

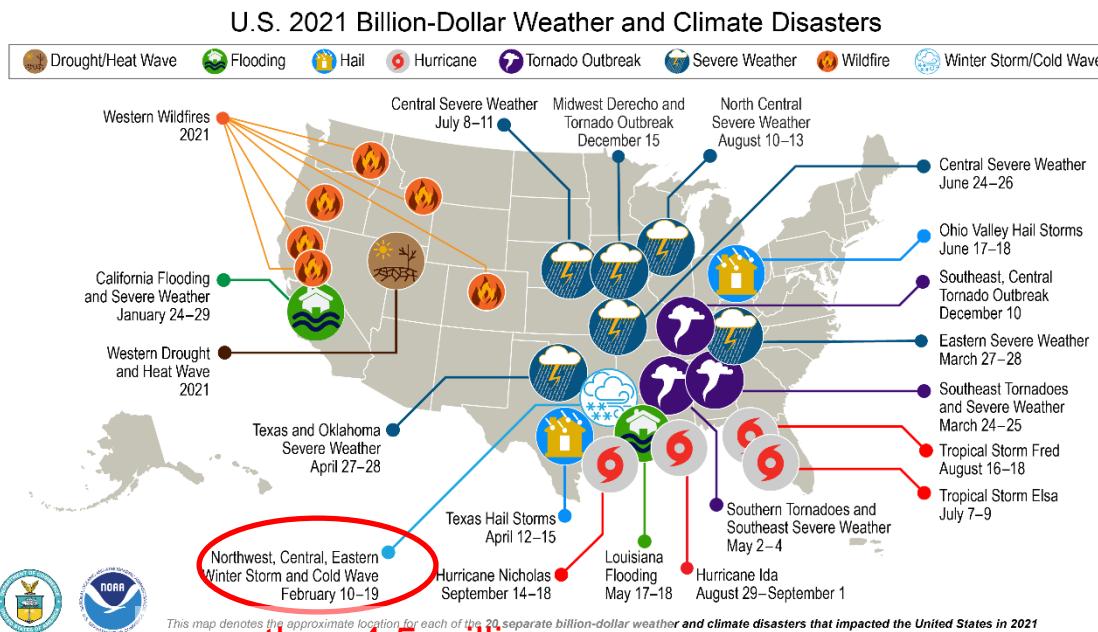
- **PhD, North Carolina State University (NCSU), FREEDM System Center**
  - Electrical engineering, 2019.08 - 2023.12
  - *Advisor: Dr. Ning Lu (IEEE Fellow)*
  - *Dissertation: Energy Management System of Renewable-powered Microgrids for Resilience Service in Distribution System*
- **Internship, Pacific Northwest National Laboratory (PNNL)**
  - Optimization and Control Group, 2021.07 – 2021.10
  - *Mentor: Dr. Di Wu*
  - *Project: Avista's Shared Energy Economy Model Pilot: A Techno-economic Assessment*
- **Electrical Engineer, China Southern Power Grid Co., Ltd.**
  - Operation and maintenance for 110-500kV power systems
- **Master, South China University of Technology (SCUT)**
  - Power System and Its Automation, 2013.09 - 2016.06
  - *Thesis: Capacity Configuration Optimization for Islanded Microgrid Considering Demand Response*
- **Bachelor, South China University of Technology (SCUT)**
  - Electrical Engineering, 2009.09 - 2013.06

- **Energy Management System of Renewable-powered Microgrids for Resilience Service in Distribution System (Proj-1)**
  - Research Background and the Project
  - Energy Management System(EMS) Design
    - Overview
    - Flexible topology control
    - Adaptive cold load pickup model
- Other Projects
  - Energy Storage Application Analytics (Proj-2)
  - Avista's Shared Energy Economy Model Pilot (Proj-3)
  - Coordinated Real-time Sub-Transmission Volt-Var Control Tool (Proj-4)
- Ongoing Work and Future Work

# Background

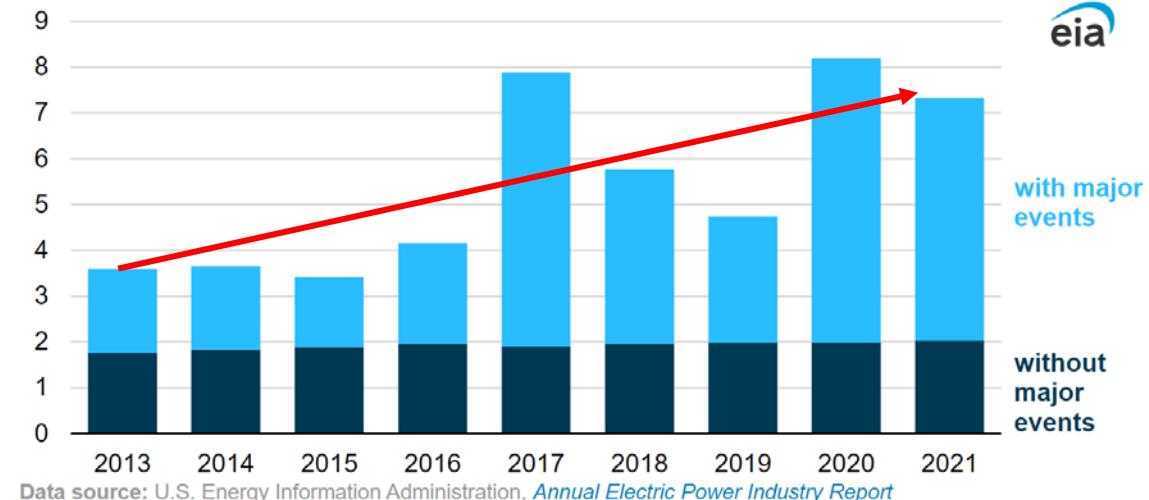
- Surging Extreme Weather Events[1]

- Large scale, long-duration, high loss disasters
- Doubled weather event related power outage in the last 10 years
- Resilience service needs



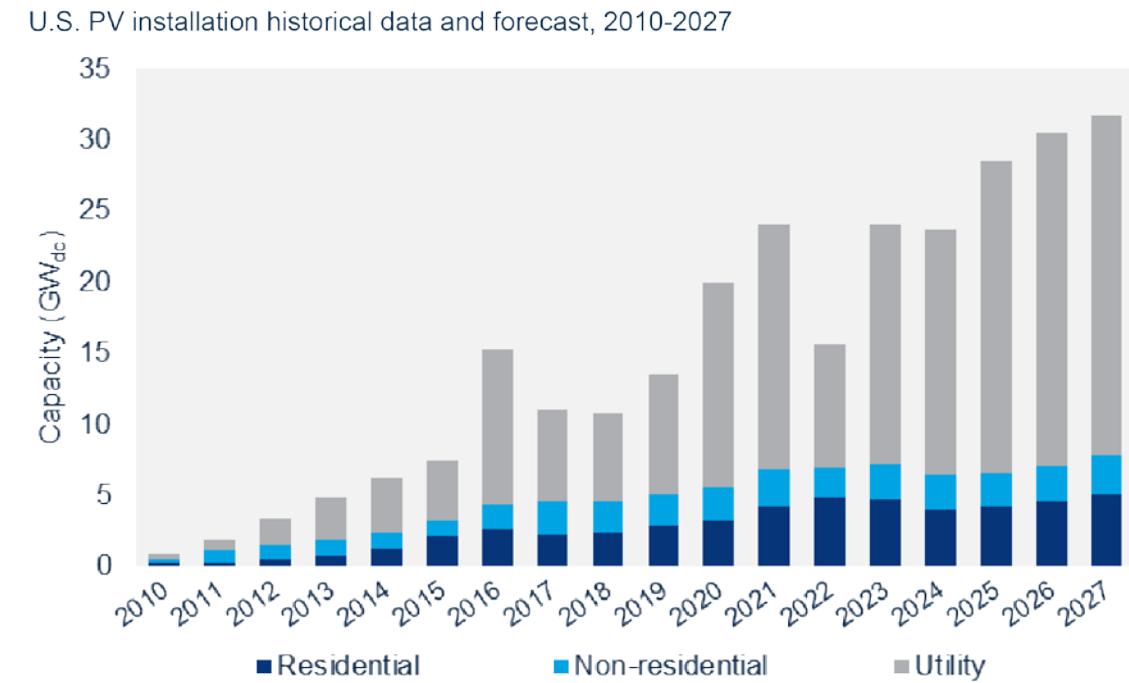
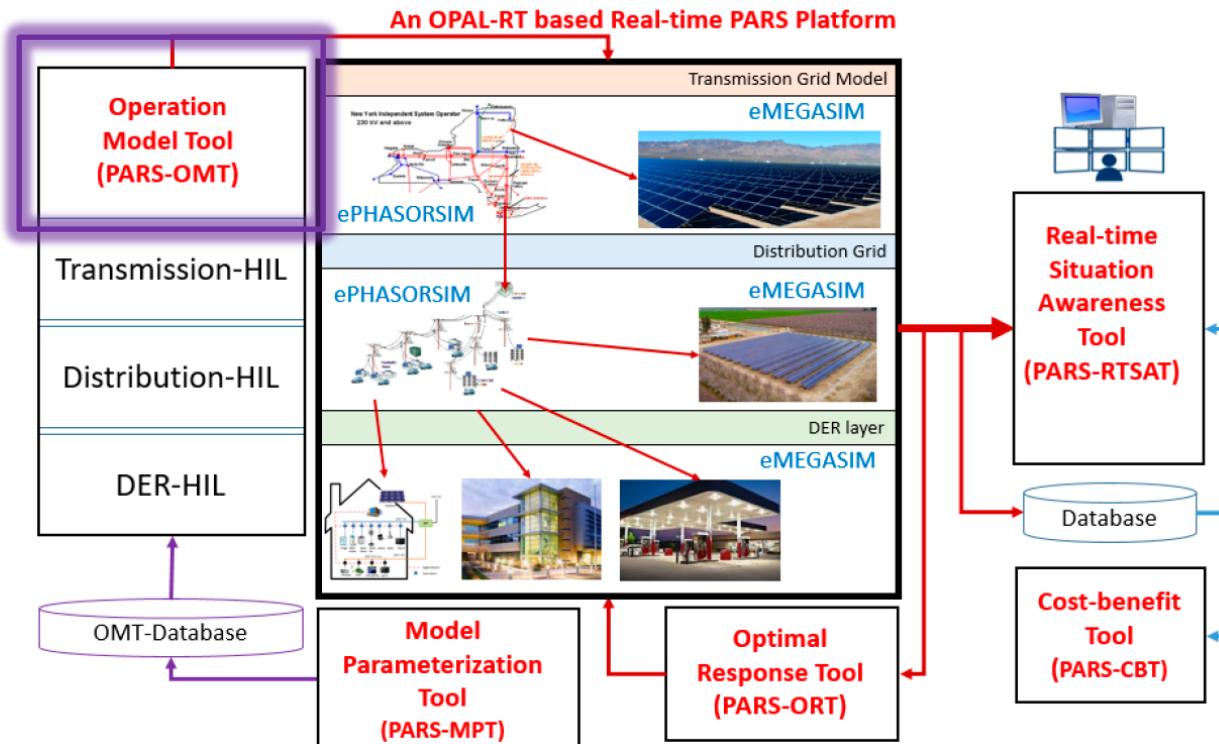
more than 4.5 million homes lost power

Average duration of total annual electric power interruptions, United States (2013–2021)  
hours per customer



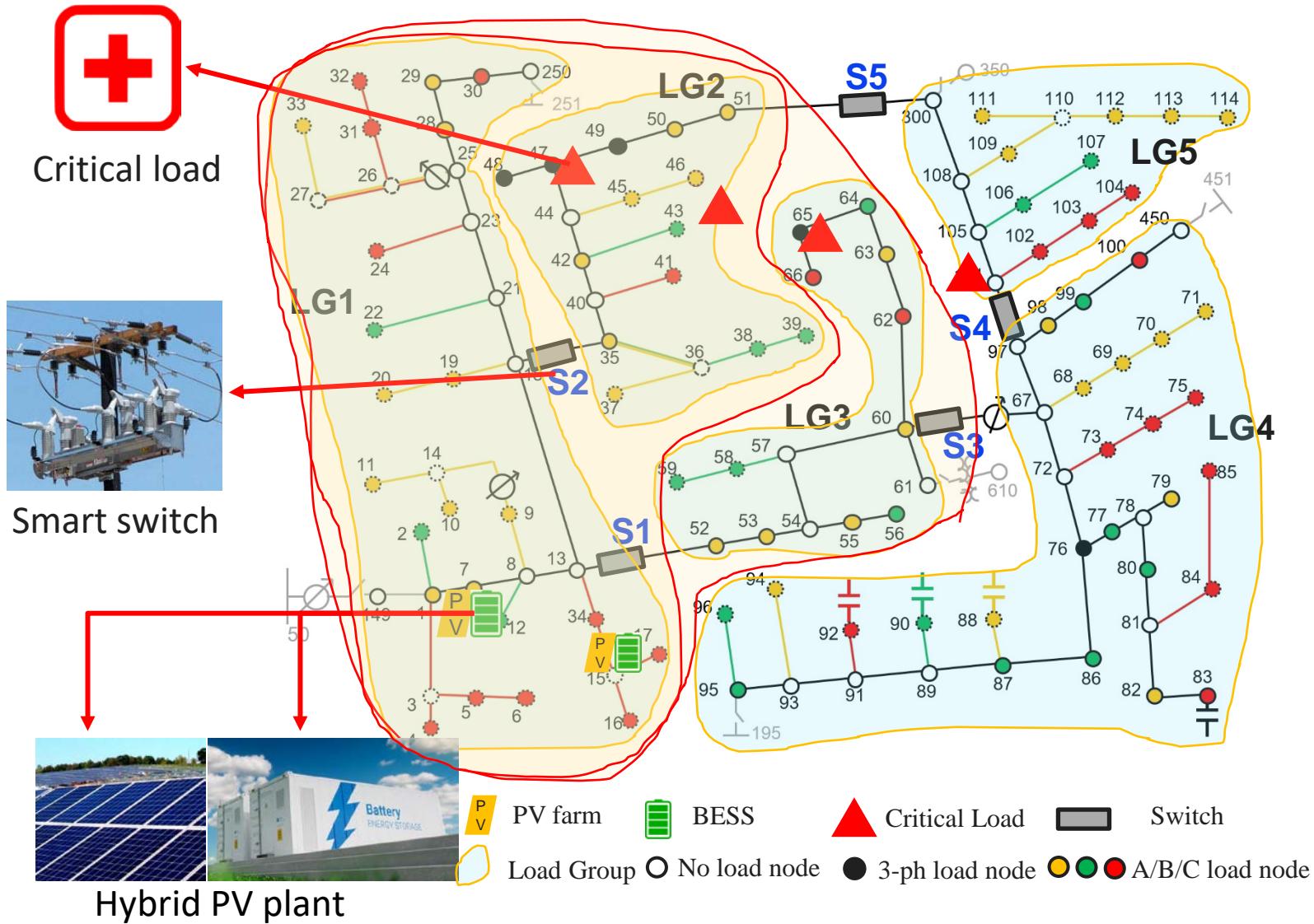
[1] NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2022)", accessed on Nov. 14, 2022. [Online]. Available: <https://www.ncei.noaa.gov/access/billions/>, DOI: 10.25921/stkw-7w73

- Photovoltaic Analysis and Response Support Platform for Solar Situational Awareness and Resiliency Services (ASSIST)[1-2]
  - Department of Energy, \$3.1 M, 2019.12 - 2023.12
  - Mainly focuses on resiliency service in the distribution system
    - Cases: 1) Utility MW-level PV plant; 2) Commercial community-level; 3) residential/rooftop-level



[1] <https://sites.google.com/a/ncsu.edu/ninglu/pars-platform>

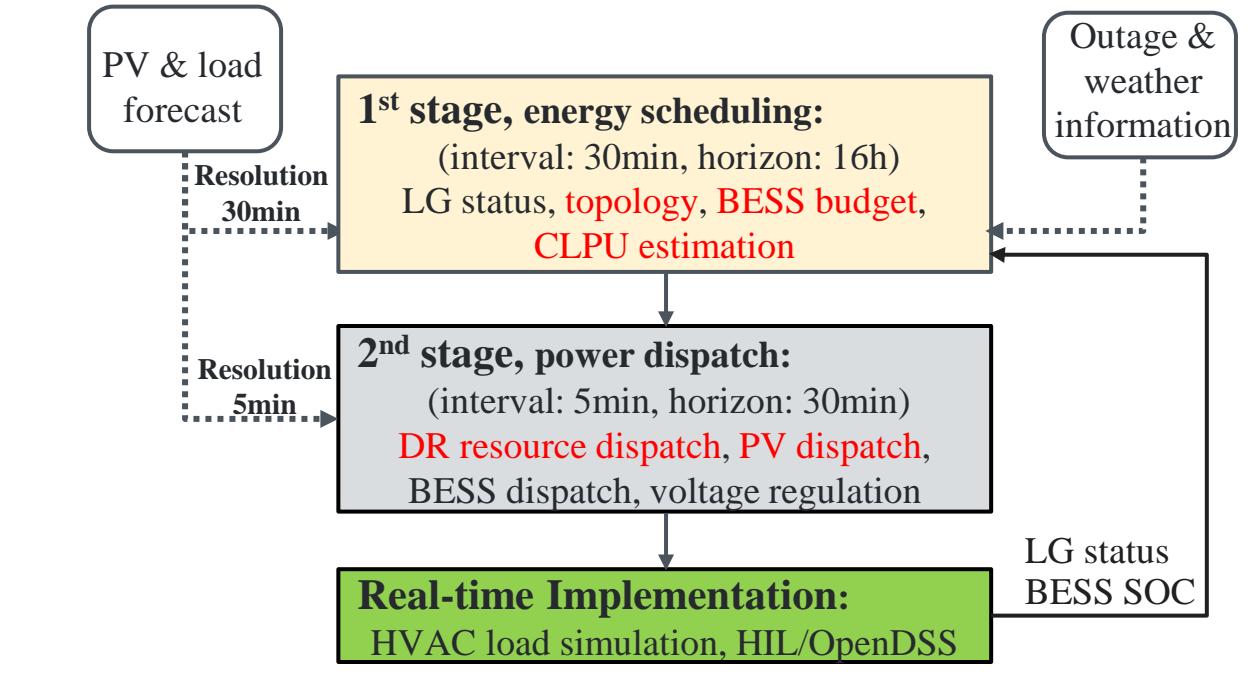
[2] final report <https://www.osti.gov/biblio/2349508>



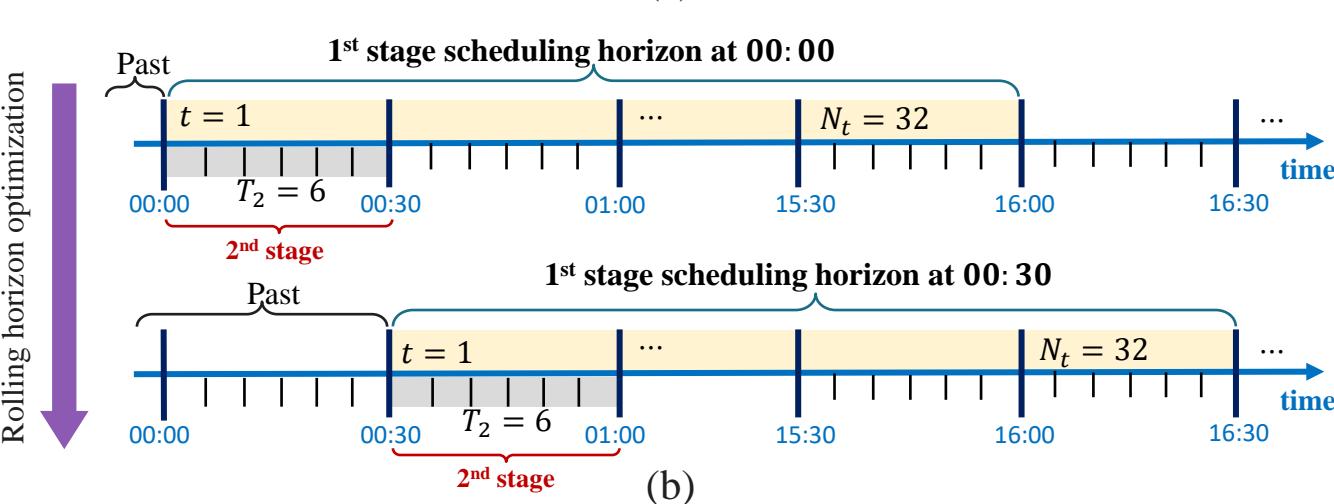
## EMS design

- Resilience service via temporary microgrid
  - Amount of served loads
- Main Design Considerations
  - Long duration: up to days
  - Radial topology control
  - Dynamic microgrid boundary
  - Customer comfort
  - Cold Load Pickup
  - Phase Load imbalance

