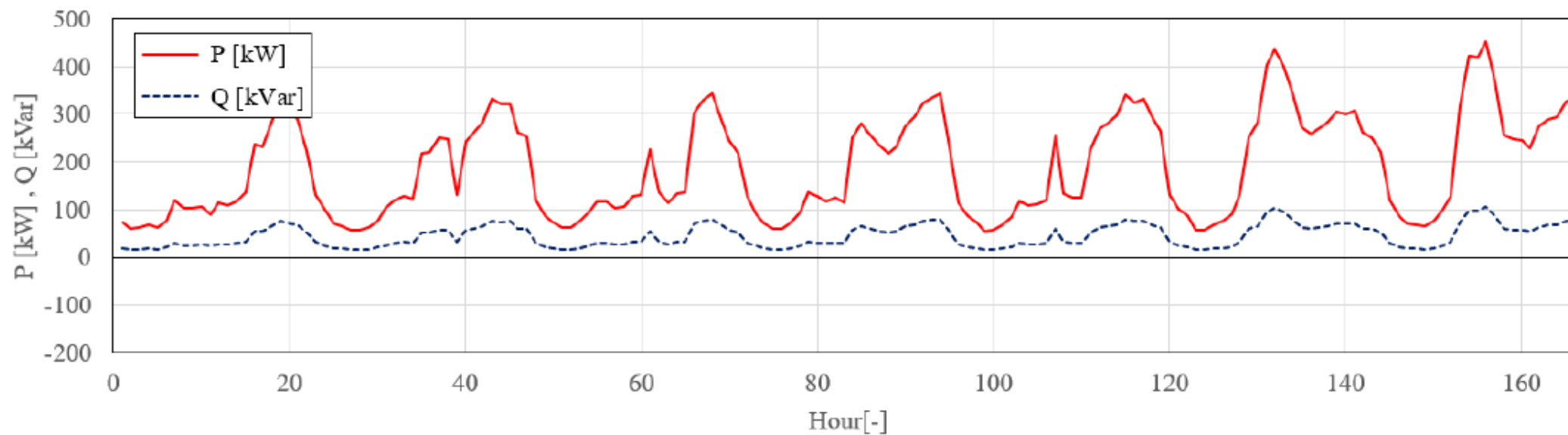


Load flow

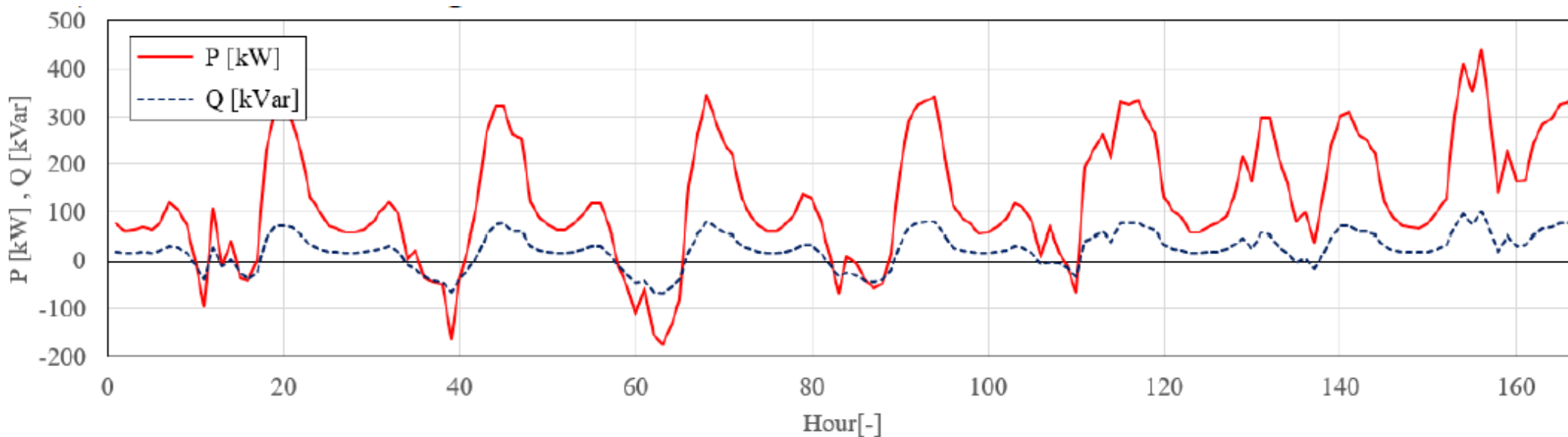
HV side of transformer



A)

