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2021 Grid of the Future Symposium

Presentation Title:
Harvesting the Nano-Grid Flexibility

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Problem Statement

- Development of consumer-owned Distributed Energy Resources (DERs) is accelerated driven by carbon-free future, grid resilience, favourable electricity time-of-day pricing, and possibility to trade power.

- A particular DER called nano-Grid (n-Grid) brings a high flexibility due to the high ramp rate of its components.

- ✓ The flexibility of the n-Grid can be harvested to:
  a) Minimize the cost of energy use by the n-Grid owner.
  b) Offer its energy capacity in the wholesale market Ancillary Service Products (ASP).
  c) Provide the distribution grid support through a retail market service.

- ✓ We will summarize several use cases of the utilization of n-Grid's flexibility.

[1] Tesla Solar Panels: What Tesla Installs at Your Home. Tesla, 2021. [Online] Available: https://www.tesla.com/support/energy/solar-panels/learn/what-tesla-installs-at-your-home.

N-Grid Features

- Controllable loads
- PV generation with smart inverter
- Battery energy storage system (BESS) with bidirectional charger
- EVs with bi-directional charger

❖ All the components are connected to a common AC bus rated at 230-240V.

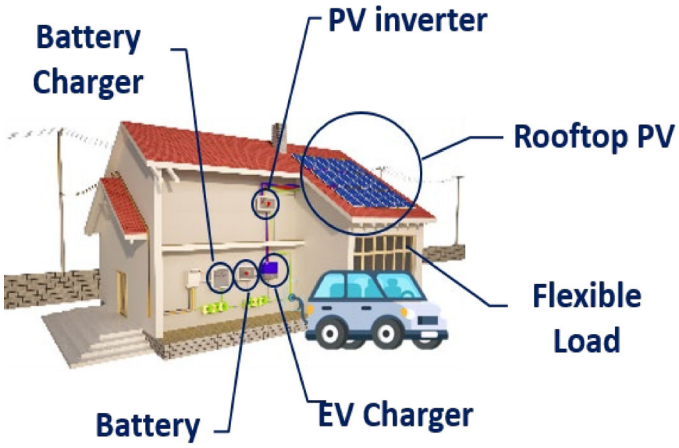

Fig. 1. n-Grid Architecture

M. Kezunovic, M. Soleimani, H. Abu-Rub, S. Bayhan, M. Trabelsi, "Hardware in the Loop Simulation of a Nano-Grid Transactive Energy Exchange", 2nd International Conference on Smart Grid and Renewable Energy (SGRE) 2019 , Doha, Qatar, November, 2019.

Harvesting n-Grid Flexibility

Mode 1	n-Grids to market operator via aggregator
Mode 2	n-Grids to distribution system operator (DSO) with or without aggregator
Mode 3	n-Grids in peer-to-peer exchange with DSO coordination, and with or without aggregator

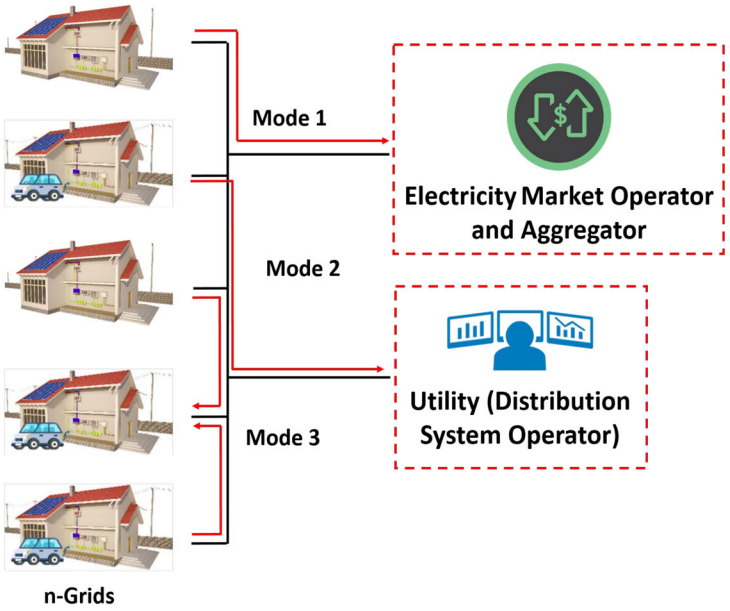

Fig. 2. n-Grid operating modes

N-Grid participation in Wholesale Market (WSM)