# Two-stage Rolling Scheduling



(a)



- **1<sup>st</sup> stage: energy scheduling**

$$\max \sum_{t=1}^{N_t} \sum_{m=1}^{N^G} \sum_{p \in \{a,b,c\}} U_{m,t}^G w_t^{\text{pref}} w_{m,p}^{\text{crit}} P_{m,p,t}^{\text{load}} \Delta t - c_1^{\text{PV}} f_1^{\text{PVcurt}}$$

**PV curtailment**

$$- f_1^{\text{CLPU}}$$

**CLPU penalty**

- **2<sup>nd</sup> stage: power dispatch**

$$\min \sum_{t'=1}^{T_2} \sum_{i=1}^{N^{\text{Node}}} \sum_{p=1}^3 U_{i,p,t'}^{\text{DR}} P_{i,p,t'} \Delta t' + c_2^{\text{low}} \Delta E^- + c_2^{\text{PV}} f_2^{\text{PVcurt}}$$

**Amount of load shedding**

**BESS deviation (< the setpoint)**

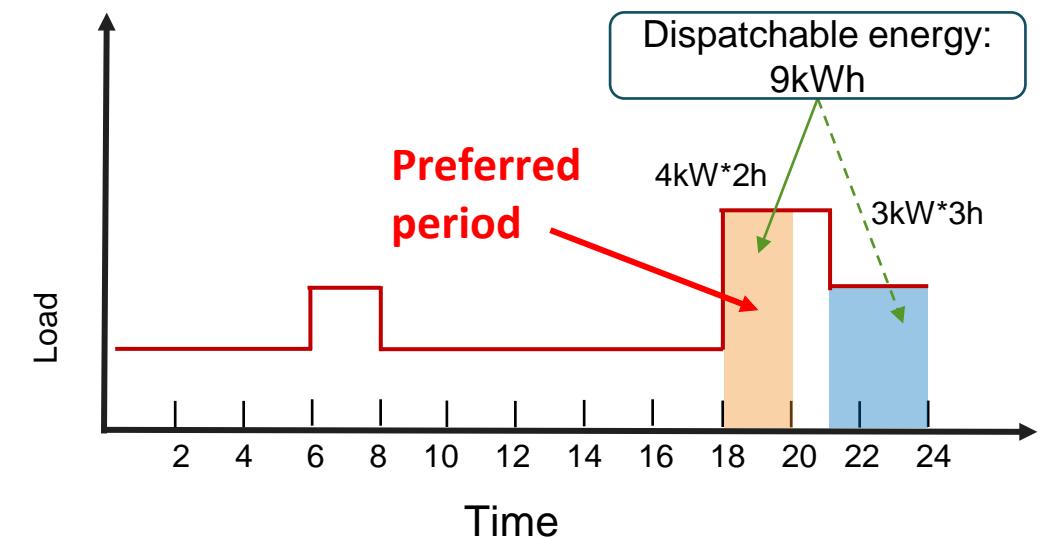
- Customer comfort consideration

- Critical load
- Minimum service duration (MSD)
- Preferred service period

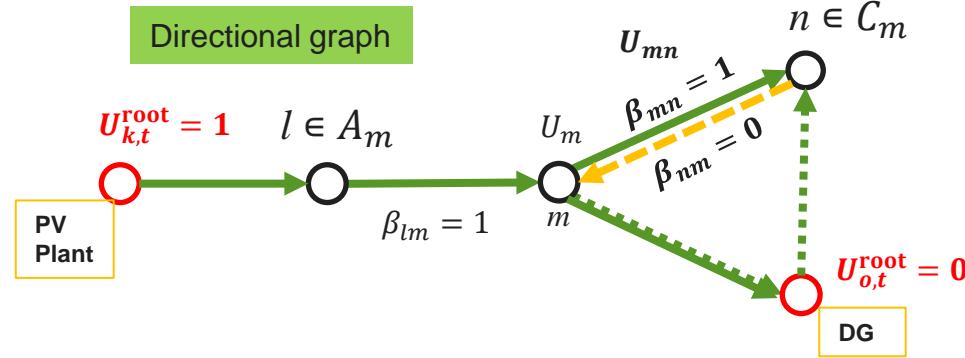
$$\max \sum_{t=1}^{N_t} \sum_{m=1}^{N^G} \sum_{p \in \{a,b,c\}} U_{m,t}^G w_t^{\text{pref}} w_{m,p}^{\text{crit}} P_{m,p,t}^{\text{load}} \Delta t - c_1^{\text{PV}} f_1^{\text{PVcurt}} - f_1^{\text{CLPU}}$$

Minimum service duration	Time /hour									
	1	2	3	4	5	6	7	8	9	10
-	✓		✓		✓		✓		✓	
2 hour	✓	✓		✓	✓		✓	✓	✓	
3 hours	✓	✓	✓		✓	✓	✓		✓	✓
4 hours	✓	✓	✓	✓					✓	✓

Frequent interruptions

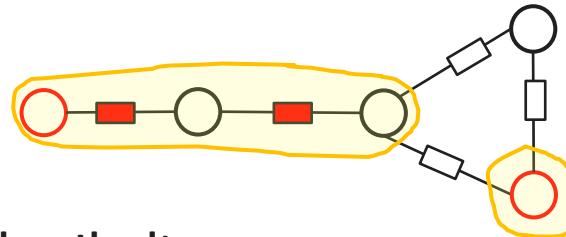


- Energy Management System of Renewable-powered Microgrids for Resilience Service in Distribution System (Proj-1)
  - Research Background and the Project
  - Energy Management System(EMS) Design
    - Overview
    - **Flexible topology control**
      - **A new set of constraints**
      - **Simulation results**
    - Adaptive cold load pickup model
- Other Projects
- Ongoing Work and Future Work



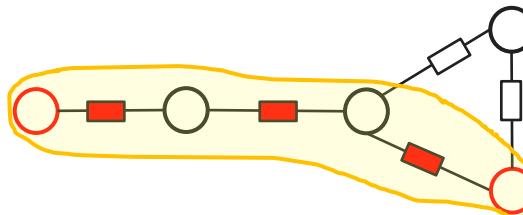
### Spanning-tree Method [1]:

- Allow only 1 grid-forming source to supply a microgrid



### Developed method:

- Allow multiple grid-forming sources to co-supply a microgrid



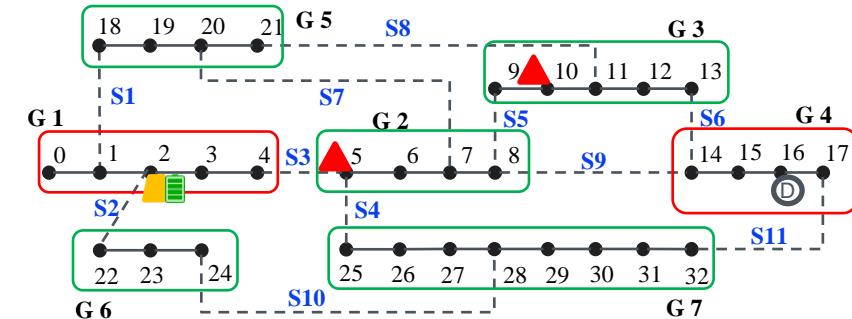
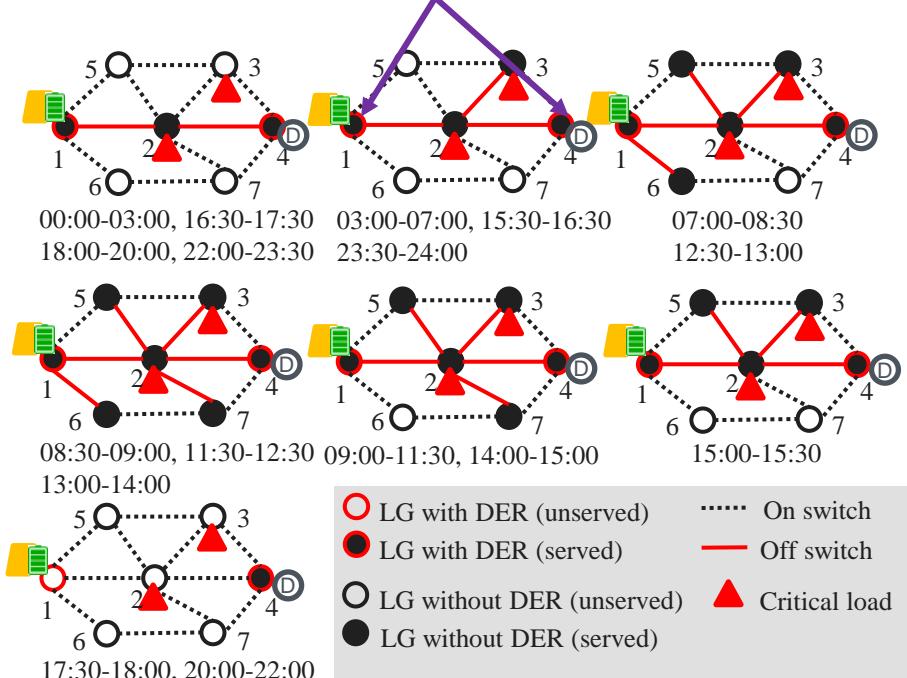
### Topology control

- Typical method: Spanning tree based
- Proposed method
  - Optimizing the number of microgrids
  - Maximizing the total benefit of different DERs
  - Diesel generator runs at the max power
  - root candidate variable  $U_{m,t}^{\text{root}}$

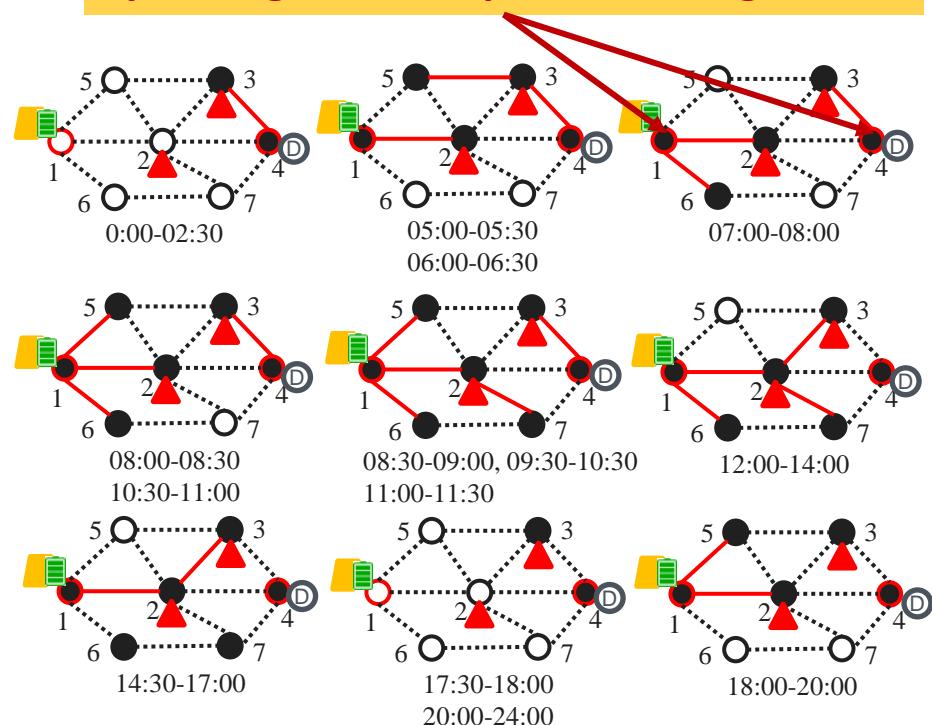
$$U_{m,t}(t) - U_{m,t}^{\text{root}} \leq \sum_{n \in A_m \cup C_m} \beta_{nm,t}(t) \leq \frac{U_{m,t} + U_{m,t}^{\text{root}} + 1}{2}$$

- Accounting for feeder topology constraints
  - Flexible topology constraints that allow multiple grid-forming sources to cooperate in one or more microgrids
    - IEEE 33-bus system, day-ahead
    - More served load, less switching operations

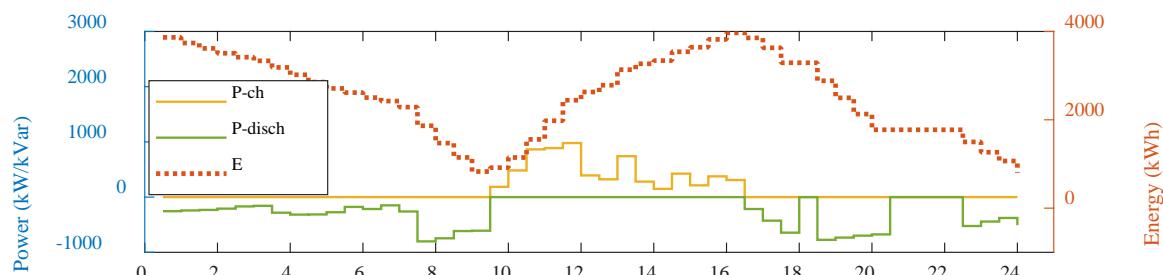
**Proposed: 2 sources power 1 microgrid**



**Spanning tree: 2 separate microgrids**

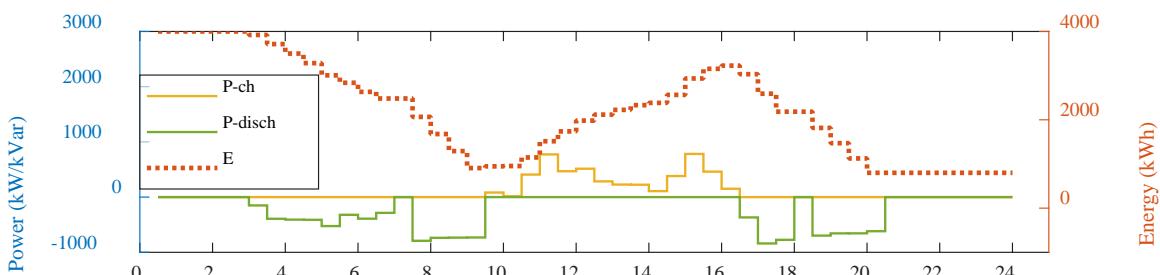


- **Coordinating Multiple DERs in a Microgrid**
  - IEEE 33-bus system, day-ahead
  - More served load, less switching operations



DG maintains Max. power

Multi-source cooperation	Total supply (kWh)			Critical load served time (h)		Num of Switching Operation
	Total	From DG	From PV plant	Node 5	Node 10	
✓	<b>22,818</b>	<b>8,054</b>	14,765	<b>21.5</b>	14	<b>23</b>
✗	20,492	5,646	14,846	14.5	<b>16.5</b>	36



DG outputs at low level

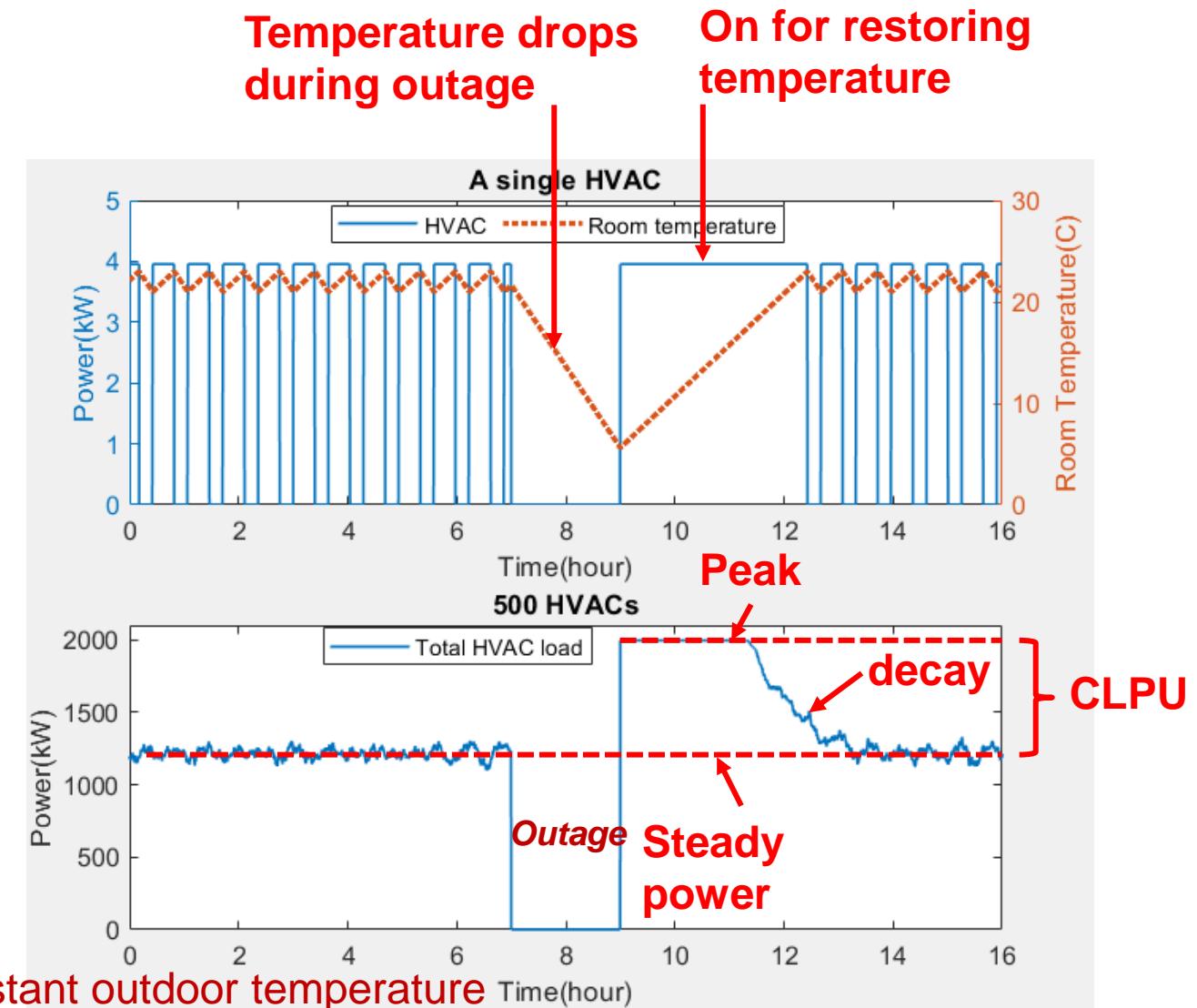
Proposed: DG mainly within the microgrid hybrid PV formed