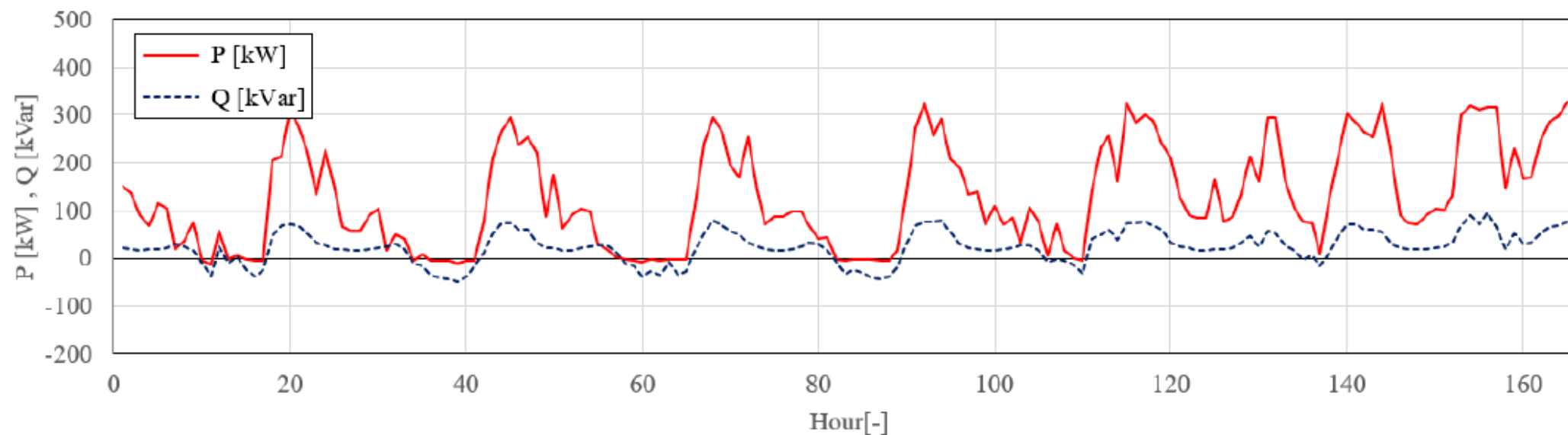


B)

