iea-isgan.org

Flexibility Markets

Taxonomy to Quantify Flexibility Potential

Factsheet

Anjali Wadhera (NRCan), Steven Wong (NRCan), Adamantios Marinakis (ETH Zürich), Regina Hemm (AIT)
ISGAN Working Group 9

December 2023

About ISGAN Discussion Papers

ISGAN discussion papers are meant as input documents to the global discussion about smart grids. Each is a statement by the author(s) regarding a topic of international interest. They reflect works in progress in the development of smart grids in the different regions of the world. Their aim is not to communicate a final outcome or to advise decision-makers, but rather to lay the groundwork for further research and analysis.

Disclaimer

Acknowledgement: NRCan would like to thank Brian McMillan and Pat Lo for their contributions to this work.

Taxonomy to Quantify Flexibility Potential

To make net zero technically and economically feasible, the future power system will need to capture flexibility from various resources (i.e., generation, storage, and loads) across various segments of the power system (i.e., generation, transmission, distribution, and end-use loads). The uptake of digitalization, the adoption of distributed energy resources and the push for cross-sectoral electrification is transforming traditional grid operation; resources with flexibility potential in distribution grids can be a key solution to support grid reliability, resiliency, and optimized system utilization via flexibility markets.

Flexibility in the context of this work is defined as "the ability of a power system to cope with variability and uncertainty in both generation and demand, while maintaining a satisfactory level of reliability at a reasonable cost, over different time horizons" [1]. Flexible resources adopted by customers across sectors can contribute to addressing grid needs, including to better integrating renewable energy. A flexible resource can be any type of technology or process capable of adjusting their generation and/or consumption patterns to provide flexibility to the grid to support its operation. While integrating these flexible resources, it is critical to understand the quantity of flexibility that can be extracted.

This factsheet provides a framework to identify and quantify flexibility potential across various customers who have flexible resources for utility planners and operators. As flexibility potential varies spatially and temporally, having a simplified methodology will be critical to understand the flexibility potential within different segments of the electric grid. Adequate analysis can help support optimized asset utilization in operation and future planning scenarios as an additional option for grid support. To this extent, different layers are proposed to identify the feasible flexibility potential.

As shown in Figure 1**Error! Reference source not found.**, there are four proposed layers to assess flexibility potential. **Technology or Process** represents the maximum amount of flexibility available as the full technical capability of the flexibility potential of the resource with no considerations beyond the physical capabilities. This could pertain to an individual resource or an aggregated set of resources. This layer assesses the resource's maximum flexibility potential if all other factors are ignored. **Communication and Controls** assesses the impact control and communication systems have on the resource's flexibility potential. This layer considers how flexibility changes based on the monitoring, automation, communication, and control infrastructure, as well as data transfer specifications. In implementation, this layer will play a key role to determine whether the flexibility is dispatchable on request, through a schedule or in real time. **Location** assesses the impact of geographic location on flexibility potential, including aspects of the interconnection (e.g., distribution or transmission connected, impact study outcomes), locational marginal price of providing a service and climate conditions. Diversity of resources will allow for different solutions to be available to support the grid in case some resources are unavailable to participate in flexibility events. Lastly, **Customer Preferences and Market Economics** considers customers' willingness, including market factors, that would enable the resource to provision the flexibility. Aspects of reliability, including the ability of a resource to provide the provisioned flexibility and risk mitigation measures to avoid stranded assets are included in this layer.

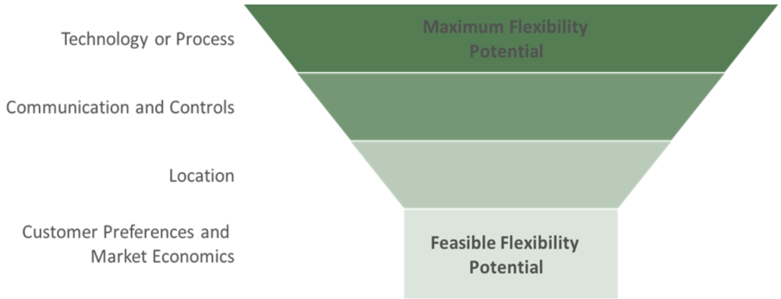

Figure 1: Taxonomy proposed to quantify flexibility potential.

The assessment of each layer relies on the consideration of various qualitative and quantitative indicators. A detailed yet non-exhaustive list of flexibility indicators compiled from scientific literature and from ISGAN Working Group 9 experts is summarized in Table 1. These indicators can be used to concretely quantify and characterize flexibility potential. The flexibility indicators listed are not all required to compute a resource's flexibility potential; there are interdependencies between indicators mentioned.