Existing: DG and hybrid PV plant run separate microgrids

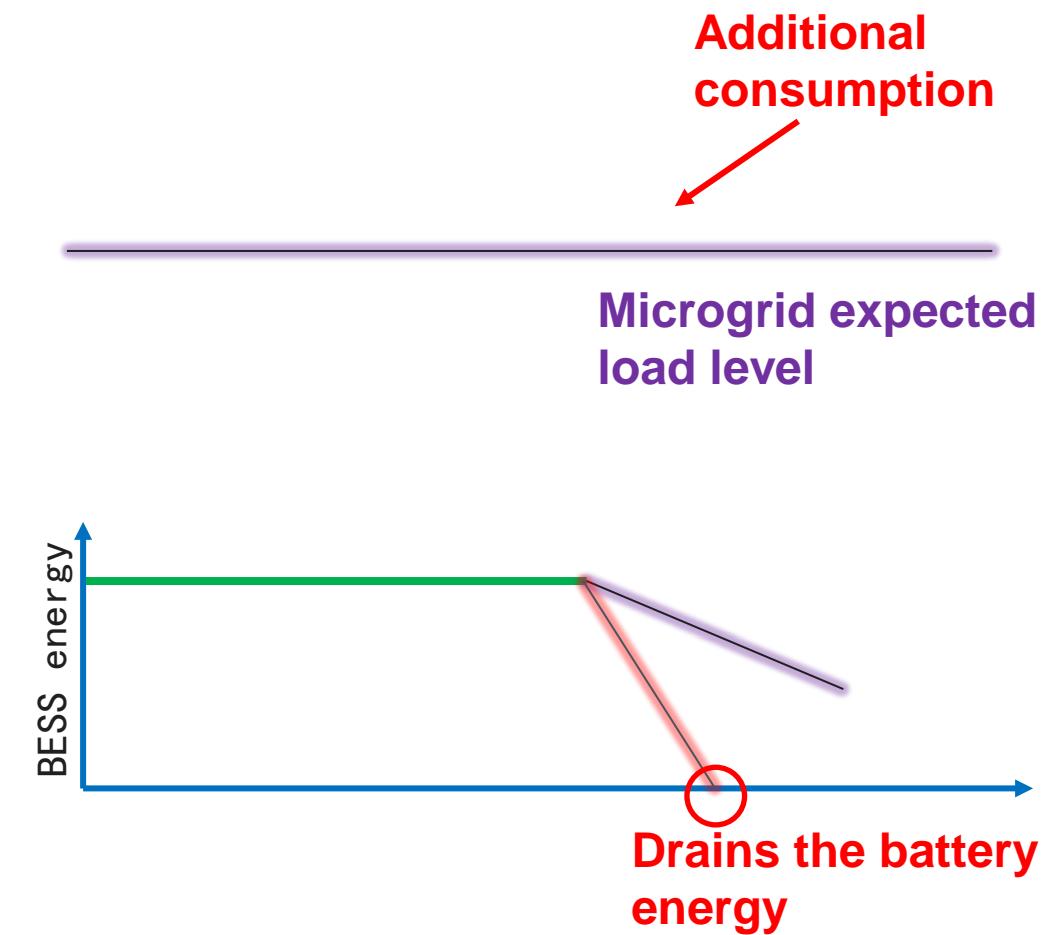
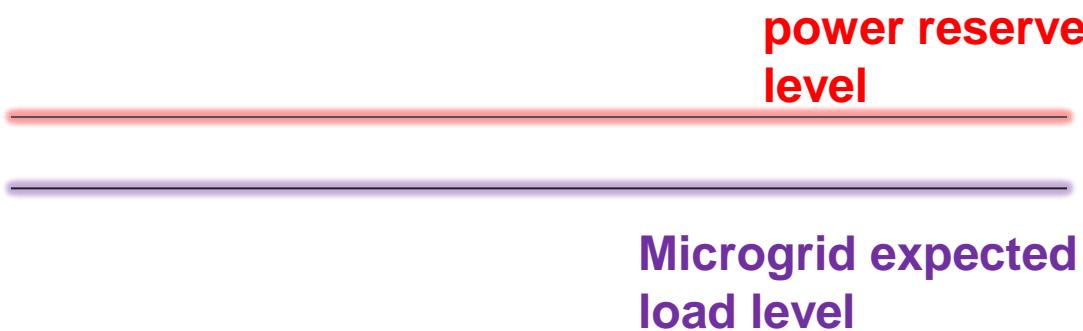
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- CLPU phenomenon

- After interruptions, the Heating, Ventilation, and Air Conditioning (HVAC) all are turned on simultaneously
- Significantly more consumption since HVACs occupies **50% load**
- Steady power, CLPU peak, decay

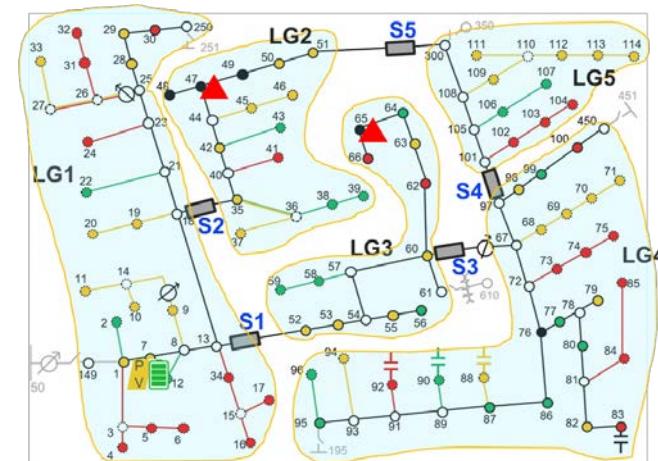
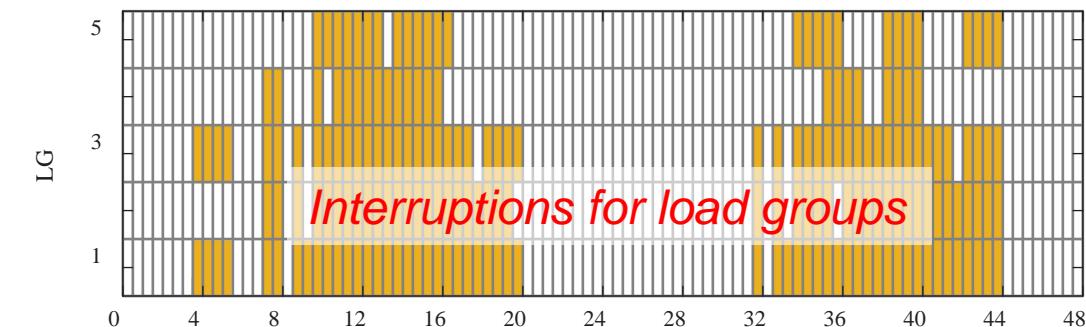
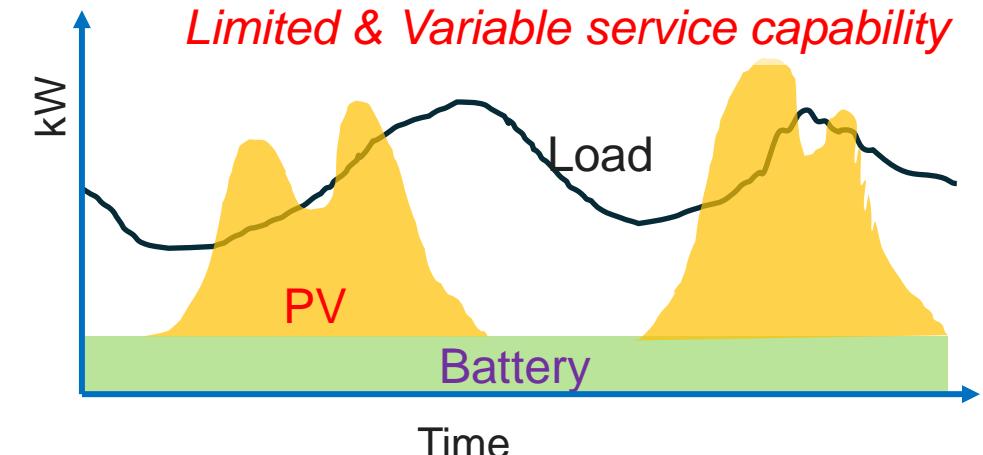


- If CLPU is not considered
  - There may **not be enough power reserve** to meet the load.
  - There will be an **energy deficit** in the hour where cold load pickup is required
  - Microgrid is forced to **shut down**



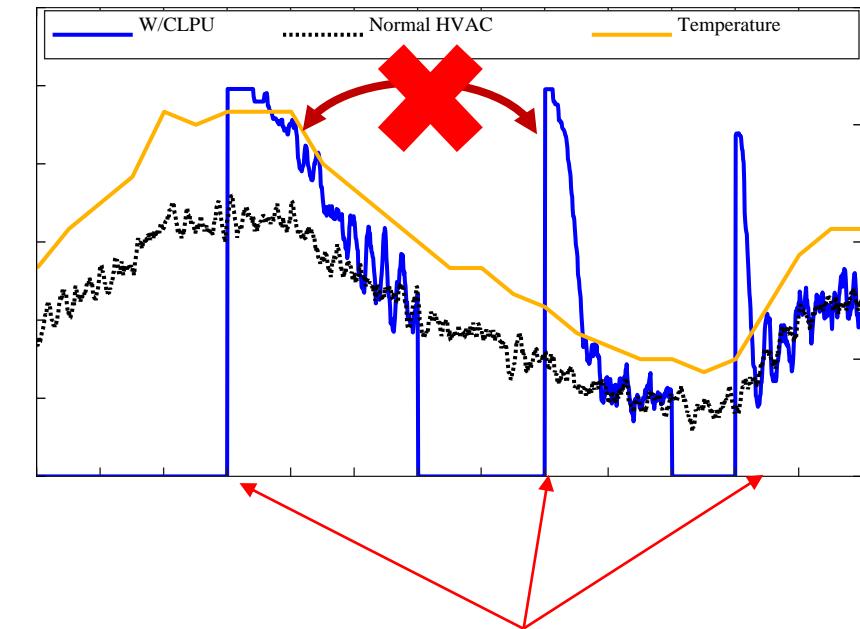
# Why modeling CLPU effects?

- **Multiple-interruptions:** Service interruptions are inevitable for microgrid powered by intermittent generation resources
  - Main power sources are **intermittent**: PV and wind
  - **Limited** power storage capacity
  - **Time-varying** load
  - **Load shedding** is needed for maintaining power and energy balance
  - Thus, multiple **CLPU** events are expected



- **Fixed CLPU [1]**
  - Obtained by CLPU under a **specified temperature and interruption scenario**
  - **Same curve parameter** used for all scenarios
  - **Very low accuracy**
    - CLPU is **sensitive** to temperatures and interruptions
  
- **Candidate [2]**
  - Generate a set of CLPU profiles considering **all CLPU occurrence scenarios** then EMS select one
  - **Impractical** when outage is long
    - The **number, timing(temperature), duration** of interruptions
    - **Too many candidates**

Sensitive to temperatures and interruptions



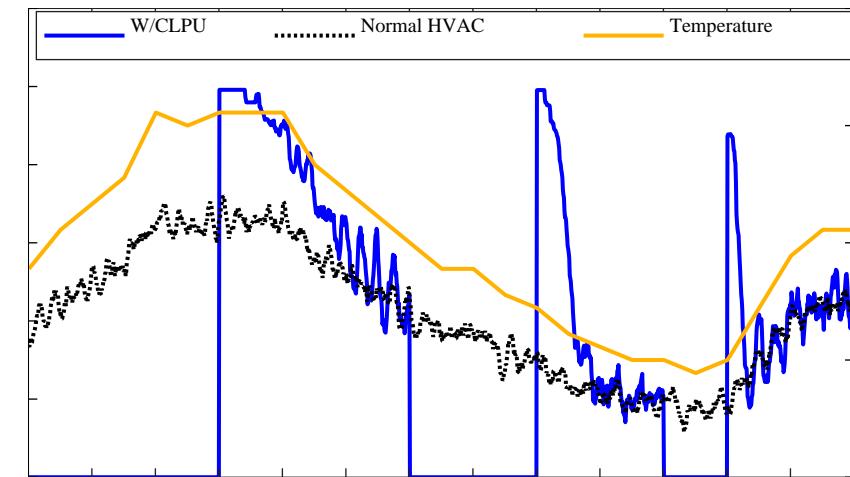
The number, timing, duration of interruptions are decided by the EMS !

[1] Chen B, Chen C, Wang J, Butler-Purry KL. Multi-time step service restoration for advanced distribution systems and microgrids. IEEE Trans Smart Grid 2018.

[2] Song M, Nejad RR, Sun W. Robust distribution system load restoration with time-dependent cold load pickup. IEEE Trans Power Syst 2021

- Challenges

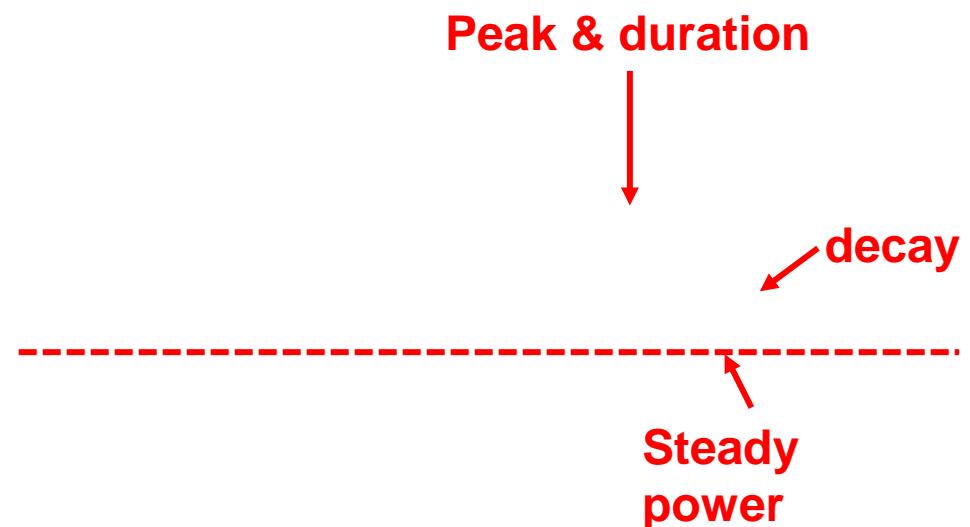
- CLPU model that **adapts** to time-varying temperature and variable interruption
  - Fixed CLPU
- No **exhaustive** CLPU simulation for each implementation
  - Candidate set
- In EMS, CLPU is decision dependent**, CLPU should be estimated within EMS



The number, timing, duration of interruptions are decided by the EMS !

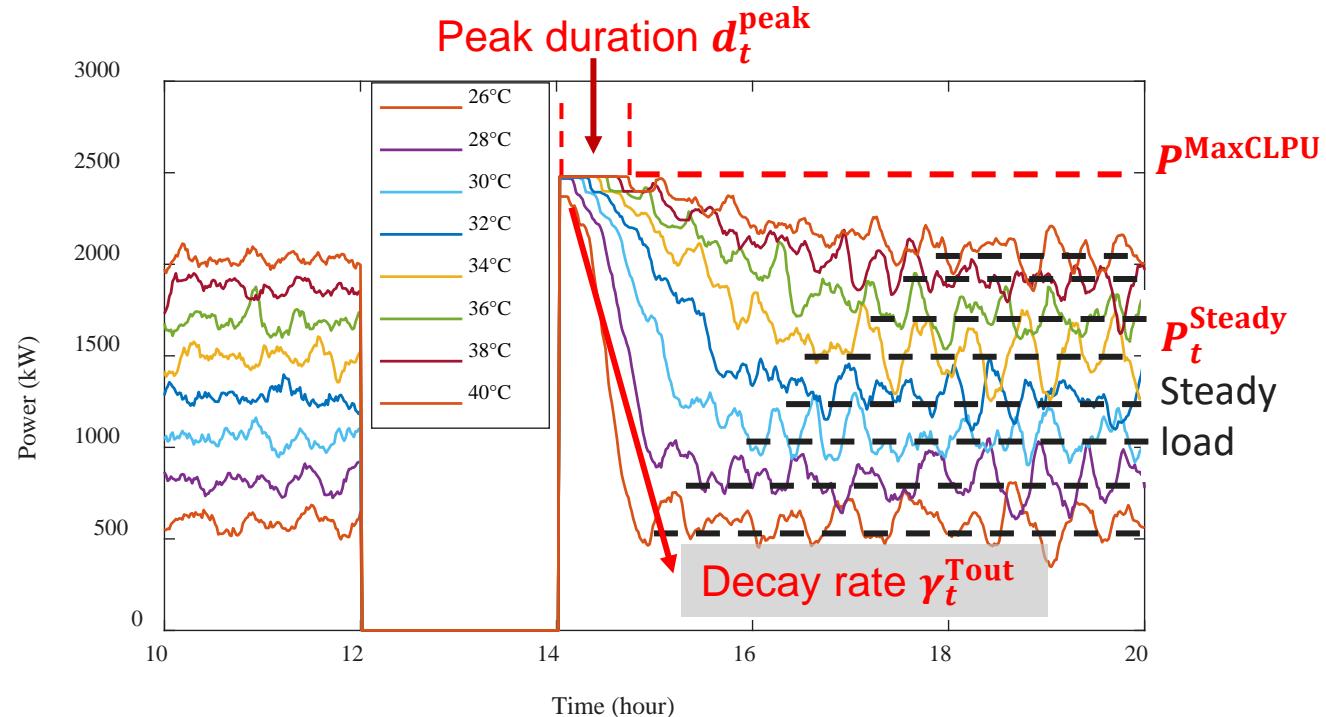
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- **Goal: Adaptive CLPU**
  - Adapt to temperature and interruption
  - No need CLPU simulation for each implementation
    - Use offline obtained parameters
- **CLPU feature identification**
  - Using 1100 heterogeneous HVACs
  - Simulate CLPU under different scenarios
    - Constant temperature: 22 - 40°C
    - Interruption duration: 1-12 hour
  - Identify characteristic parameters



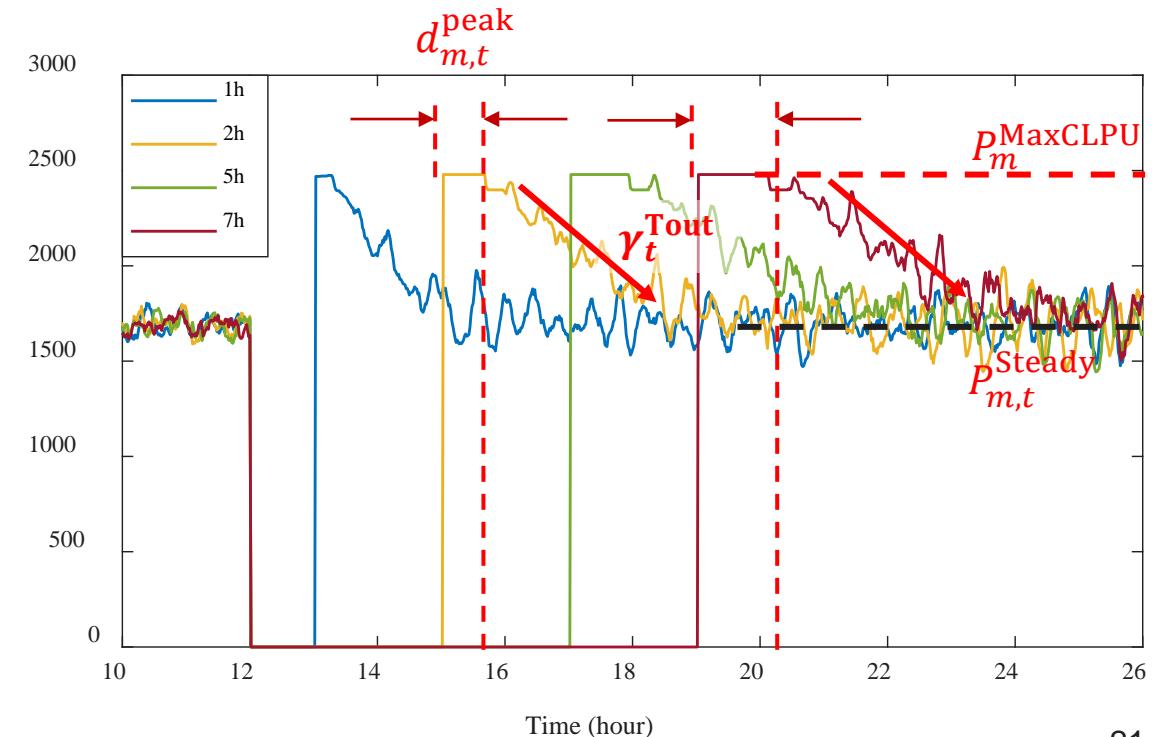
- **Ambient temperature**

- Very slightly impact on **CLPU peak**  $P^{\text{MaxCLPU}}$
- Decides **steady load**  $P_t^{\text{Steady}}$
- Higher temp → longer **peak duration**  $d_t^{\text{peak}}$
- Higher temp → slower **decay rate**  $\gamma_t^{\text{Tout}}$