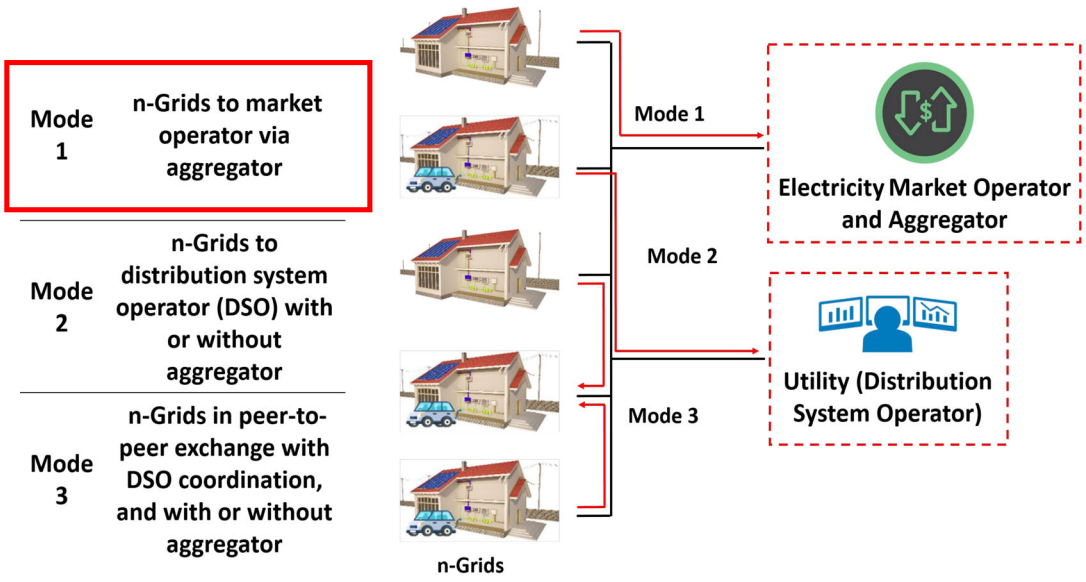

Fig. 2. n-Grid operating modes

N-Grid participation in Wholesale Market (WSM)

Table 1. Different ASPs offered in the market

Type of ASP	Main purpose	Requirements	Time-frame
Frequency regulation	Maintain Freq. to 60Hz	Equipped with AGC	~ 4 Sec
Spinning reserve	Contingency Response	Sync. to Grid	< 10 min
Non-spinning reserve	Contingency Response	Be able to Sync. to Grid	< 10 min

- The minimum capacity required for participation in the WSMs in the US is 100 kW to 1 MW.
- Participation of n-Grids in the WSM calls for an aggregator to aggregate n-Grids' resources and participate in the WSM on their behalf.

[2] ERCOT Business Practice. (ERCOT Public [Online] Available: www.ercot.com/content/wcm/key_documents_lists/89328/BusinessPractice_AS_MarketSubmissions_Version1_4.doc).

N-Grid Resource Management for WSM

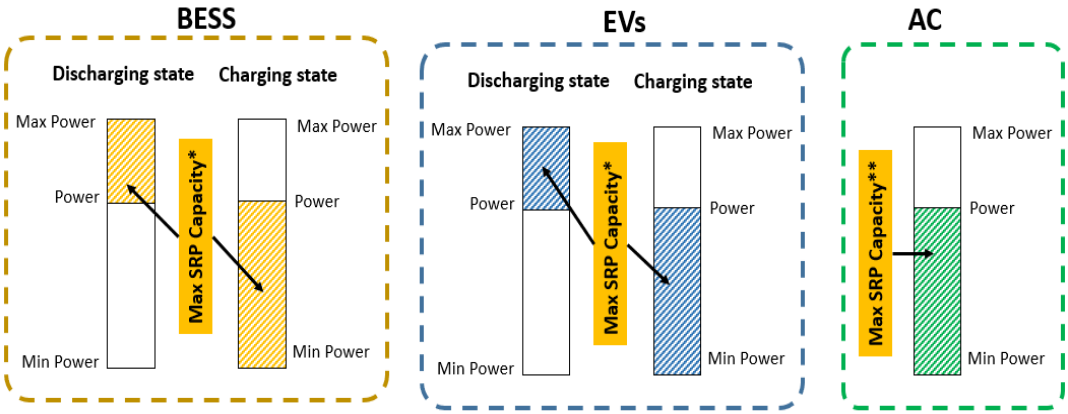

Fig. 3. Flexibility of n-Grid resources deployed for spinning reserve

- In BESSs and EVs, the reserve capacity is limited by the remaining energy.
- In AC, the reserve capacity is also limited by the temperature comfort range of occupants.