Table 1: Examples of flexibility indicator considered within each taxonomy layer.

Taxonomy Layer	Flexibility Indicator
Technology or Process	Controllability [2]–[5] Energy capacity [2], [6]–[8] Energy loss per time [2] Ramp rate [2], [4], [6], [7] Reactive power capacity [2], [4] Real power capacity [2], [6]–[9] Rebound [2] Time necessary to achieve maximum response [2], [6]–[9] Type of flexible resource [2]
Communication and Controls	Controller time lag [6], [7] Coordination scheme Data necessary to estimate flexibility [4] Interoperability standards Response granularity [6] Time delay to observe response on network [2], [9] Visibility of production/consumption [4]
Location	Connection to grid [2] Cost to retrofit to provision flexibility Implementation requirements [3], [4], [6] Regulatory framework
Customer Preferences and Market Economics	Access to markets Cost to operate for flexibility services [2] Credibility [2] Customer behaviour [5] Frequency resource can be provisioned [2] Maximum response duration [2], [7], [9] Minimum time required to switch between states [2], [3], [9] Participation models in markets

Predictability [2]
Resource consumption/production curve
Resource ownership type [2]
Response reliability [2]
Time necessary between events [2], [6], [8]
Time required for a resource to determine participation in events
Variability in consumption/production [4]

There is an opportunity to tap into flexibility potential across a diverse set of resources. Leveraging a common framework like the proposed taxonomy to quantify flexibility potential would help streamline how to calculate flexibility potential across a diverse set of resources. Further research compiling key flexibility indicators to compute flexibility potential would help identify where flexibility exists and any external factors that may be impacting the potential available. Infrastructure, communication systems and control strategies can be re-evaluated to determine if additional flexibility can be extracted. The location may be one of the constraints that must be planned around; however, further investigation of interconnection requirements and regulations may be another avenue to maximizing flexibility potential from this layer. Lastly, significant opportunity exists in designing markets to influence customer preferences. Current grids can evolve to include customers as a dynamic segment of the grid instead of a static load. Grid operation in the future can evolve by leveraging flexible resources connected to distribution grids as an additional product available to system operators in the transition to net zero.

References

[1] J. Ma, V. Silva, R. Belhomme, D. S. Kirschen, and L. F. Ochoa, “Evaluating and Planning Flexibility in Sustainable Power Systems,” IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 200–209, Jan. 2013, doi: 10.1109/TSTE.2012.2212471.

[2] M. Z. Degefa, I. B. Sperstad, and H. Sæle, “Comprehensive classifications and characterizations of power system flexibility resources,” Electric Power Systems Research, vol. 194, p. 107022, May 2021, doi: 10.1016/j.epsr.2021.107022.

[3] O. Ma et al., “Demand Response for Ancillary Services,” IEEE Transactions on Smart Grid, vol. 4, no. 4, pp. 1988–1995, Dec. 2013, doi: 10.1109/TSG.2013.2258049.

[4] North American Electric Reliability Corportation, “Distributed Energy Resources: Connection Modeling and Reliability Considerations,” Feb. 2017. [Online]. Available: https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report.pdf

[5] R. G. Junker et al., “Characterizing the energy flexibility of buildings and districts,” Applied Energy, vol. 225, pp. 175–182, Sep. 2018, doi: 10.1016/j.apenergy.2018.05.037.

[6] F. Oldewurtel et al., “A framework for and assessment of demand response and energy storage in power systems,” in 2013 IREP Symposium Bulk Power System Dynamics and Control - IX Optimization, Security and Control of the Emerging Power Grid, Rethymno: IEEE, Aug. 2013, pp. 1–24. doi: 10.1109/IREP.2013.6629419.

[7] R. Pratt and Z. Taylor, “Recommended Practice for Characterizing Devices’ Ability to Provide Grid Services,” Pacific Northwest National Laboratory, For Review - Do Not Distribute. [Online]. Available: https://gmlc.doe.gov/sites/default/files/resources/Recommended%20Practice%20Grid%20Services%20from%20Devices%20Ch%201-2_0.pdf

[8] A. Balint and H. Kazmi, “Determinants of energy flexibility in residential hot water systems,” Energy and Buildings, vol. 188–189, pp. 286–296, Apr. 2019, doi: 10.1016/j.enbuild.2019.02.016.

[9] A. Wang, R. Li, and S. You, “Development of a data driven approach to explore the energy flexibility potential of building clusters,” Applied Energy, vol. 232, pp. 89–100, Dec. 2018, doi: 10.1016/j.apenergy.2018.09.187.