- **Interruption duration**

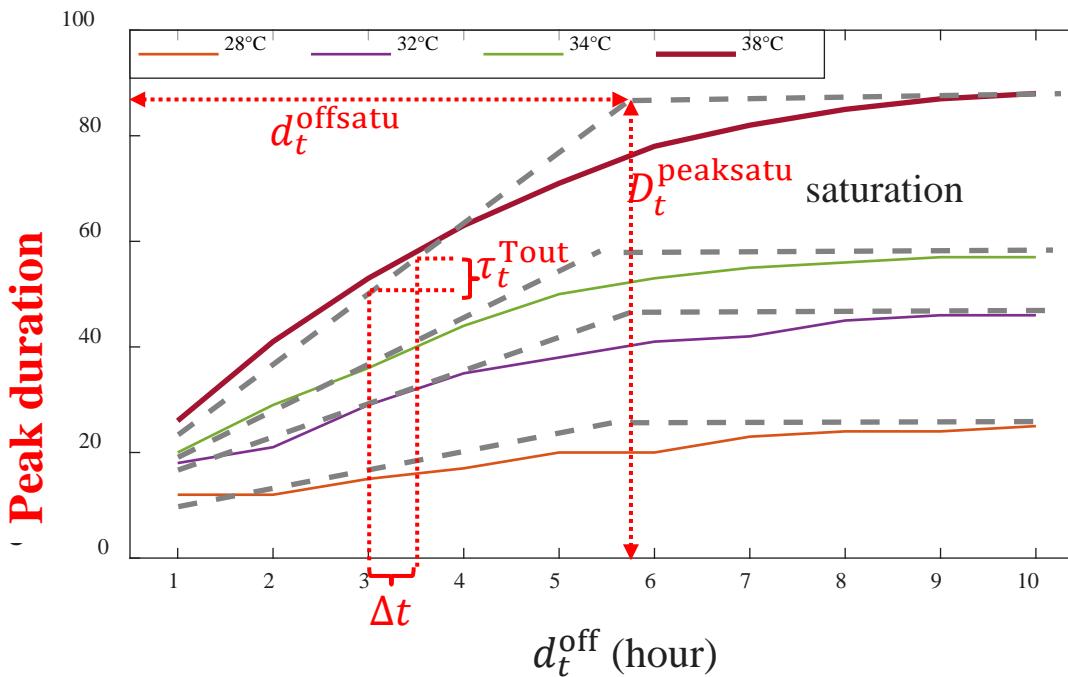
- Very slightly impact on **CLPU peak**  $P^{\text{MaxCLPU}}$
- Very slightly impact on **decay rate**  $\gamma_t^{\text{Tout}}$
- Longer outage → longer **peak duration**  $d_t^{\text{peak}}$



# Model CLPU

- Simplification**

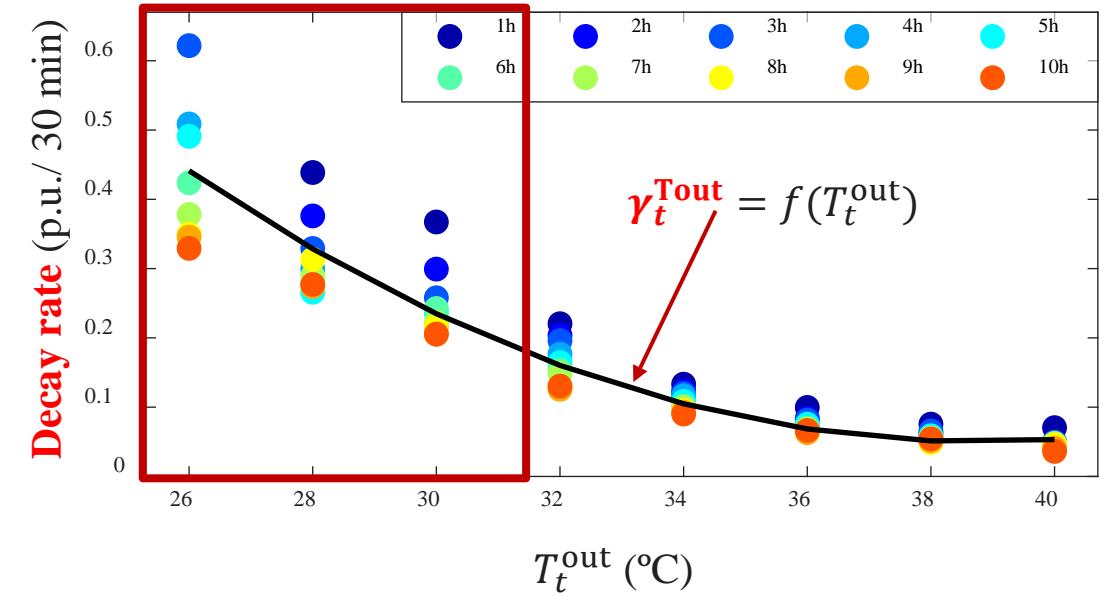
- Peak duration  $d_t^{\text{peak}}$ 
  - Capture impacts by temperature and interruption using **peak duration rate**  $\tau_t^{\text{Tout}}$
  - Saturation  $D_t^{\text{peaksatu}}$
  - 2-piece linearized curves of temperatures**



- Simplification**

- CLPU decay rate  $\gamma_t^{\text{Tout}}$ 
  - when  $> 30^\circ\text{C}$ , **nearly no** impact of interruption
  - when  $< 30^\circ\text{C}$ , nighttime usually has long (>5h) interruptions due to **no PV**
  - Using **equivalent curve** to capture the impact of temperature

Night in summer



# Adaptive CLPU model

- Adaptive CLPU model

Count peak duration

$$d_{t_H}^{\text{peak}} = \begin{cases} \sum_{t=t_0}^{t_H} \tau_t^{\text{Tout}}, & \sum_{t=t_0}^{t_H} \tau_t^{\text{Tout}} < D_{m,t_H}^{\text{peaksatu}} \\ D_{m,t}^{\text{peaksatu}}, & \sum_{t=t_0}^{t_H} \tau_t^{\text{Tout}} \geq D_{m,t_H}^{\text{peaksatu}} \end{cases}$$

HVAC load factor

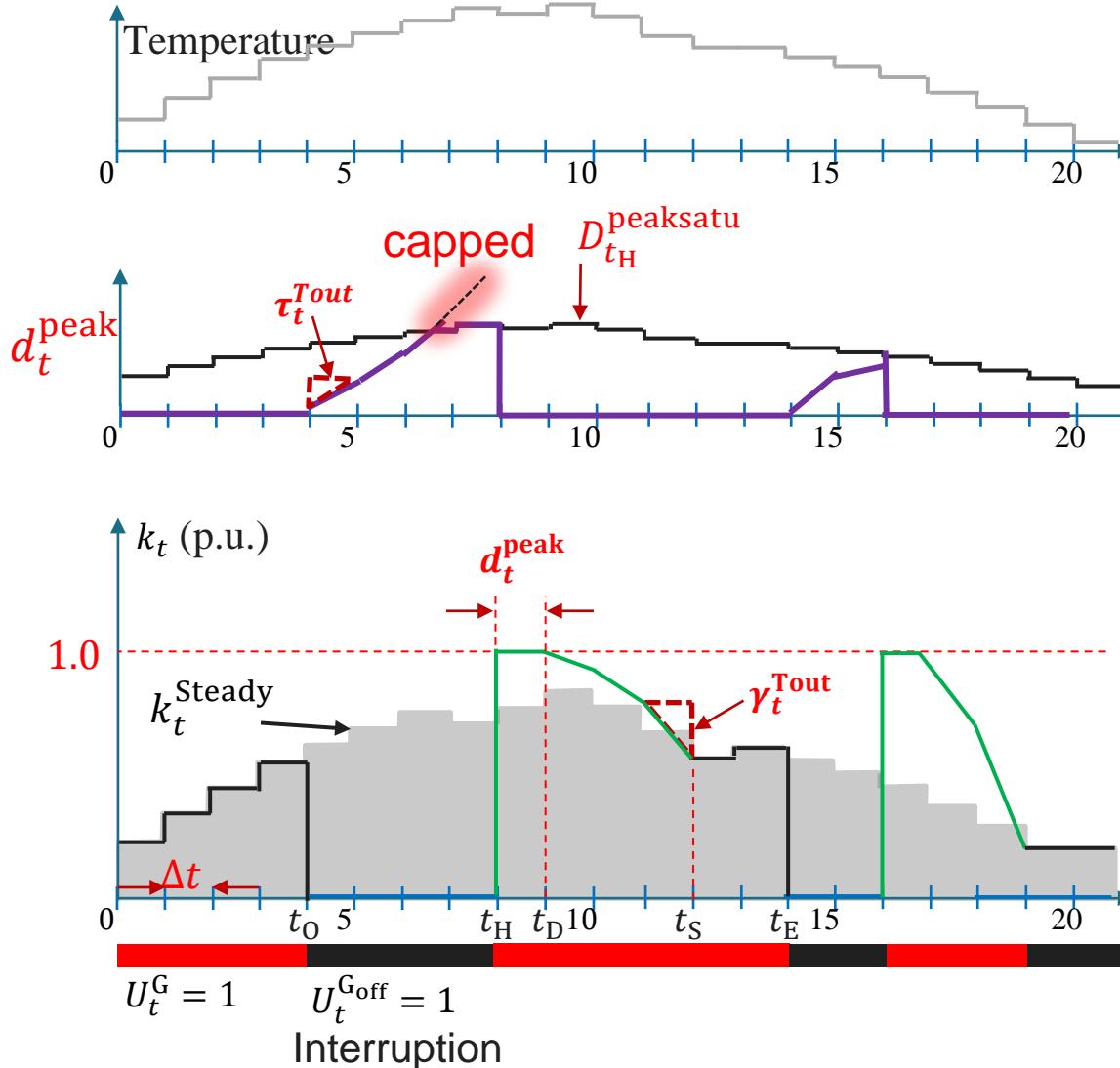
$$k_t = \begin{cases} 0, & t \in (t_0, t_H) \\ 1, & t \in [t_H, t_D] \\ 1 - \sum_{t=t_D}^t \gamma_t, & t \in (t_D, t_S) \\ k_t^{\text{Steady}}, & t \in [t_S, t_E] \end{cases}$$

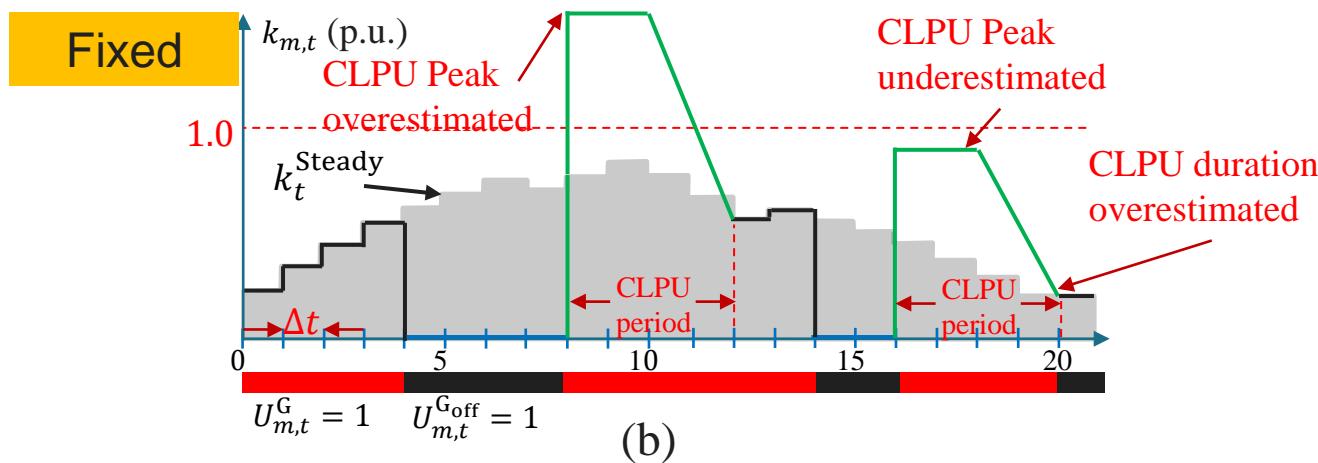
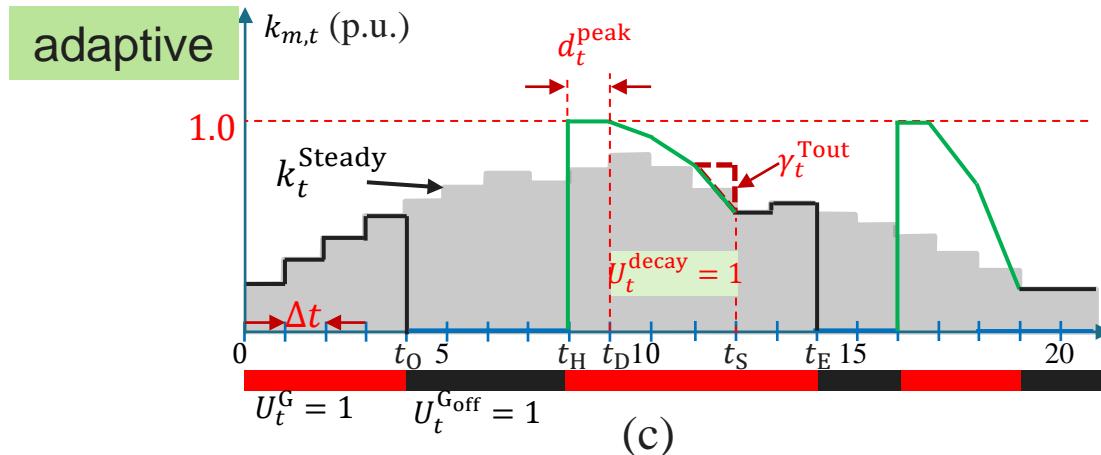
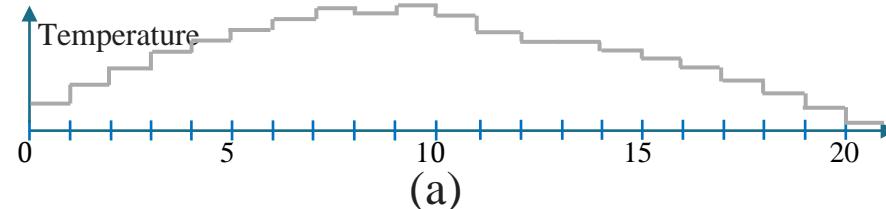
CLPU load factor

$$k_t^{\text{CLPU}} = \begin{cases} 0, & t \in [t_0, t_H) \\ k_t - k_t^{\text{Steady}}, & t \in [t_H, t_E] \end{cases}$$

CLPU load consumption

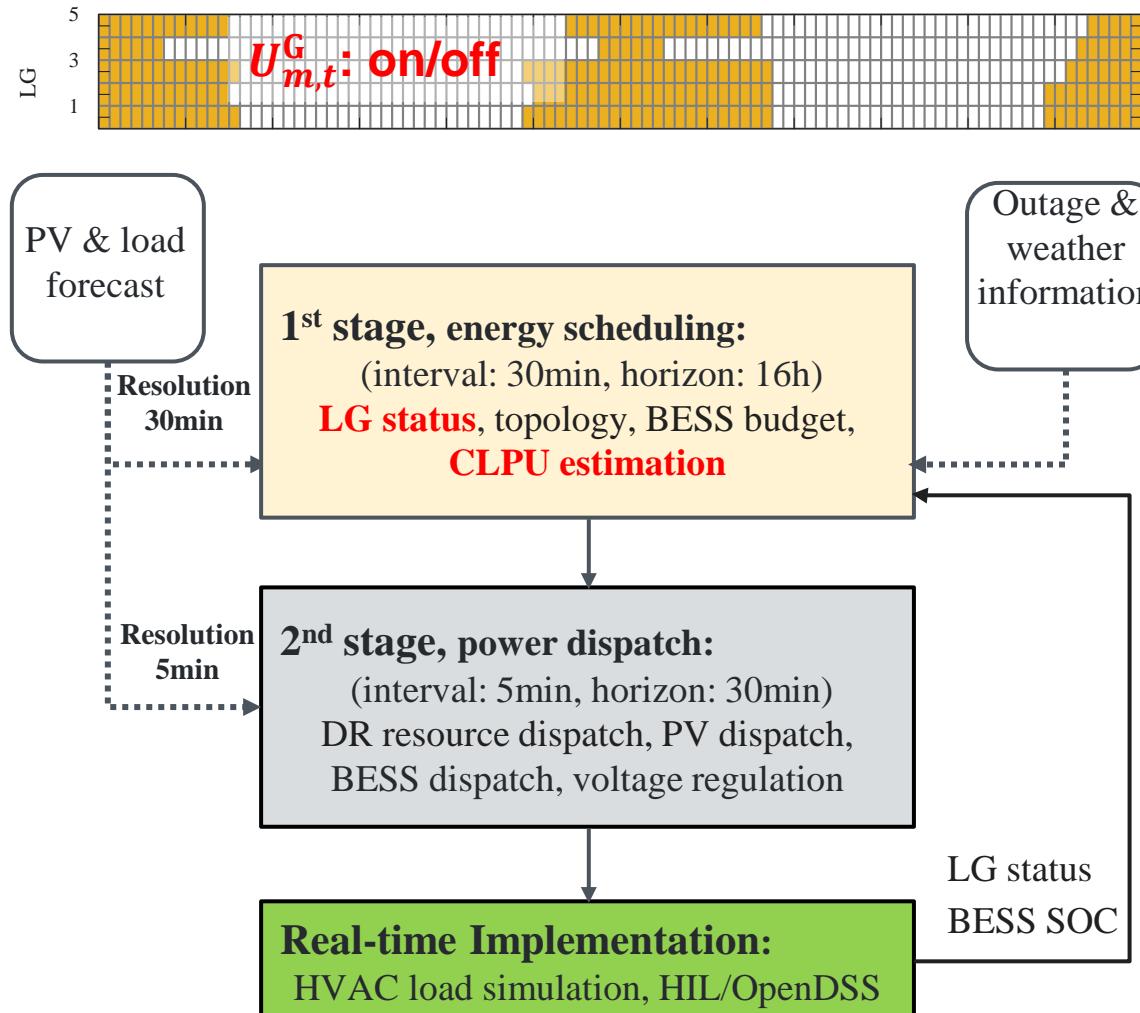
$$P_t^{\text{CLPU}} = k_t^{\text{CLPU}} P^{\text{MaxCLPU}}$$





- **Fixed v.s. Adaptive CLPU model**

- Peak estimation error
- Peak duration estimation error
- Decay estimation error



- **1<sup>st</sup> stage: energy scheduling**
  - CLPU estimation using adaptive CLPU
  - Penalty CLPU to serve more baseload (non-HVAC)

$$\max. f_1^{\text{load}} - c^{\text{PV}} f_1^{\text{PVcurt}} - \mathbf{f}_1^{\text{CLPU}}$$