N-Grid Resource Management for WSM

- The aggregator is envisioned as a mediator between the n-Grids and the WSM.
- It can manage the n-Grids resources directly through internet of things (IoT).
- The aggregator must capture different uncertainties to ensure its profitability:
  - market prices,
  - EVs arrival, departure and initial energy,
  - ambient temperature,
  - PV generation and
  - n-Grids' electric load.

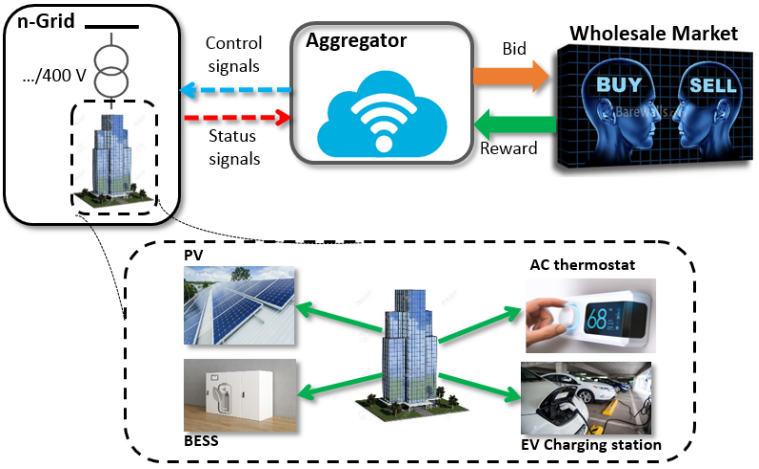

Fig. 4. The n-Grid aggregator framework for participation in WSM.

[3] M. Khoshjahan, M. Soleimani and M. Kezunovic, "Flexibility Provision by Distributed Prosumers in Wholesale Electricity Market," The IET CIRED Workshop, Berlin, Germany, September 2020.

Case Study and Simulation Results

A proper optimization framework is a bi-level optimization in which the uncertainties are captured through predefined scenarios.

- The aggregator schedules the n-Grids at the upper-level optimization and
- runs an estimate of the market at the lower-level to obtain the forecasted marginal prices.

Our case studies demonstrate that:

- ✓ The aggregator can make significant profit out of ASPs in the market.
- ✓ In fact, the spinning reserve profitability is ~10% of the total energy costs.
- ✓ The ASP is mostly provided by the EVs connected to the commercial buildings. Then, EVs in residential buildings, BESSs and ACs.
- ✓ EV and BESS provide high ASP energy amounts since they can operate in both charging and discharging modes.
- ✓ The AC load is not significant and cannot offer much capacity due to temperature limits set by the occupants.

Benefits of n-Grid Resource Flexibility for WSM

- Modern WSMs suffer of low flexibility caused by high penetration of intermittent renewable resources, e.g., wind farms and solar plants.
  - The high ramp rate and storage capacity of n-Grids can be utilized to mitigate renewable generation intermittencies.
  - Their ramp rate can be also employed in procurement of spinning reserve and frequency regulation.
  - Under attractive incentives, they can also participate in demand response and load shedding programs.

N-Grid Participation in Retail Market (RTM)

- Supporting the grid through interactions between DSO and n-Grids.
  - Incentive programs.
  - Real-time bidding.
- Interactions:
  - Direct interactions between n-Grids and DSO.
  - Interactions through aggregators.