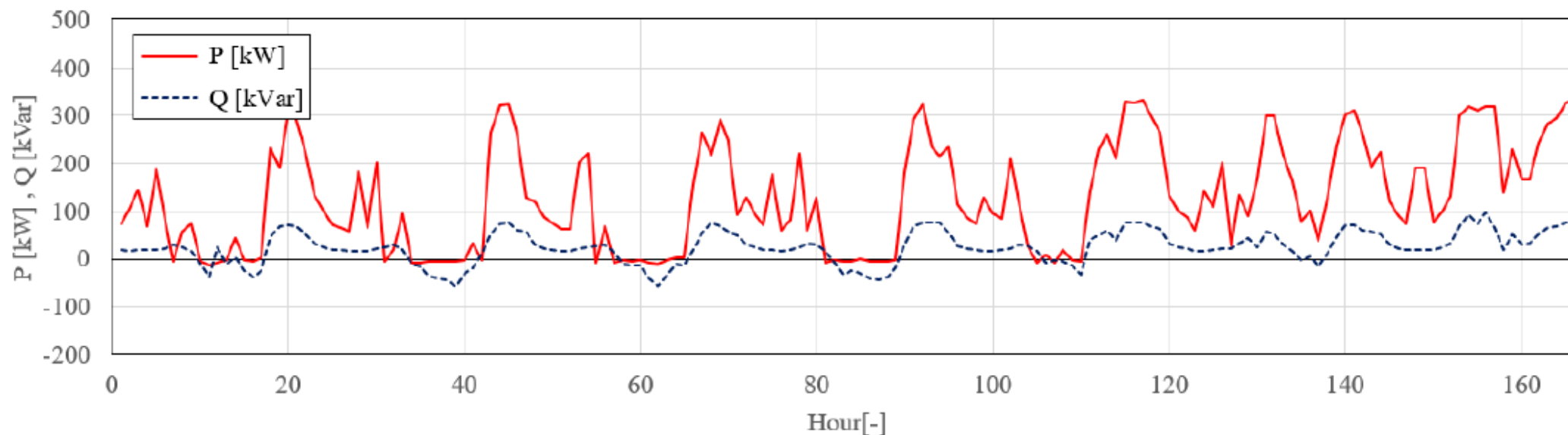


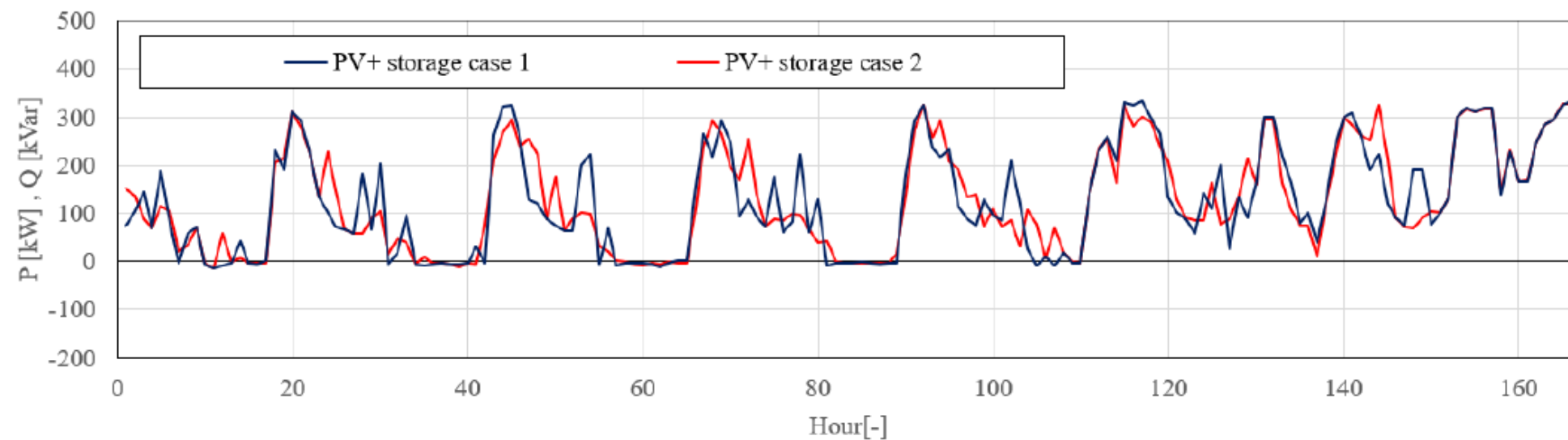
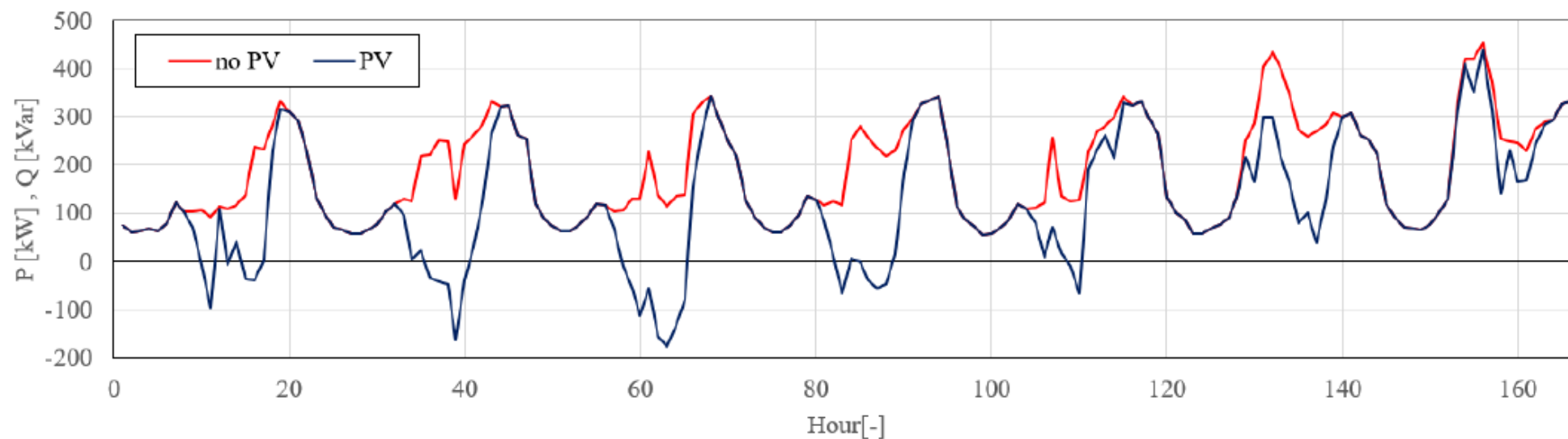


C)



B)





Results





Results

Losses

		Lines	Transformer ΔP [kWh]
A)	no PV	260.00	321.00
B)	PV	194.00	194.00
C)	PV+ storage case 1	188.00	296.00
D)	PV+ storage case 2	180.00	180.00

Power flow

		Into the grid		Out of the grid	
		P [kWh]	Q [kVArh]	P [kWh]	Q [kVArh]
A)	no PV	31477.33	7558.02	0.00	0.00
B)	PV	22360.10	5009.73	1583.41	1082.91
C)	PV+ storage case 1	21645.09	4999.34	192.85	904.33
D)	PV+ storage case 2	21617.30	4991.30	128.60	906.73



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Results

		P [kW]		Q [kVar]		S [kVA]
A)	no PV	451.14		106.34		463.51
B)	PV	439.08	↓	101.89	↓	439.08
C)	PV+ storage case 1	333.68	↓	98.66	↓	347.95
D)	PV+ storage case 2	327.11	↓	96.67	↓	341.09

Maximum transmission loading of transformer

Conclusions

- Complex calculating model of small distribution grid was developed (algebraic optimization GAMS + power flow OPEN DSS). Scenarios with solar generation, battery pool and distributed batteries were compared and quantified
- Distributed batteries have proven to be the best option. Minimizing:
 - Power losses in the grid
 - Active and reactive power flow out of the grid
 - Maximum transmission loading of the transformer
- Reliability and resiliency will still stay as major deciding factors between both battery scenarios

Thank you for
your attention