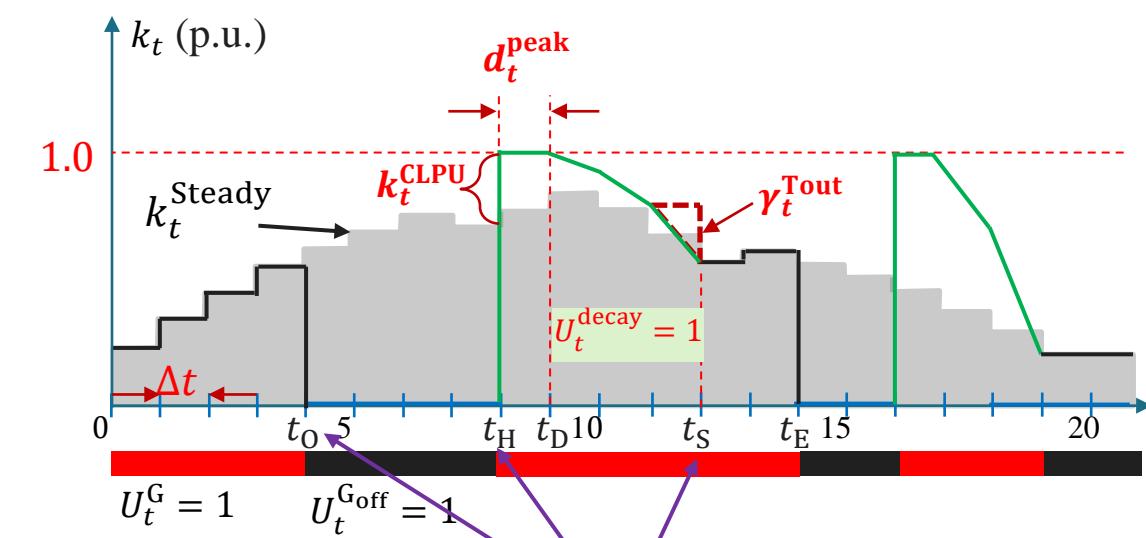
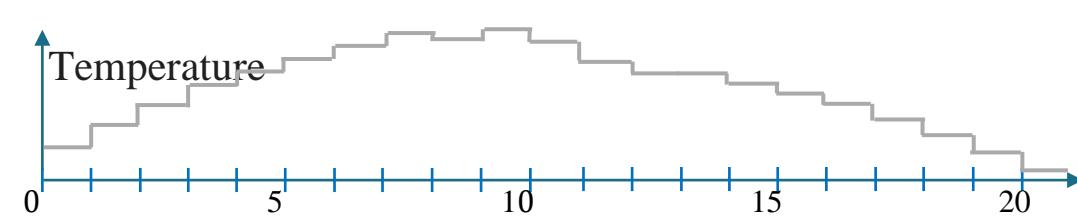
CLPU penalty

$$P_{m,p,t}^{\text{serve}} = U_{m,t}^G P_{m,p,t}^{\text{norm}} + P_{m,p,t}^{\text{CLPU}}$$

*decision-dependent*

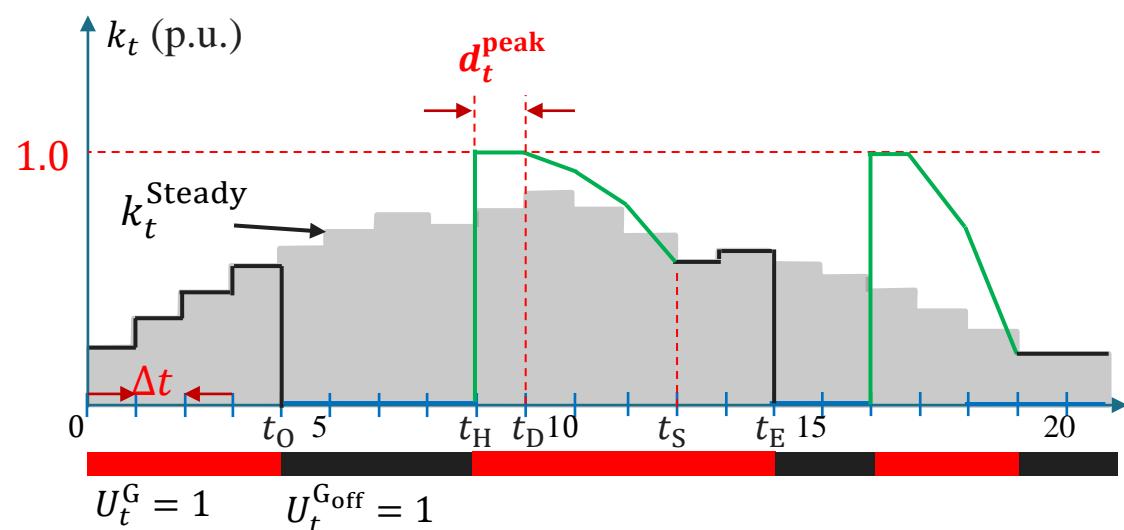
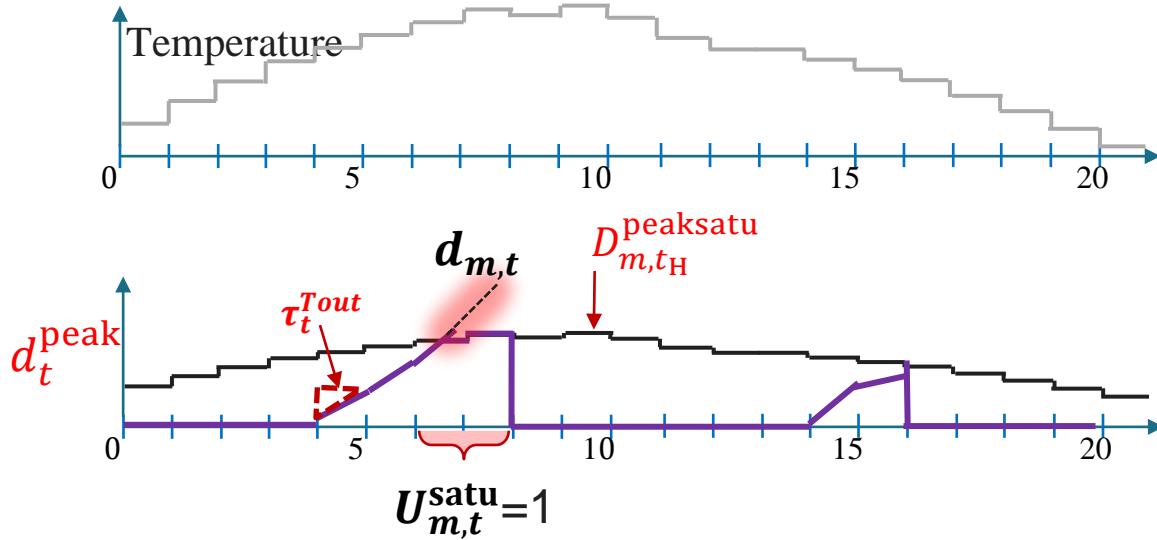


- **2<sup>nd</sup> stage: power dispatch**
  - Interpolate the 1<sup>st</sup> stage CLPU estimation



The number, timing, duration of interruptions  
are optimized by the EMS !

- **Adaptive CLPU enhanced EMS (1<sup>st</sup>)**
  - Group status/interruption is decision variable
  - EMS cannot use the adaptive CLPU model directly
  - Reformulation for integration in MILP EMS algorithm [1]



- Step 1: CLPU Peak duration

$$d_{t_H}^{\text{peak}} = \begin{cases} \sum_{t=t_0}^{t_H} \tau_t^{\text{Tout}}, & \sum_{t=t_0}^{t_H} \tau_t^{\text{Tout}} < D_{m,t_H}^{\text{peaksatu}} \\ D_{m,t}^{\text{peaksatu}}, & \sum_{t=t_0}^{t_H} \tau_t^{\text{Tout}} \geq D_{m,t_H}^{\text{peaksatu}} \end{cases}$$

$$U_{m,t}^{G\text{off}} = 1 - U_{m,t}^G$$

$$0 \leq d_{m,t} \leq M U_{m,t}^{G\text{off}}$$

$$d_{m,t} + M U_{m,t}^G \geq d_{m,t-1} + \tau_{m,t}^{\text{Tout}} U_{m,t}^{G\text{off}} \Delta t$$

$$U_m^{\text{satu}} \leq U_{m,t}^{\text{off}}$$

$$d_{m,t}^{\text{peak}} \geq D_{m,t}^{\text{peaksatu}} U_{m,t}^{\text{satu}}$$

$$d_{m,t}^{\text{peak}} \geq d_{m,t} - M U_{m,t}^{\text{satu}}$$

ignores saturation and cumulate peak duration when outage with  $d_{m,t}$

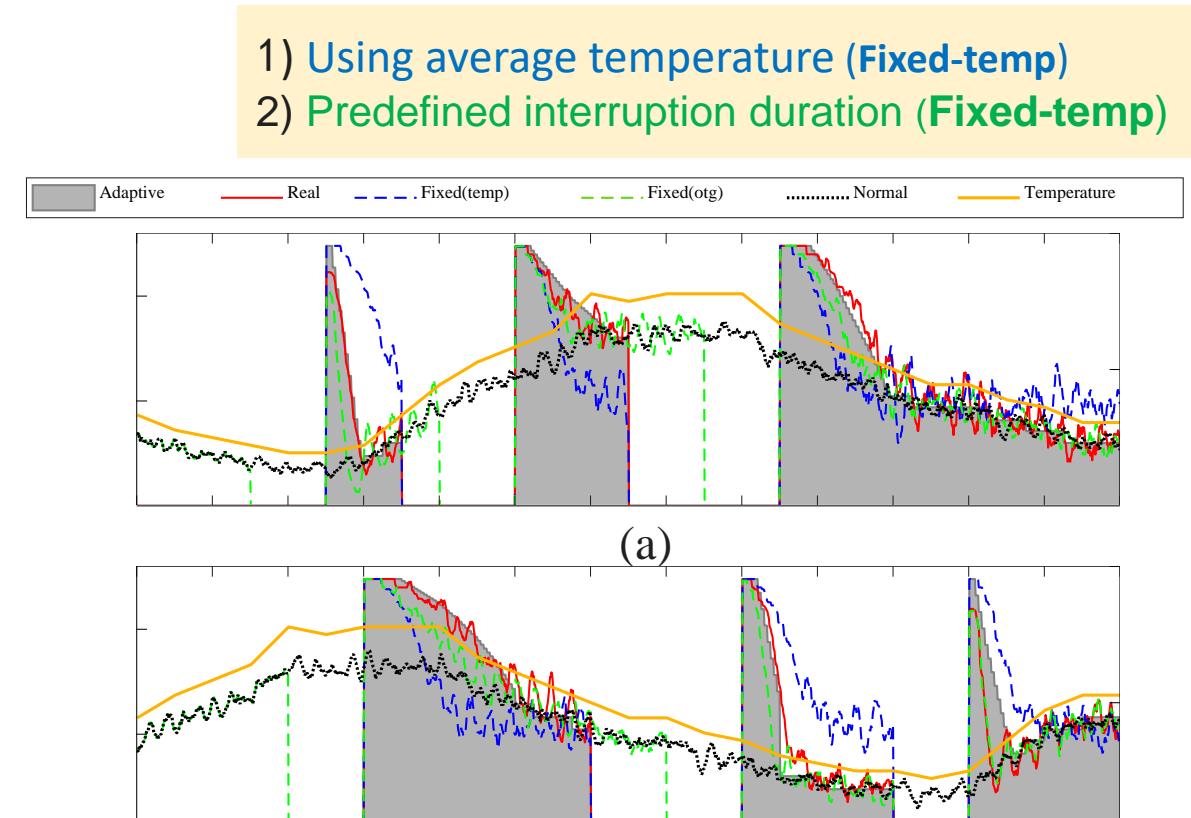
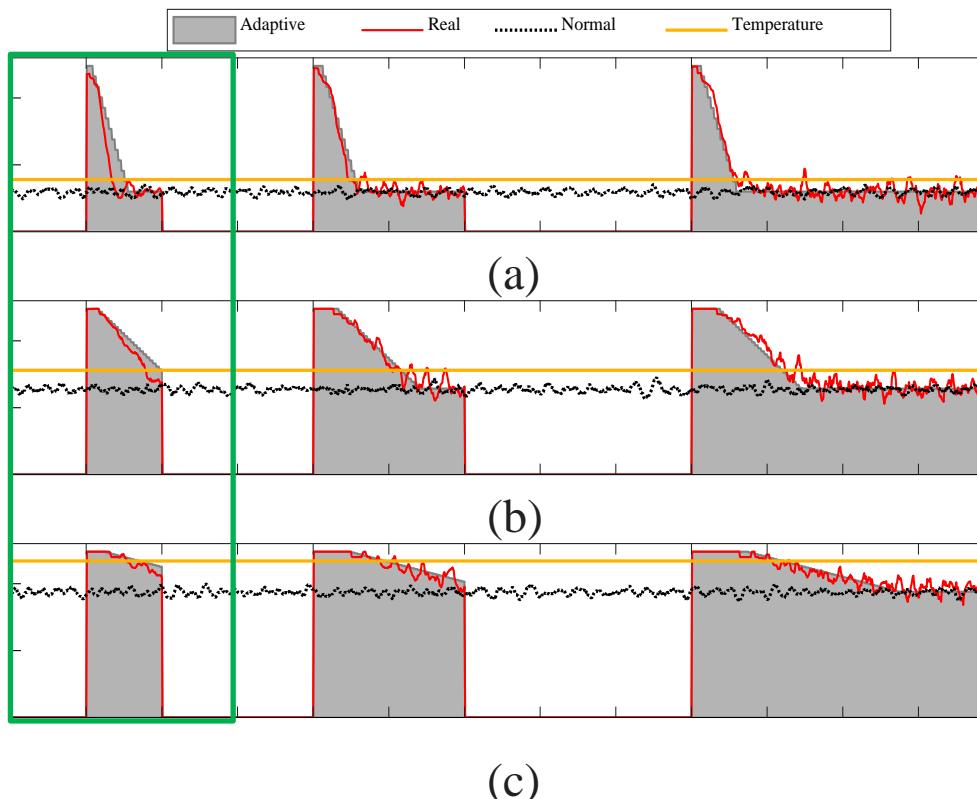
count saturation with  $U_{m,t}^{\text{satu}}$

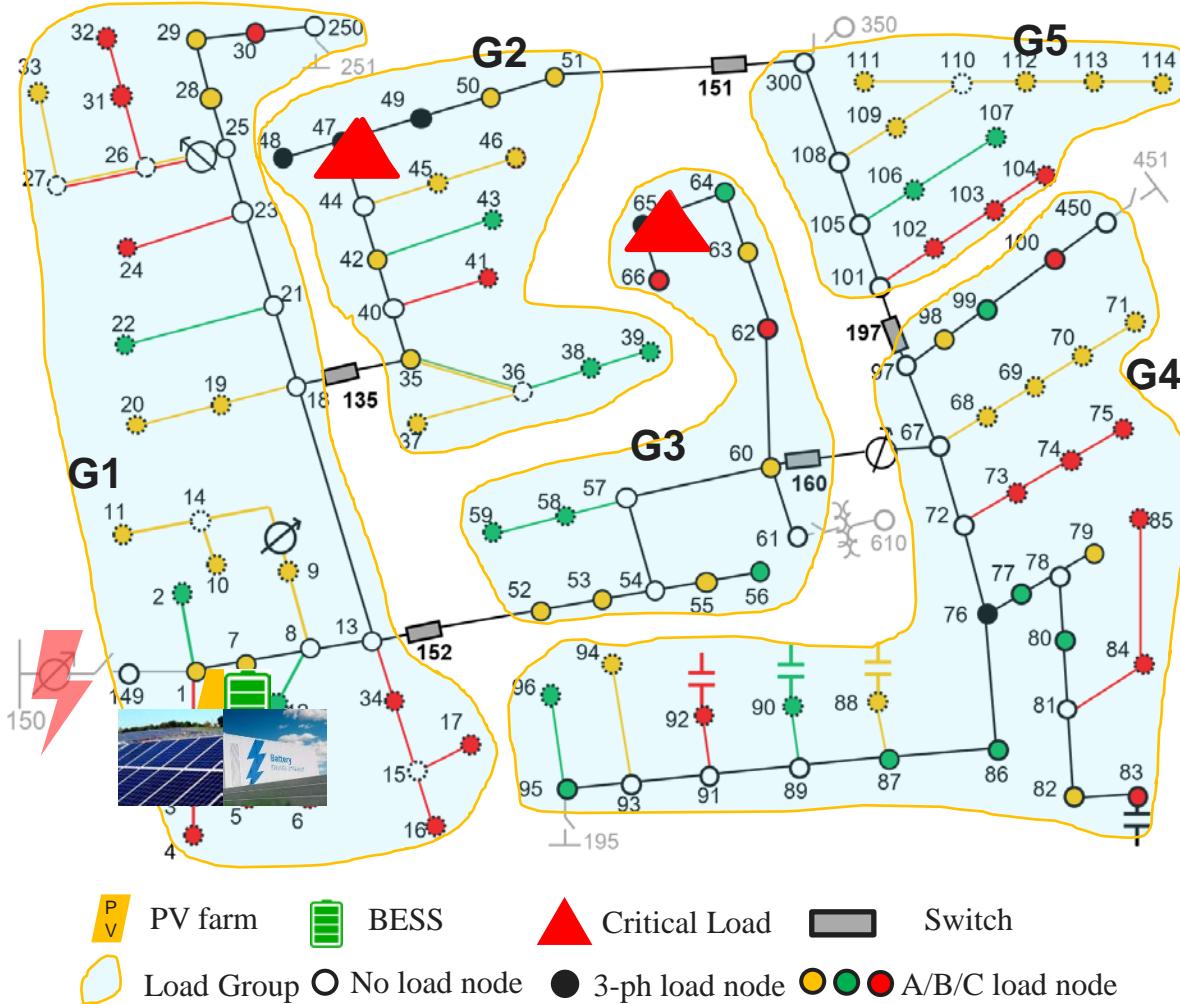
! Minimize CLPU

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- Static verification of the adaptive CLPU model

- Predefined temperature and interruption duration
- Constant or time-varying temperature





## Test system

- 123-bus system, unbalanced
- 5 switches, 5 node groups, 1 loop
- Interval: 30 minutes (1st); 5 minutes (2nd)
- Horizon: 16 hours (1st); 30 minutes (2nd)

## Generation

- Hybrid PV plant: PV, 4,500 kW; battery, 6,000 kWh (3000 kW)
- Reserve: **15 %**