Mode 1	n-Grids to market operator via aggregator
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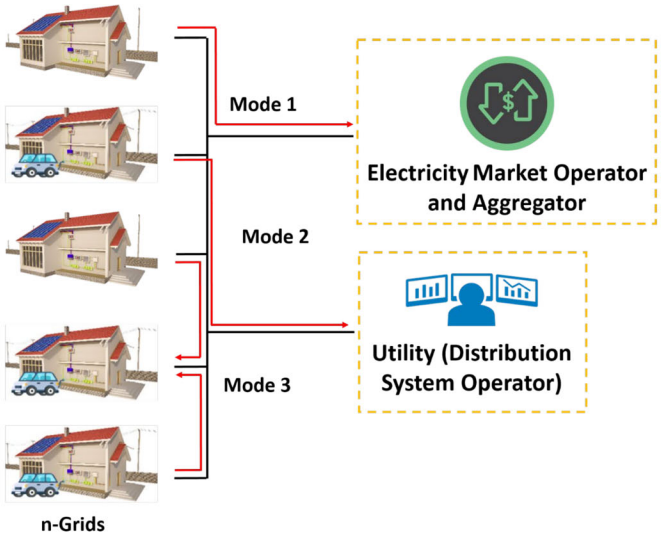
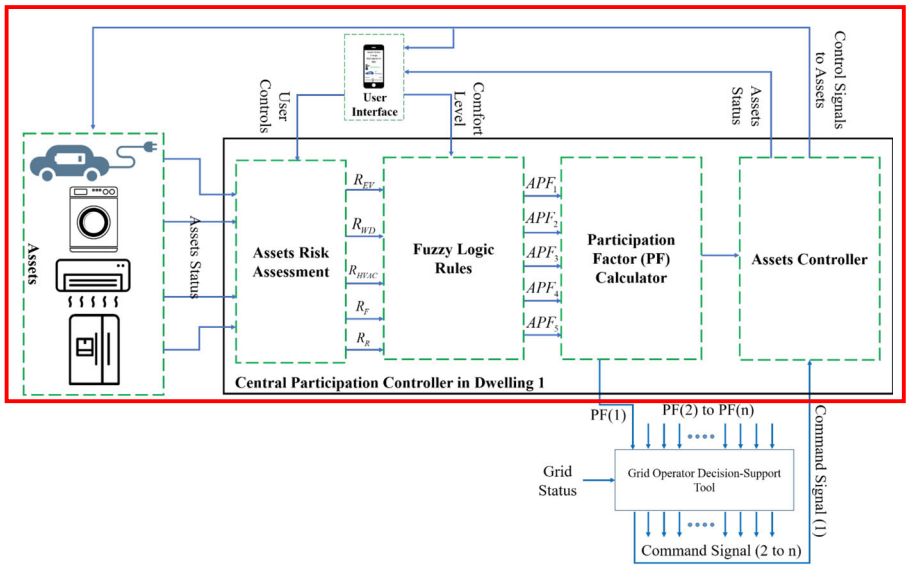


N-Grid Resource Management for RTM

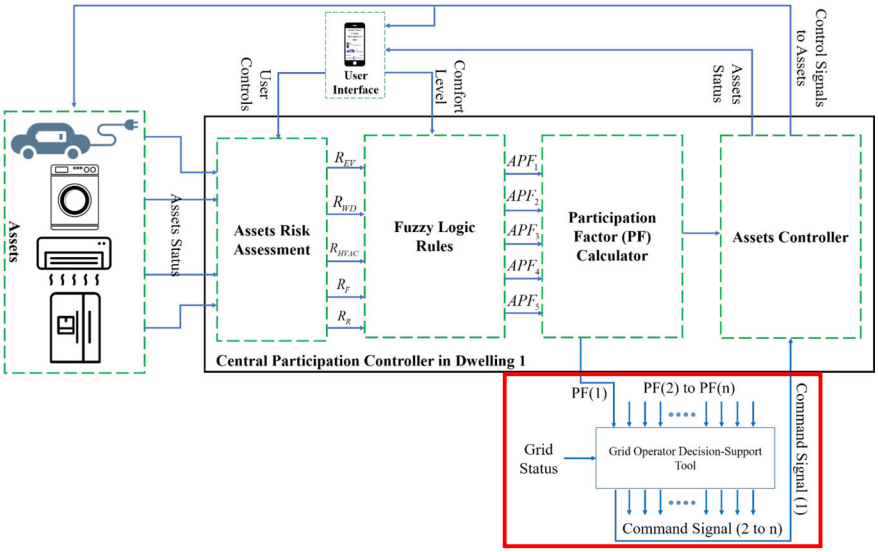
- Managing the resources using on-site controller:
  - Specific characteristics of each component.
  - Control signals from user interface.
  - Level of comfort.
- Output is an index, namely Participation Factor (PF), for DSO decision support tool.



[4] M. Soleimani and M. Kezunovic, "Mitigating Transformer Loss of Life and Reducing the Hazard of Failure by the Smart EV Charging," IEEE Transactions on Industry Applications, Vol. 56, No. 5, pp. 5974-5983, Sept.-Oct. 2020.