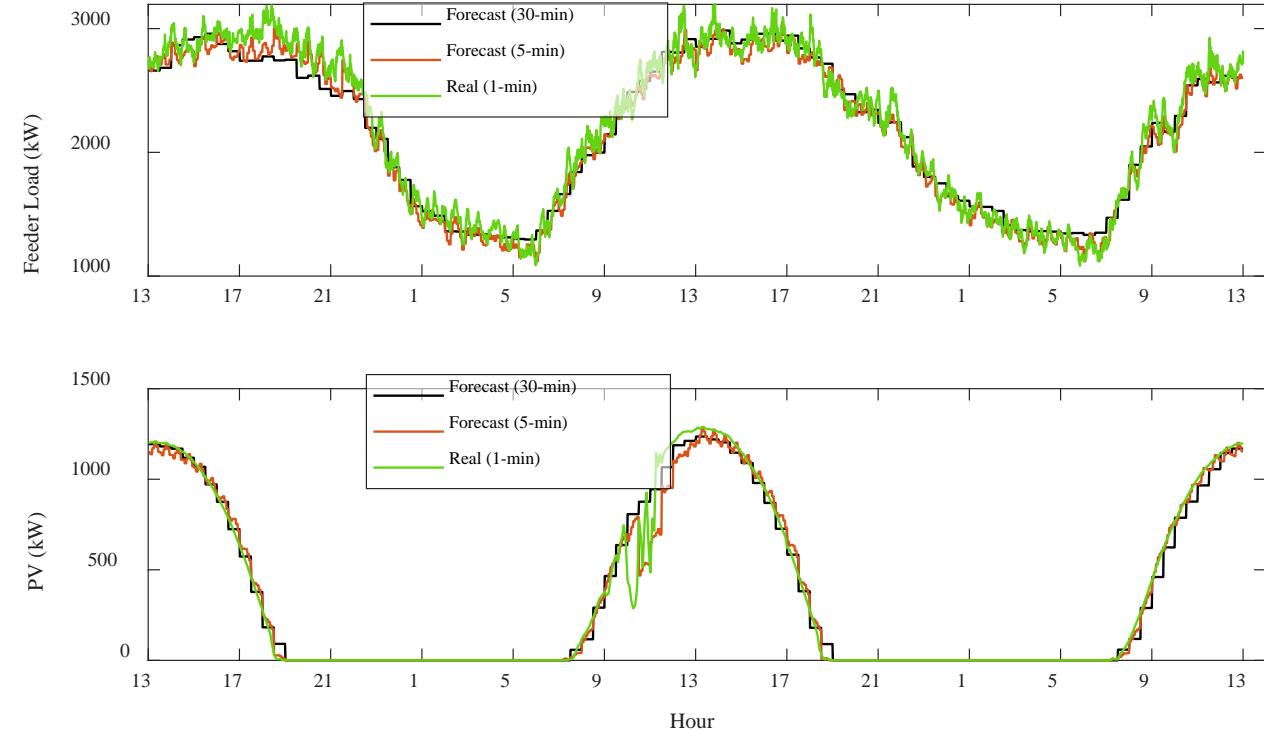
## Load

- Critical load: **node 47** (40 kW per phase), **node 65** (50 kW per phase)
- Preferred service period: 7:00-9:00, 18:00-20:00
- Minimum service duration : **2 hours**

## Outage

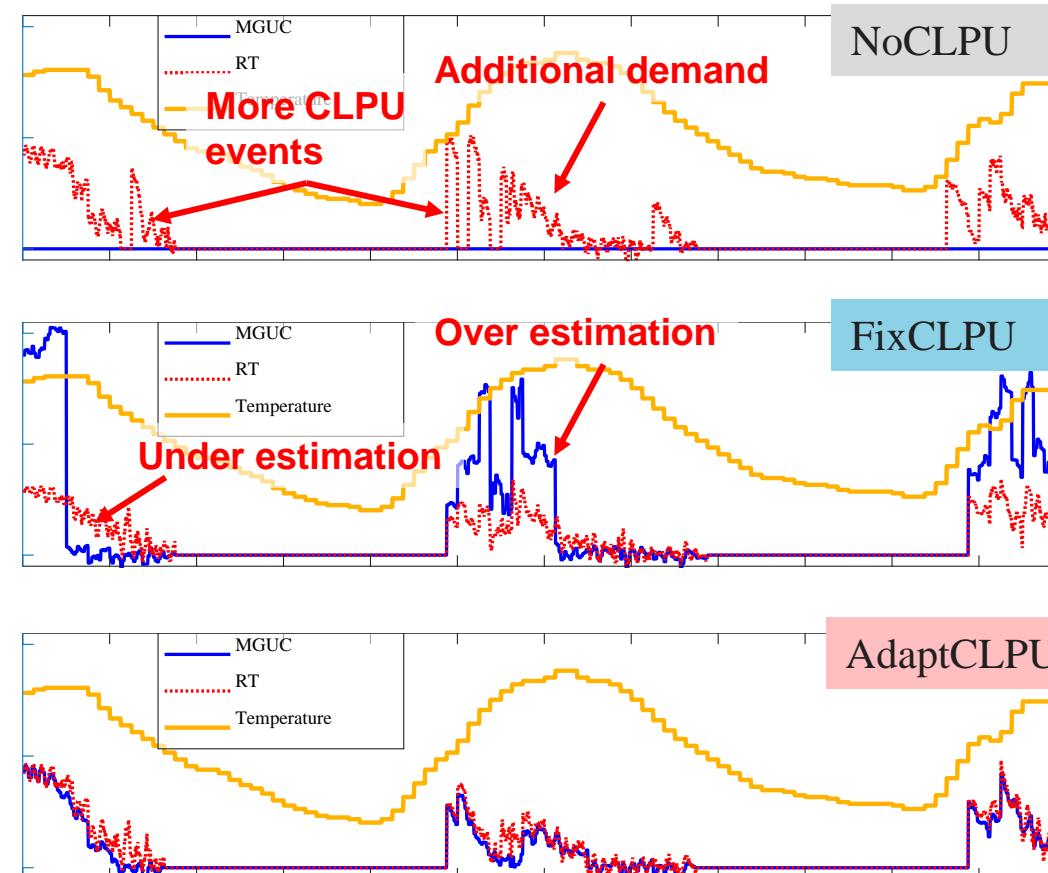
Substation is down for 2 days

Case	CLPU Model	
1	NoCLPU	do not consider the CLPU effect.
2	FixCLPU	CLPU increment equal to normal load, 2h CLPU duration (ave_temp 29°C)
3	AdaptCLPU	Adaptive CLPU model



Normal load and PV during the 2-day outage

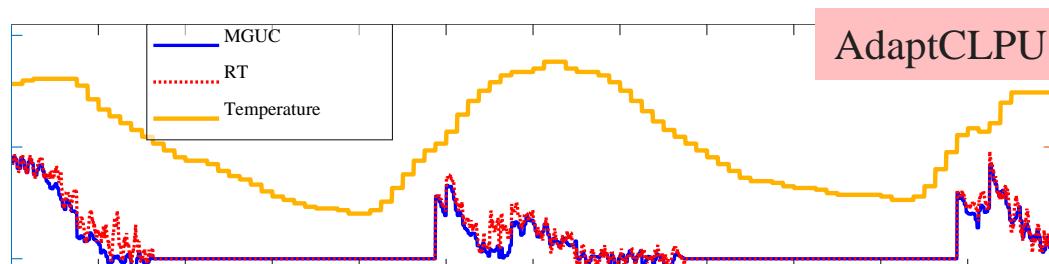
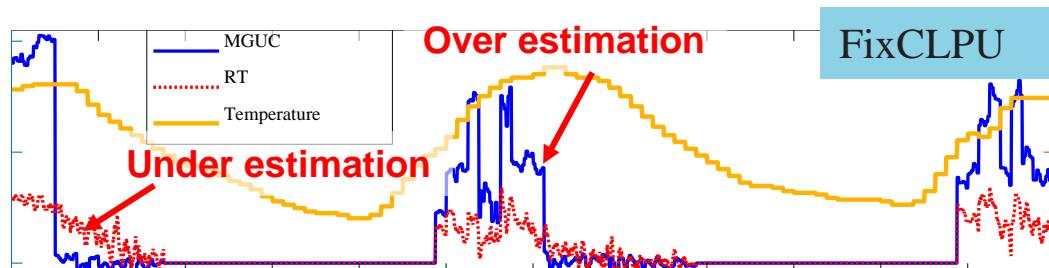
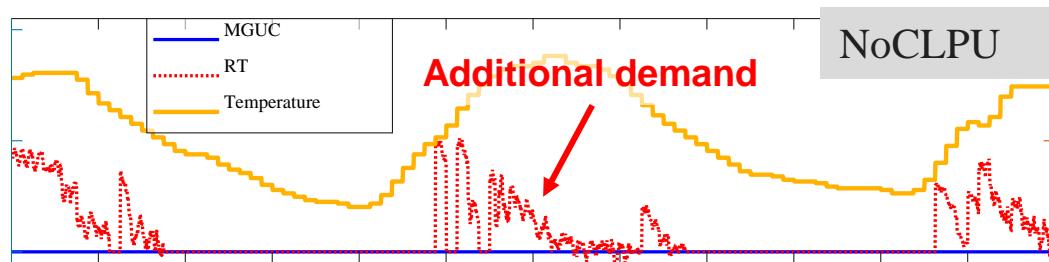
- CLPU



MGUC: EMS scheduling

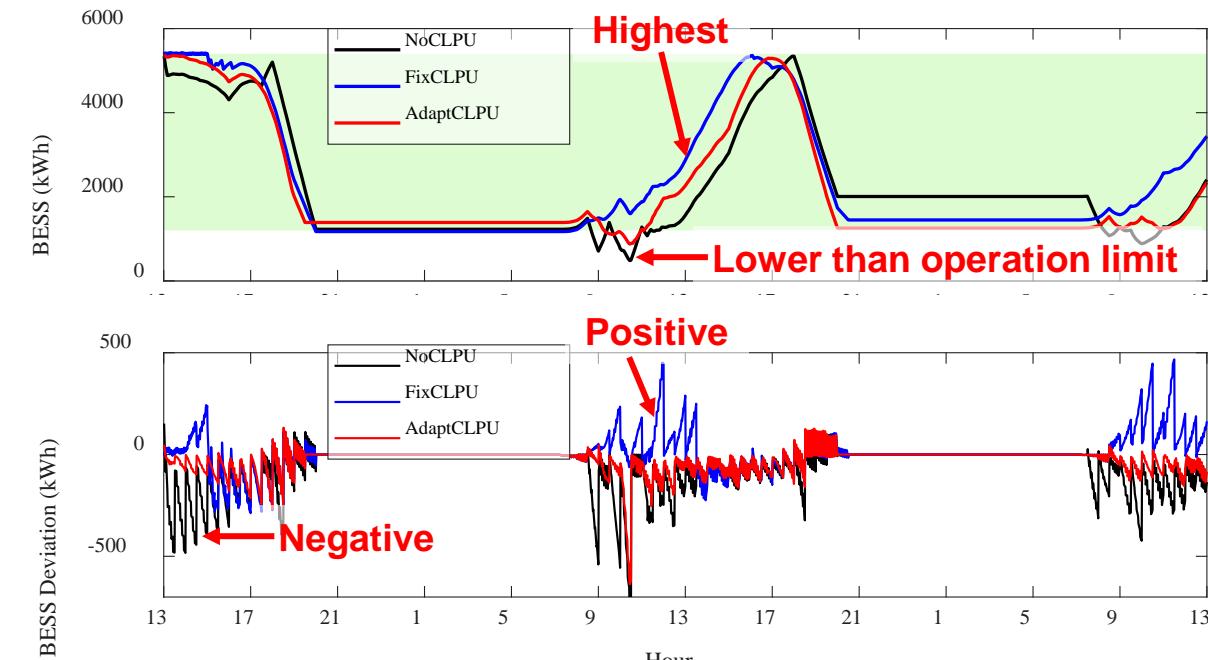
RT: real-time simulation (1-min)

- CLPU & BESS



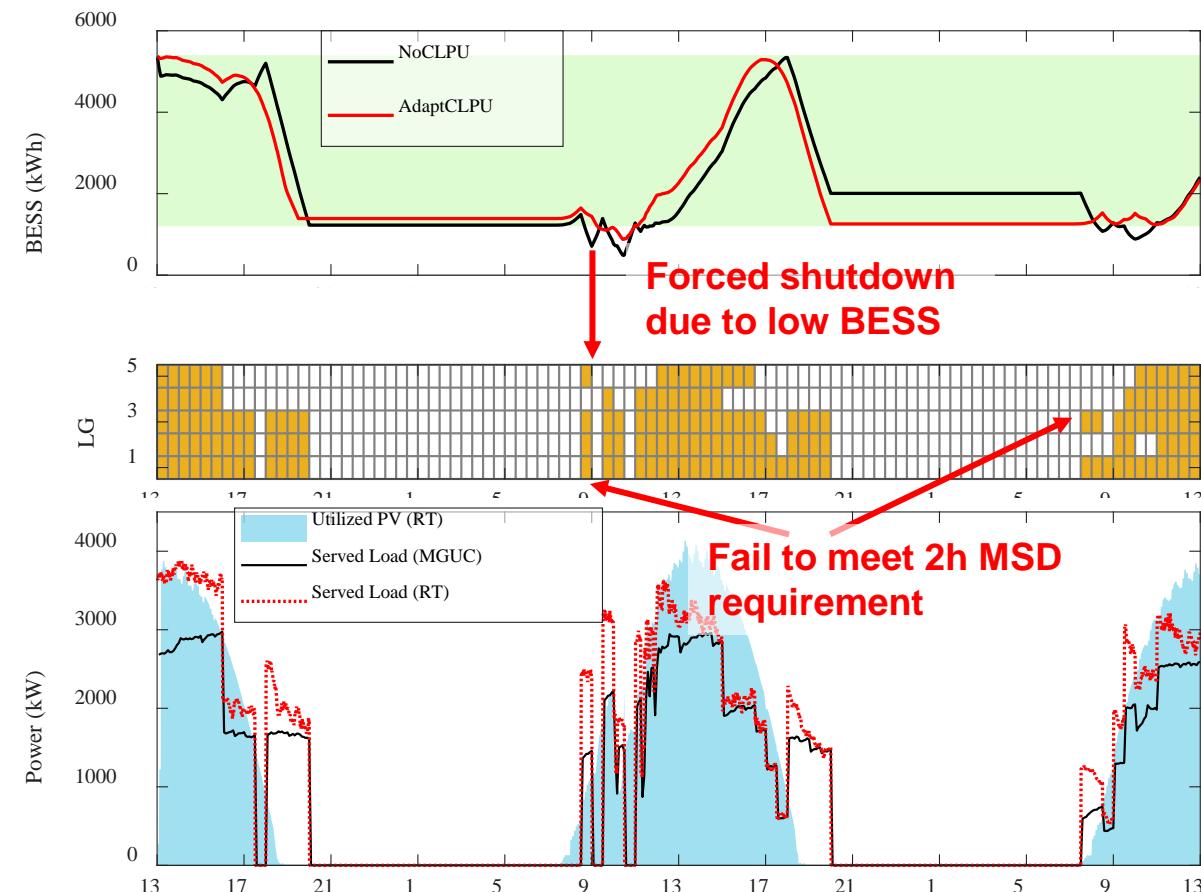
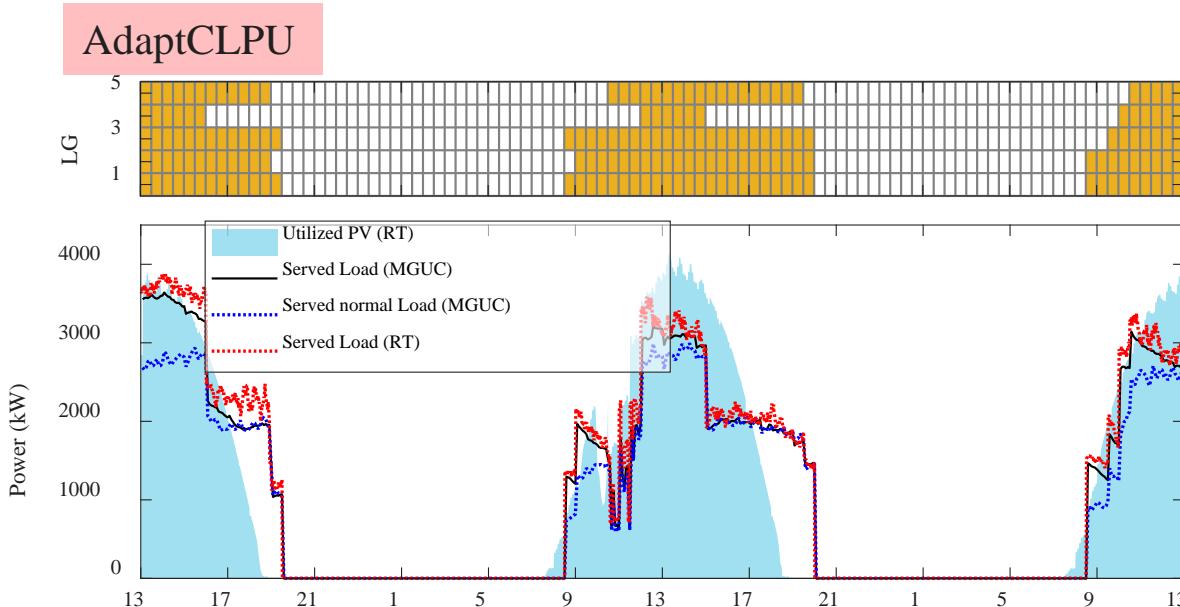
MGUC: EMS scheduling

RT: real-time simulation (1-min)



- **NoCLPU:** large unscheduled demand → negative BESS deviation
- **FixCLPU:** CLPU overestimation → high SOC level and positive BESS deviation

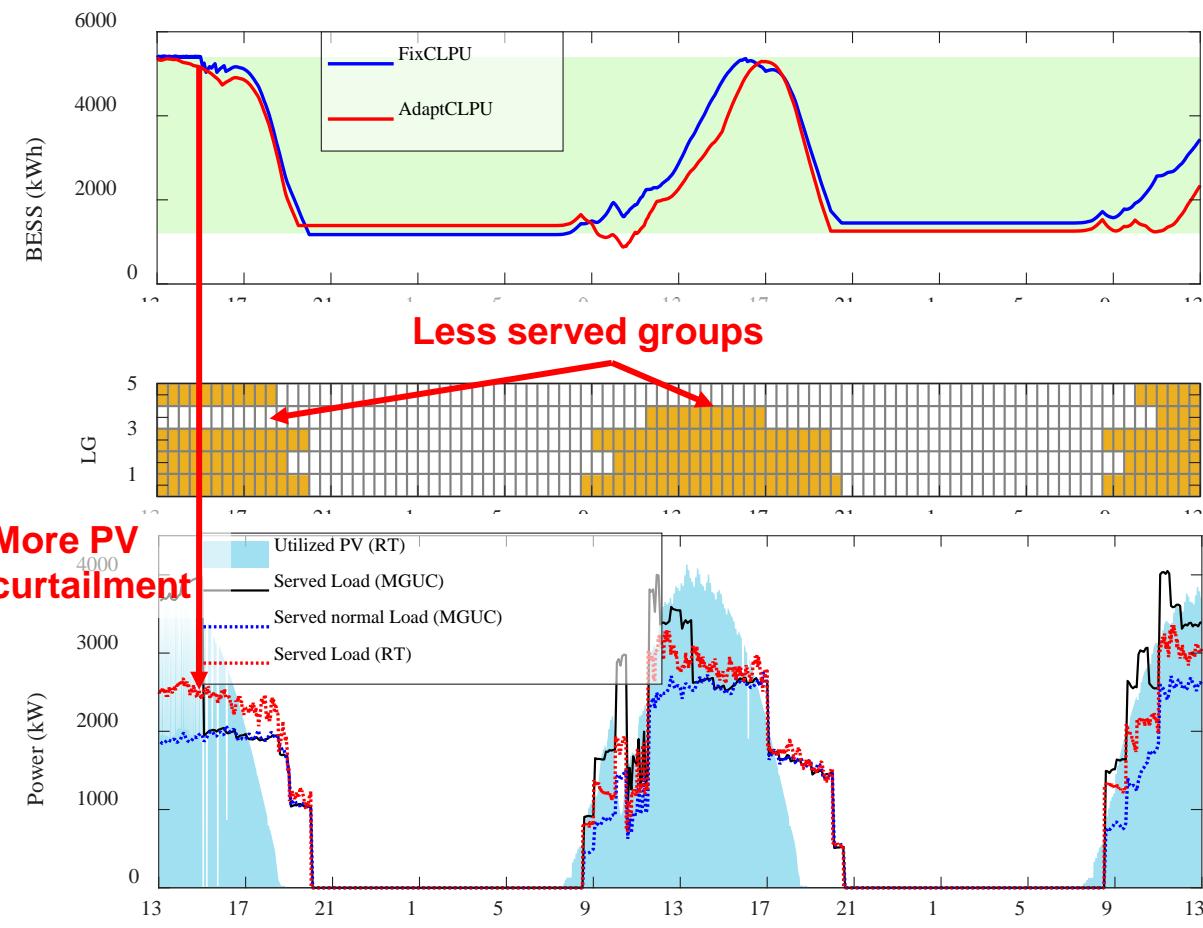
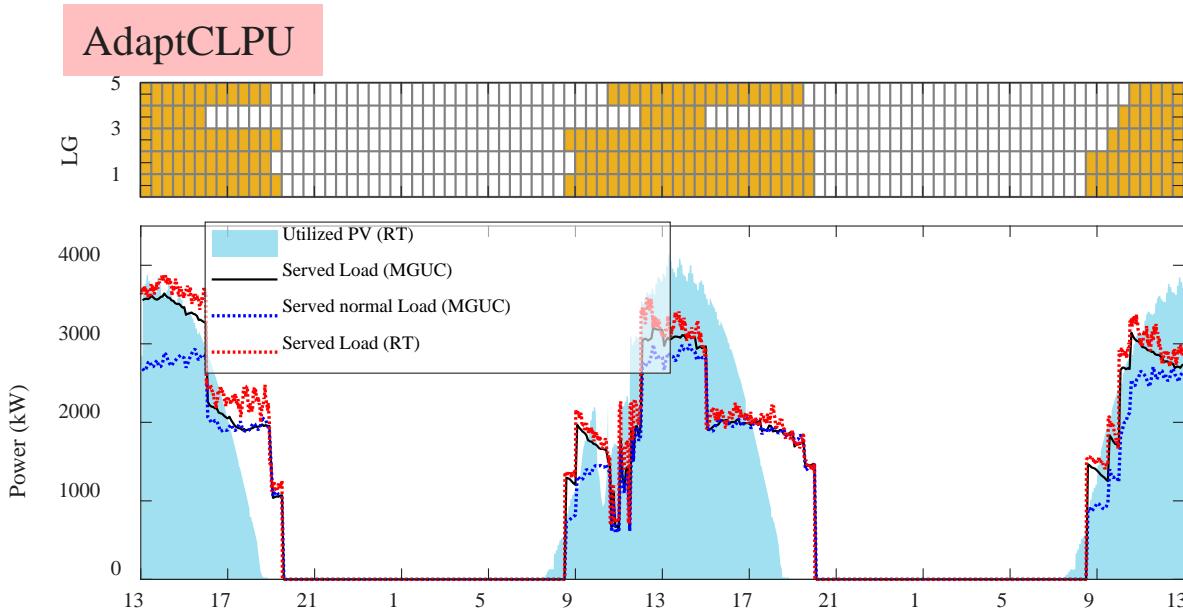
- AdaptCLPU v.s. NoCLPU



- **NoCLPU**

- Lower customer comfort (minimum service duration)
- Unstable microgrid operation

- AdaptCLPU v.s. FixCLPU



- FixCLPU

- Lower customer comfort (unfair)
- Less PV utilization

- Overall performance

Case	Served load (kWh)	Served load in preferred periods (kWh)		Served critical load (kWh)	Served baseload (kWh)	Curtailed PV (kWh)	CLPU (kWh)		
		total	CLPU part				Actual	Estimated	Estimation deviation
NoCLPU	54493	10196	1757	4734	21438	2999	7697	-	-7697
FixCLPU	50737	7445	540	4814	20464	5877	5893	12885	+6992
AdaptCLPU	55173	7771	667	4857	22210	2591	6835	5565	-1270

- AdaptCLPU
  - More served total load, critical load, baseload
  - Less PV curtailment and CLPU estimation error

# GUI Demonstration

GUI\_MW\_PV\_Case1

**Photovoltaic Analysis and Response Support (PARS) Platform**  
Use case 1: Distribution System Restoration using Hybrid PV Plant  
Created by Rongxing Hu (rhu5@ncsu.edu) Version 1.0 May 2022

**U.S. DEPARTMENT OF ENERGY**

**NC STATE**

**1. Simulation Setup**

**Set Simulation**

Simu-scenario: Cold Load Pickup  
Start Day: 1 Start Hour: 1  
End Day: 1 End Hour: 1

**2. Energy Management Setup**

PV rating-ph (kW)	1200
Battery rating-ph (kW)	1000
Ch/Disch Efficiency	0.95
Battery rating (kWh)	6000
Initial SOC	0.9
Max SOC	0.9
Min SOC	0.2
Imbalance factor	0.5
Reserve factor	0.15
Preferred period (h)	8-9, 19-20
Preferred weighting	1.5
Min service duration (h)	2
Critical weighting	4

**3. Run**

**Set GUI mode**

Display saved results  
 Run simulation

**Confirm Setup**  
**Run Case**  
**Get Report**

**Circuit IEEE 123**

**Statistics**

Battery

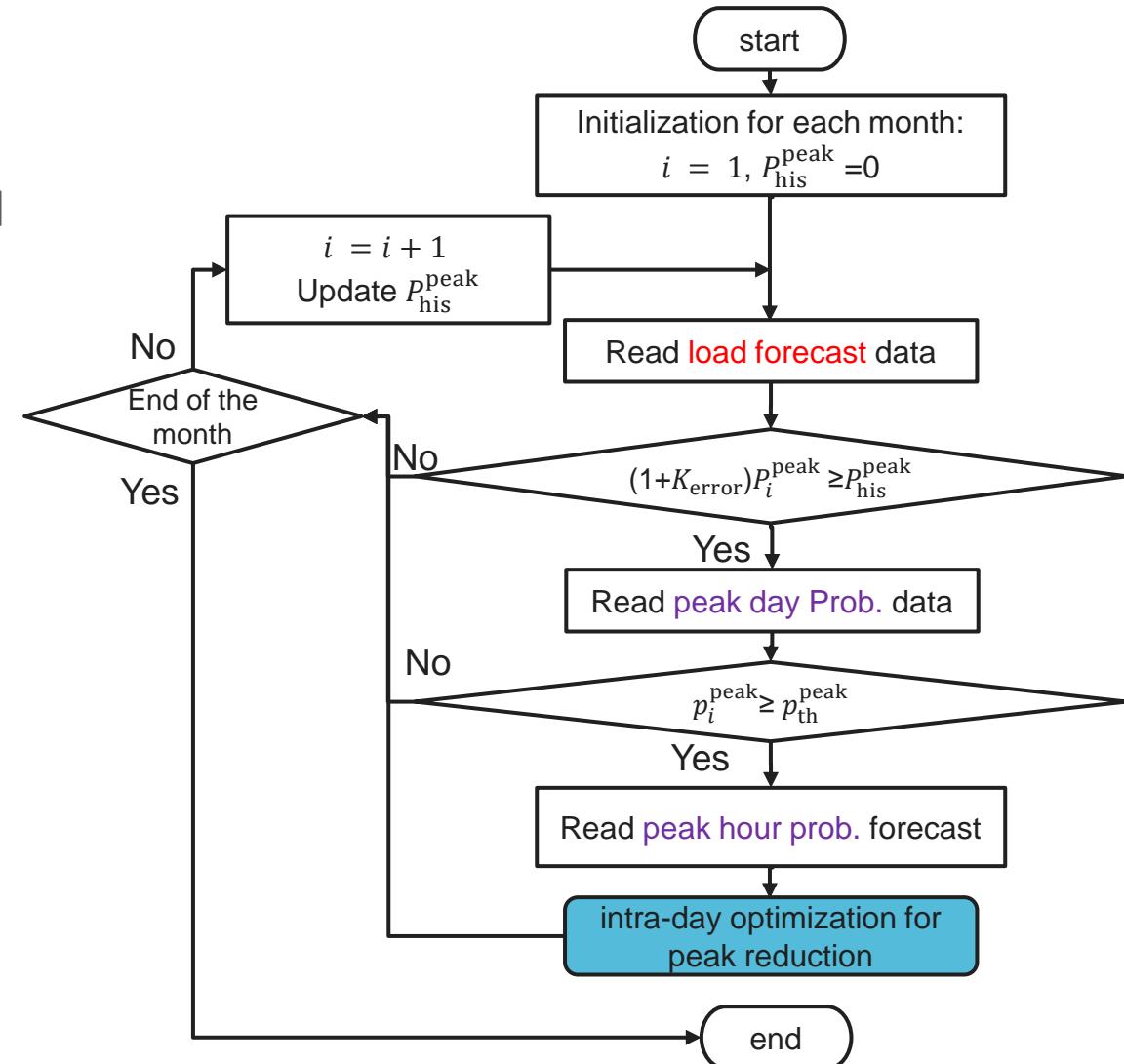
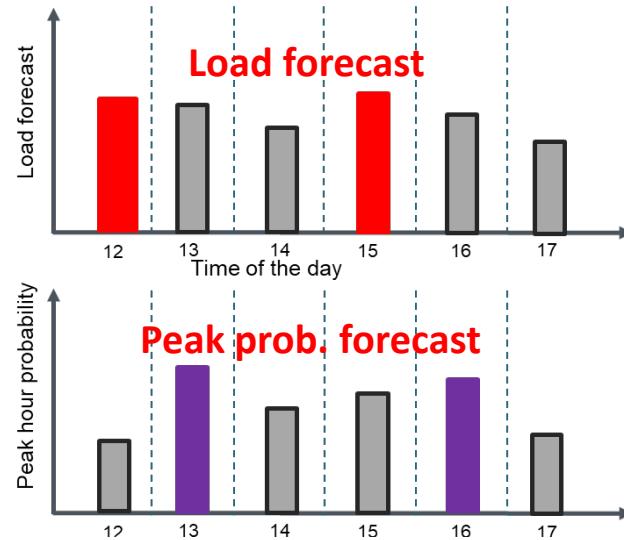
Served Group



<https://youtu.be/b5sv8SozFSk>

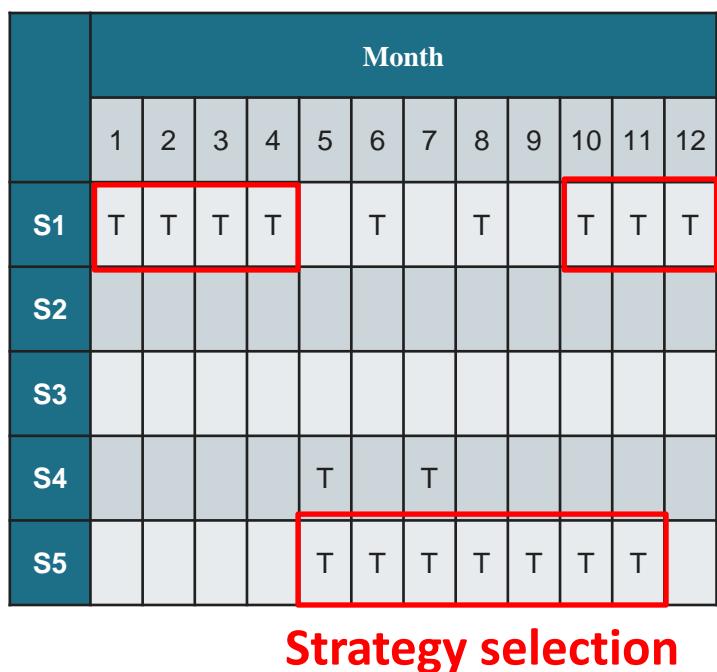
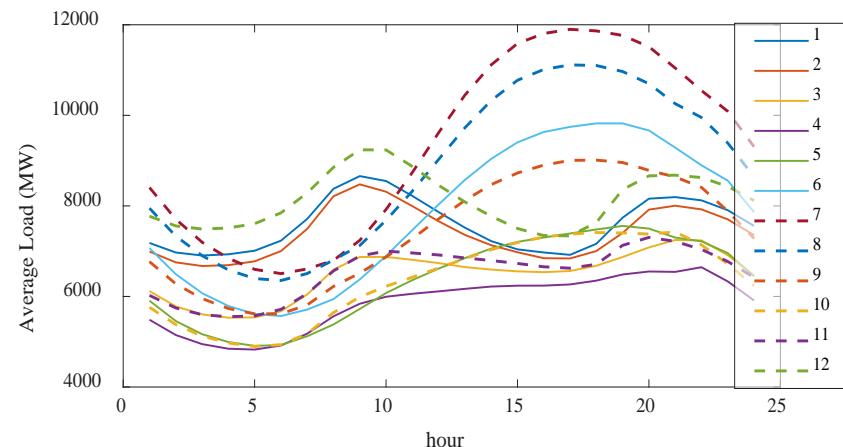
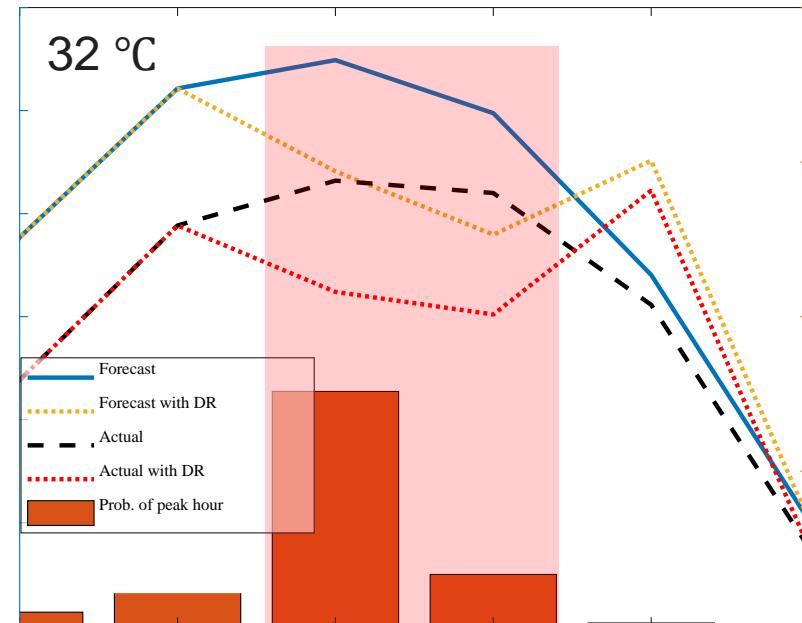
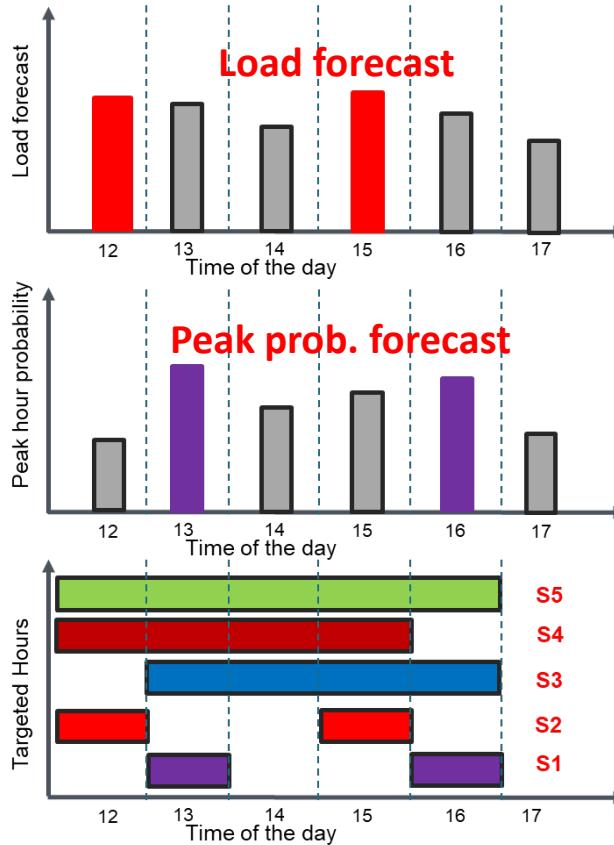
- **Energy Management System of Renewable-powered Microgrids for Resilience Service in Distribution System (Proj-1)**
  - Research Background and the Project
  - Energy Management System(EMS) Design
    - Overview
    - Flexible topology control
    - Adaptive cold load pickup model
    - Phase Imbalance
- **Other Projects**
  - Energy Storage Application Analytics (Proj-2)
  - Avista's Shared Energy Economy Model Pilot (Proj-3)
  - Coordinated Real-time Sub-Transmission Volt-Var Control Tool (Proj-4)
- **Ongoing Work and Future Work**

- Energy Storage Application Analytics
  - PNNL, NCSU, and local small utility @ ElectriCities
  - Coordinating BESS, Diesel generators, CVR, demand response of HVAC to reduce peak load
    - Monthly peak (hourly), **20\$/kW**, (energy rate: 0.03 \$/kWh)

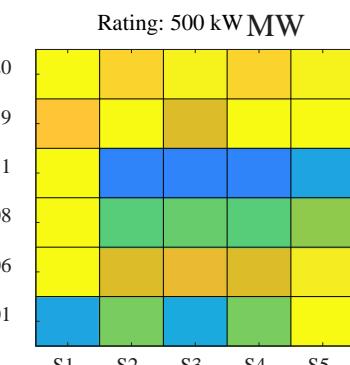
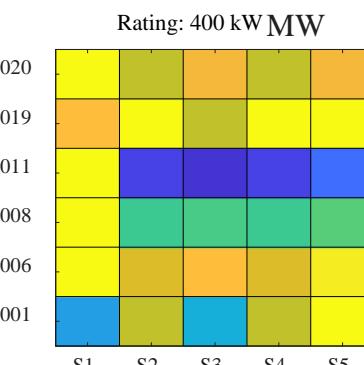
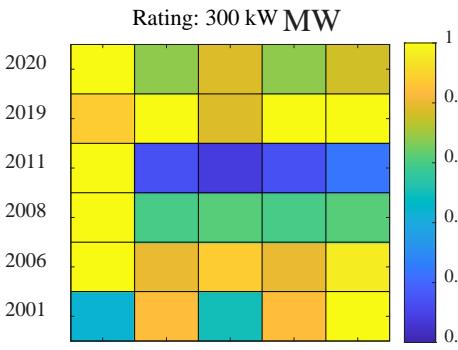
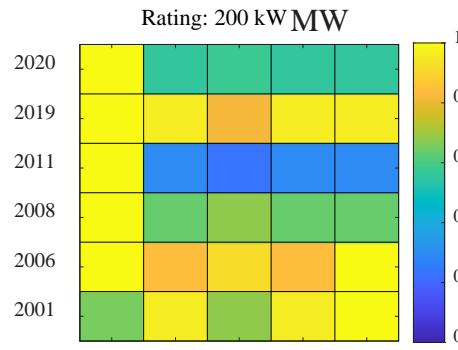
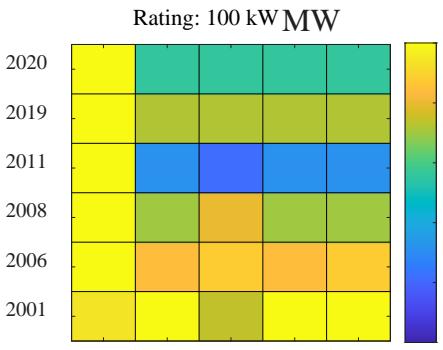