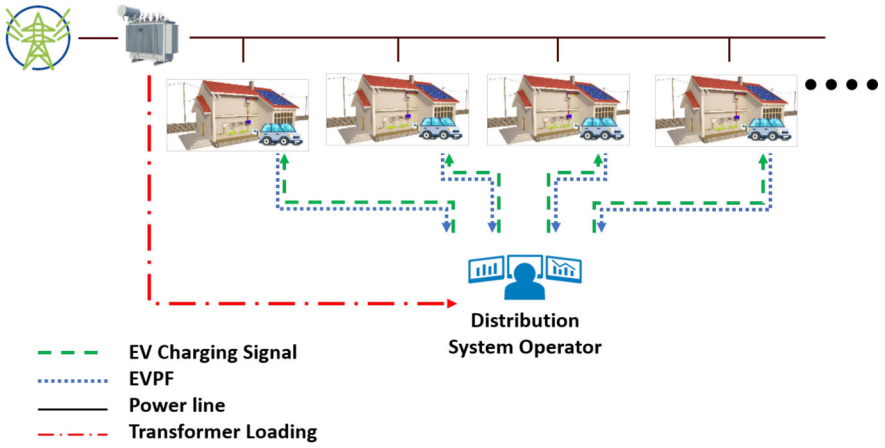
DSO Decision Support Tool

- Receives Participation Factors from n-Grids' on-site controllers.
- Receives grid status from meters in the grid.
- Uses an algorithm to optimally deploy n-Grid resources.
- Send the command signal back to n-Grids' controllers to control the resources.



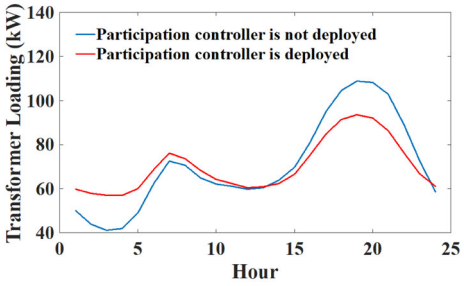
Transformer Overloading Example

- High penetration of EVs is causing overloading for transformers.
- Overloading may cause loss of life and lead to failure.
- The impact of EV charging is controlled by DSO and n-Grids interactions through on-site controllers and DSO decision support tool.



[4] M. Soleimani and M. Kezunovic, "Mitigating Transformer Loss of Life and Reducing the Hazard of Failure by the Smart EV Charging," IEEE Transactions on Industry Applications, Vol. 56, No. 5, pp. 5974-5983, Sept.-Oct. 2020.

Case Study and Simulation Results



Transformer loading before with and without DSO/n-Grid interactions

- It was observed that using the proposed framework, the peak of the load curve is effectively shaved.
- Using DSO and n-Grid interactions, the loss of life which is caused by transformer overloading is reduced from 53.5% to 3.1%.
- It is observed that the value of the paid incentives to the n-Grid is considerably lower than the economic benefit, which shows the proposed framework is profitable for DSO and n-Grids.

Scenario	Loss of life (%)	Economic impact transformer ageing and failure ($)	Paid Incentives ($)
A	53.5	7579	0
B	3.1	3361	1342

[5] M. Soleimani and M. Kezunovic, "Risk-Based Residential Demand Side Response," CIRED 2021 Conference, Geneva, Switzerland, Sept. 2021.

Benefits of n-Grid Resource Flexibility for RTM

- Distributed resources in n-Grid can be deployed by DSO to support the grid operation, including:
  - Peak shaving
  - Voltage regulation
  - Others…
- This deployment should not have a significant negative impact on the comfort of n-Grid owner.
- The interactions between DSO and n-Grids are regulated in an incentive- or bidding-based framework, namely Retail Market.

Conclusion and Acknowledgement

Conclusion:

- The n-Grid flexibility may be utilized in both WSM and RTM.
- For best results, the WSM participation may be coordinated through an aggregator as outlined by the FERC Order 2222.
- A local n-Grid energy management function may be needed to allow individual consumer decisions about an optimal use of the n-Grid resources.
- The WSM and Distribution company operators are expected to gain benefits from the n-Grid flexibility through ASP and grid support services, respectively.

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References

[1] Tesla Solar Panels: What Tesla Installs at Your Home. Tesla, 2021. [Online] Available: https://www.tesla.com/support/energy/solar-panels/learn/what-tesla-installs-at-your-home.

[2] ERCOT Business Practice. (ERCOT Public [Online] Available: www.ercot.com/content/wcm/key_documents_lists/89328/BusinessPractice_AS_MarketSubmissions_Version1_4.doc).

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