- **Energy Storage Application Analytics**

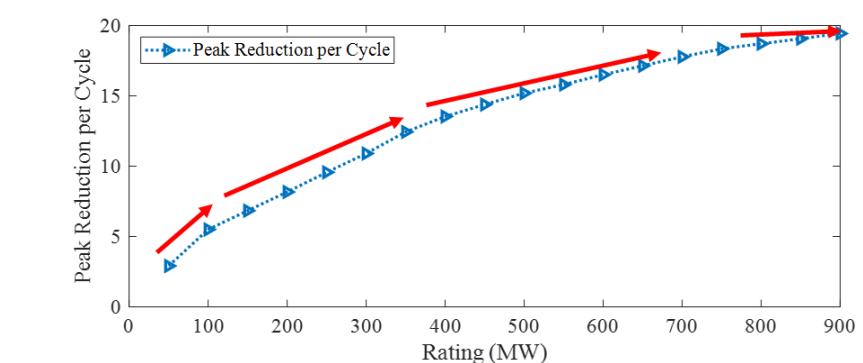
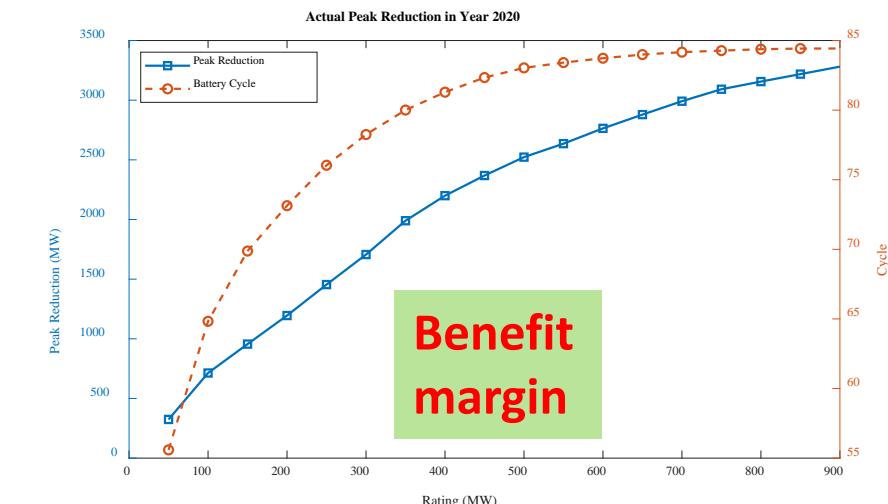
- Benefit analysis, Reduction strategy
- Payback load of DR



- Energy Storage Application Analytics
  - Benefit analysis, Reduction strategy
  - Payback load of DR



	Rating (MW)				
	100	200	300	400	500
S1	5	5	4	4	4
S2	1		1	1	1
S3					1
S4	1		1	1	1
S5	1	1	2	3	4



- **Avista's Shared Energy Economy Model Pilot (Proj-3)**

- Internship project at PNNL
- Techno-economic Assessment of the WSU campus microgrid
  - Microgrid EMS: BESS, PV, Flexible building load (virtual BESS)
  - Cost of investment, energy, and demand charge, resilience improvement
  - Estimated optimal battery reserve requirement for DR program (contract)

Table 4.2. Present Value Costs vs. Benefits in The Base Scenario

	Costs	Benefits
Capacity value		\$137,033
Energy arbitrage		\$196,175
Ancillary services		\$29,743
Energy charge reduction		\$163,906
Demand charge reduction		\$283,462
Demand response		\$93,082
BESS capital cost	\$1,670,000	
PV capital cost (excluding residual)	\$875,467	
PV O&M cost		\$28,181
BMS upgrade cost		\$342,000
Total	\$2,915,648	\$903,402

Cost and benefits

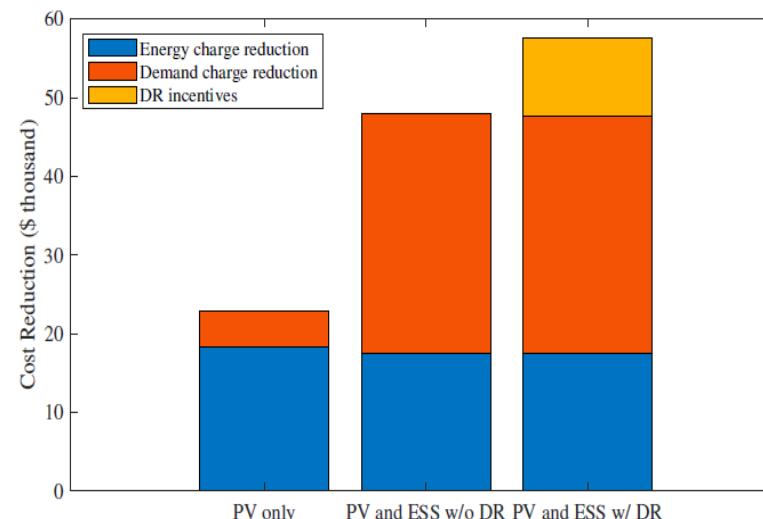


Figure 4.7. Annual cost saving.

Annual cost saving

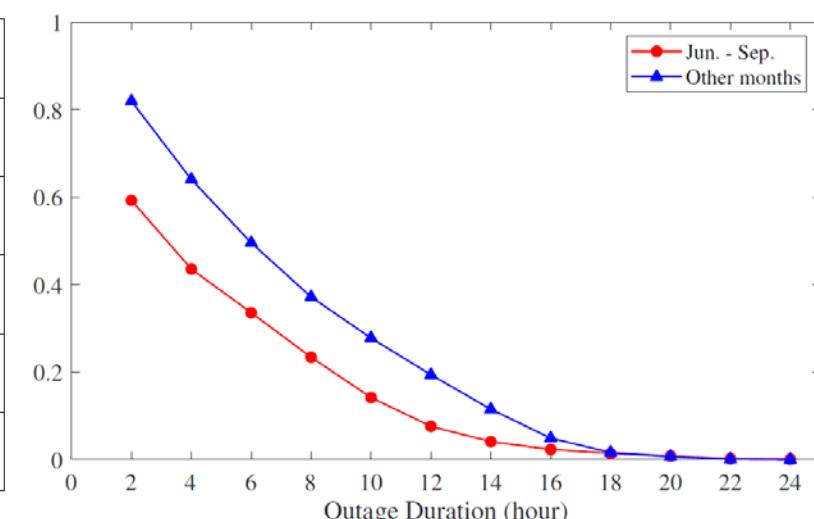
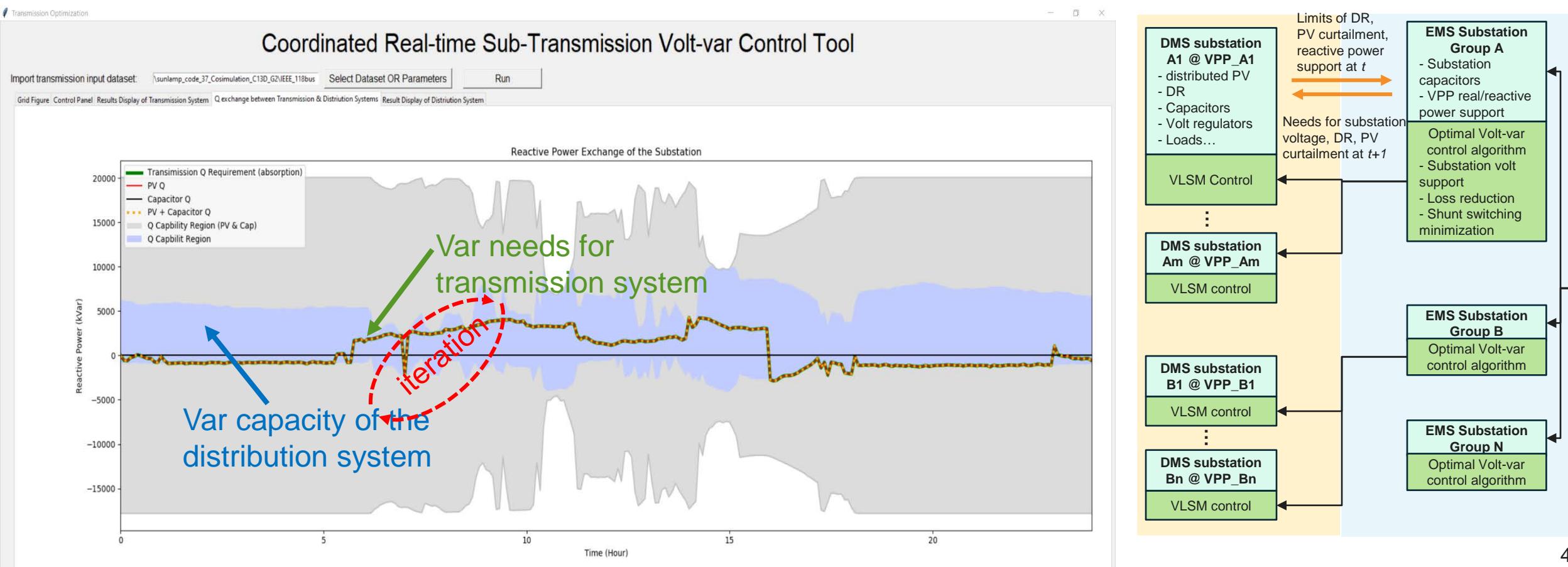


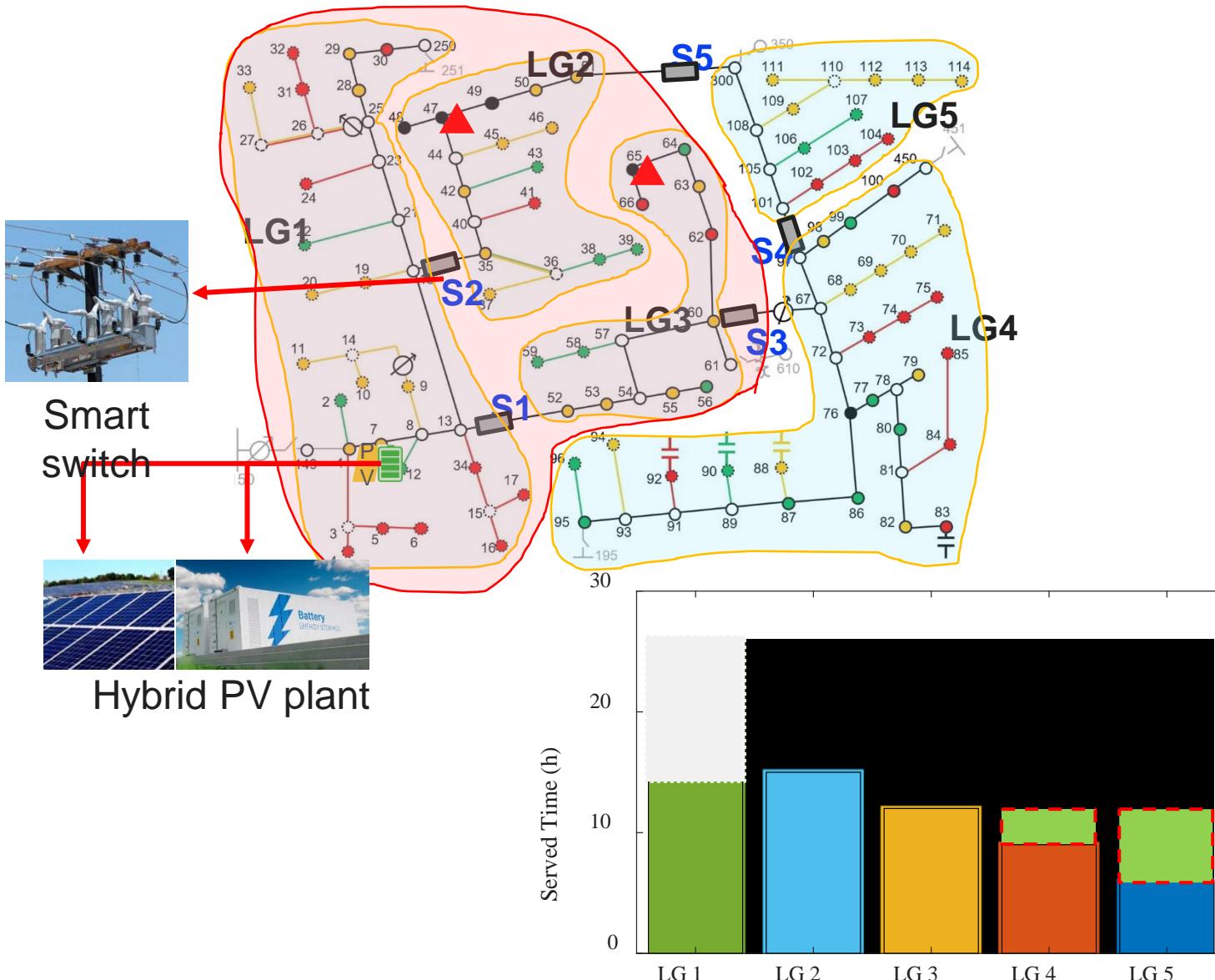
Figure 4.10. Survivability with a random BESS SOC when an outage occurs.

Resilience improvement  
(survivability)

- Integration of the Coordinated Real-time Sub-transmission Volt-Var Control Tool (CReST-VCT) into Energy Management Systems (EMS)
- Developed a python-based GUI for the real-time (5-min) co-simulation platform
- Validated control strategies for the coordinative transmission-distribution Volt-Var control

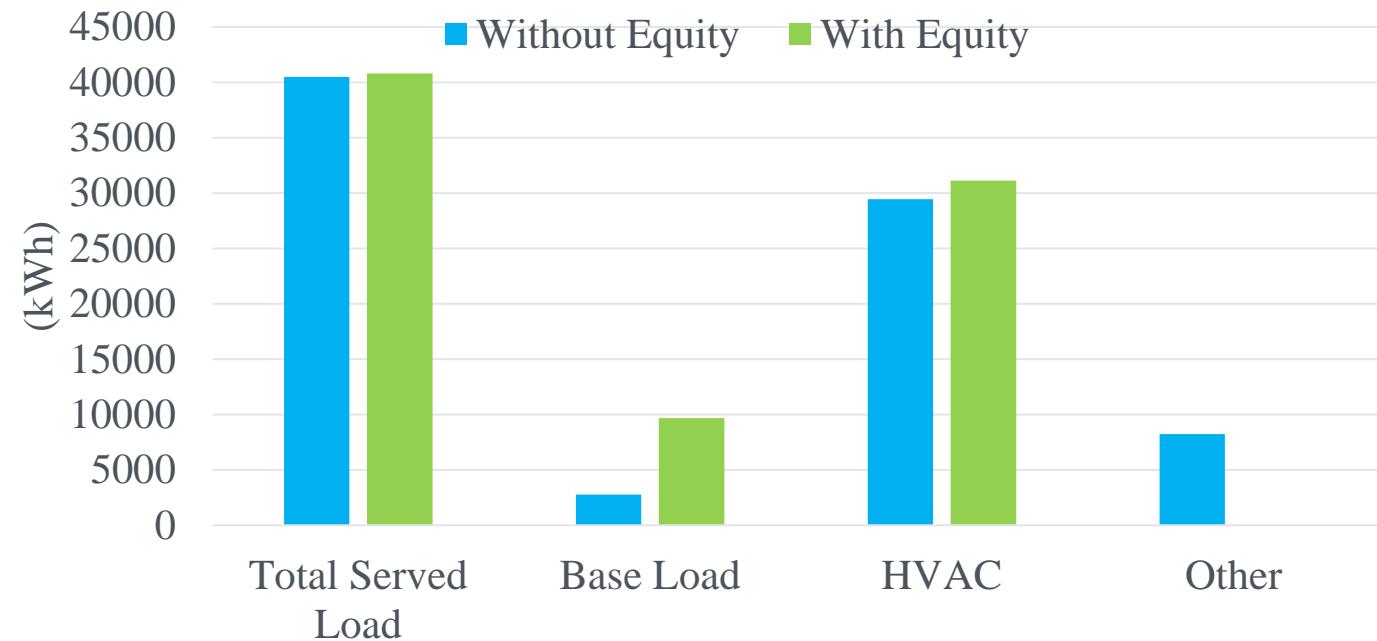


- **Energy Management System of Renewable-powered Microgrids for Resilience Service in Distribution System (Proj-1)**
  - Research Background and the Project
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- **Other Projects**
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  - Coordinated Real-time Sub-Transmission Volt-Var Control Tool (Proj-4)
- **Ongoing Work and Future Work**



- Service restoration via MW-PV & battery system powered microgrid
  - More served loads
  - More served customers
- Main Considerations
  - Switch on/off Load group
  - No sub-meter control capability
  - Radial topology
  - Customer comfort
  - Cold load pickup (HVAC)
- Fairness
  - Location-dependent
  - Ignore value of different loads

# Equity: Preliminary Results



- **With equity consideration**
  - More **base-load (+250%)** served
  - More **HVAC loads (+6%)** served

- **Model-Free approach for operation and control of microgrids and DERs**
  - RL approach for microgrid resiliency service
  - Volt-Var Control for high renewable-penetrated distribution systems
- **Transmission-distribution systems' co-simulation considering high-penetration distributed PV systems**
  - Local DERs → distribution system could be power source (e.g. at noon) → co-simulation
  - So many feeders and detailed circuit → not possible to conduct co-simulation directly
  - How to simplify the distribution systems (eg. 500-bus → 10-bus)
- **Virtual Power Plant (VVP) and demand response (DR)**
  - Demand-side resources (DSRs) @ PV systems, electric vehicles (EV), and HVACs
  - Users' benefit @ Peak load reduction, energy cost reduction...
  - DSRs are aggregated for transactions, how to consider the operation/control constraints of distributed DSRs?

1. **Rongxing Hu**, Ashwin Shirsat, Valliappan Muthukaruppan, et all., "Adaptive Cold-Load Pickup Considerations in 2-Stage Microgrid Unit Commitment for Enhancing Microgrid Resilience," *Applied Energy*, 2024. **(Proj-1, EMS-CLPU)**
2. **Rongxing Hu**, Ye Kai, Hyeonjin Kim, et al., "Design Considerations of a Coordinative Demand Charge Mitigation Strategy." *In 2023 PESGM*. **(Proj-2)**
3. **Rongxing Hu**, Yiyan Li, Si Zhang, et al., "A Load Switching Group based Feeder-level Microgrid Energy Management Algorithm for Service Restoration in Power Distribution System." *In 2021 PESGM*. **(Proj-1, EMS-topology)**
4. **Rongxing Hu**, Ning Lu, et al., "Equity-oriented Resiliency Service via Microgrid in Distribution System." *Manuscript in preparation.* **(Proj-1, EMS-equity)**
5. Ashwin Shirsat, Valliappan Muthukaruppan, **Rongxing Hu**, et al., "A secure and adaptive hierarchical multi-timescale framework for resilient load restoration using a community microgrid," *IEEE Transactions on Sustainable Energy*, 2023. **(Proj-1, EMS)**
6. Yiyan Li, Si Zhang, **Rongxing Hu**, et al., "A meta-learning based distribution system load forecasting model selection framework," *Applied Energy*, 2021. **(Proj-1, forecast)**
7. Si Zhang, Mingzhi Zhang, **Rongxing Hu**, et al., "Reinforcement Learning for Volt-Var Control: A Novel Two-stage Progressive Training Strategy." *In 2022 PESGM*. **(Proj-1, volt control)**
8. Ashwin Shirsat, Valliappan Muthukaruppan, **Rongxing Hu**, et al., "Hierarchical Multi-timescale Framework for Operation of Dynamic Community Microgrid", *In 2021 PESGM*. **(Proj-1, EMS)**
9. Valliappan Muthukaruppan, **Rongxing Hu**, Ashwin Shirsat, et al., "Multi-Feeder Restoration using Multi-Microgrid Formation and Management", submitted to *2024 PESGM*. **(Proj-1, EMS)**

- **Reviewer**
  - IEEE Transactions on Sustainable Energy (60+, **outstanding reviewer**)
  - Applied Energy (20+)
  - IEEE Power Engineering Letters (5+)
  - IEEE Open Access Journal of Power and Energy (15+, **outstanding reviewer**)
  - 2021-2024 IEEE PES General Meeting (10+)
- **Presentation**
  - “Design Considerations of a Coordinative Demand Charge Mitigation Strategy”, PESGM conference, 2023
  - “Distribution Resiliency Frameworks with High PV Penetration”, FREEDM Tech Webinar, 2022
  - “A Load Switching Group based Feeder-level Microgrid Energy Management Algorithm for Service Restoration in Power Distribution System”, PESGM conference, 2021

# Thank You (Q&A)