Study Committee C1

Power System Development and Economics

Paper 10392_2022

Effects of the COVID-19 Pandemic on Distribution Load Profiles

Vincent Westfallen, Marina Mondello, Susanne Aguilar

Commonwealth Edison

Motivation

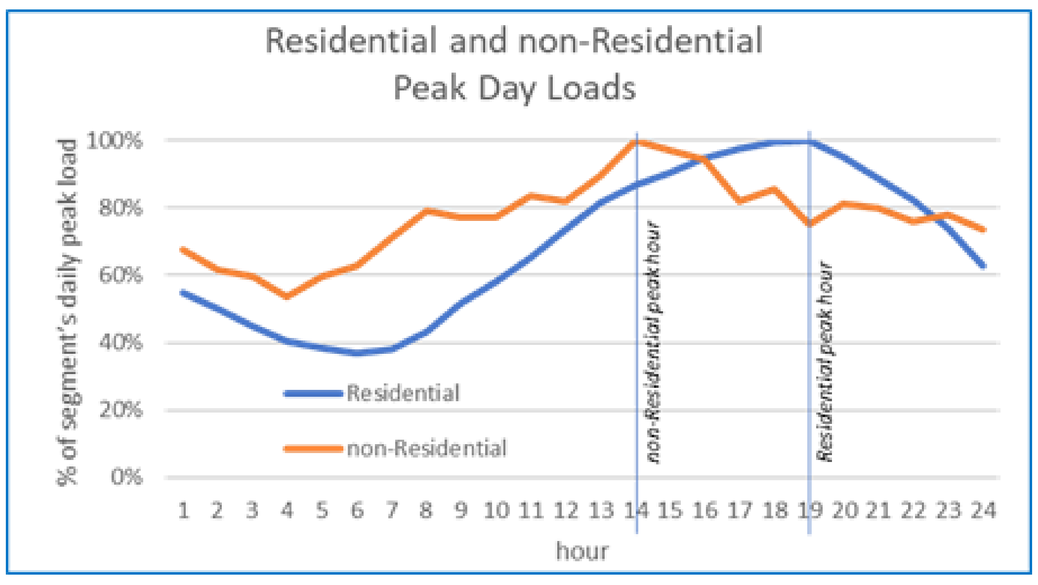
- Pandemic-induced changes in utility customer behavior along with other complex changes in demand patterns related to a range of new grid features that are presently emerging pose new challenges to distribution grid planners. Traditionally, load projections have been based on historical load behavior and have very often focused on peak hour load characteristics. Faced with new grid features that lack historical data suitable for the development of projections and an evolving risk environment that is characterized by increased uncertainty, grid planners require new methodologies and new tools to help them ensure adequate investment in grid infrastructure to meet future demand under changing reliability and resilience challenges.

Method/Approach

- This paper explores the more granular effects of pandemic-induced changes in utility customer behavior on load profile curves of distribution level components and proposes a methodology to incorporate considerations related to those changes in the distribution planning process.

Objects of investigation

- In order to provide a few helpful definitions for the discussion that follows we will refer to individual native customer class loading of a particular circuit or substation as its load segments. Here, we distinguish between residential and non-residential **segments**, but these can be further refined as needed. The various pandemic-induced phenomena being considered along with new technologies and grid capabilities are called **features**. The timing of the maximum magnitude of one load segment relative to another or to a feature is its **coincidence**. The likelihood that a particular circuit or substation is impacted by a given feature and its exposure to impact is described qualitatively as its **propensity** to said feature.



Experimental setup & test results

- This analysis requires construction of 24-hour time series data sets for peak, off peak, and other significant days for each disaggregated load segment and for the features that are being considered. AMI and other data sources can be utilized in this process.
- Initial peak and minimum load magnitude as well as duration are captured to identify a range of likely trajectories for these critical parameters by varying component specific propensities toward individual features that are expected over the course of time, leading to the planning horizons of interest.
- Each feature can be characterized by its natural coincidence with various customer class segments.
- Scenarios can be created for a component by summing the daily time series data sets of load segments and the features expected to be experienced by the component, scaled to reflect propensity.
- Scenarios should encompass all variables that are pertinent including peak days, different seasons, minimum load days, weekdays and weekends.

	Feature	Coincidence Level with Various Load Segments
Pandemic Related	Loss of non-residential load	Pre-pandemic Residential +
		Pre-pandemic non-Residential -
	Residential load shift	Pre-pandemic Residential +
		Pre-pandemic non-Residential +
Non-Pandemic Changes	Re-purposed non-Residential property	Residential +
		non-Residential +
	EV home charging	Residential +
		non-Residential +
	EV workplace charging	Residential +
		non-Residential +
	Other types of electrification	Residential +
		non-Residential +
	Solar PV	Residential -
		non-Residential -
	Storage	Residential -
		non-Residential -
	Demand Response	Residential -
		non-Residential -

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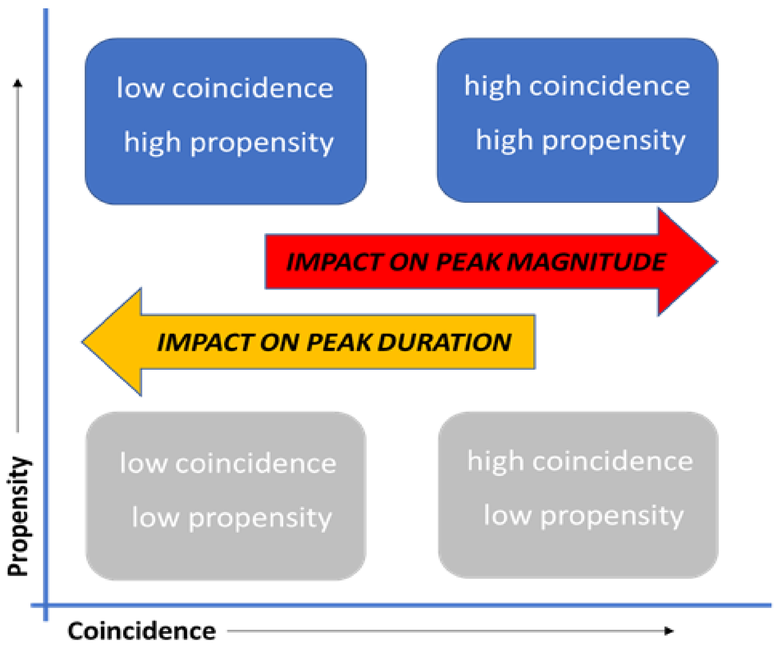
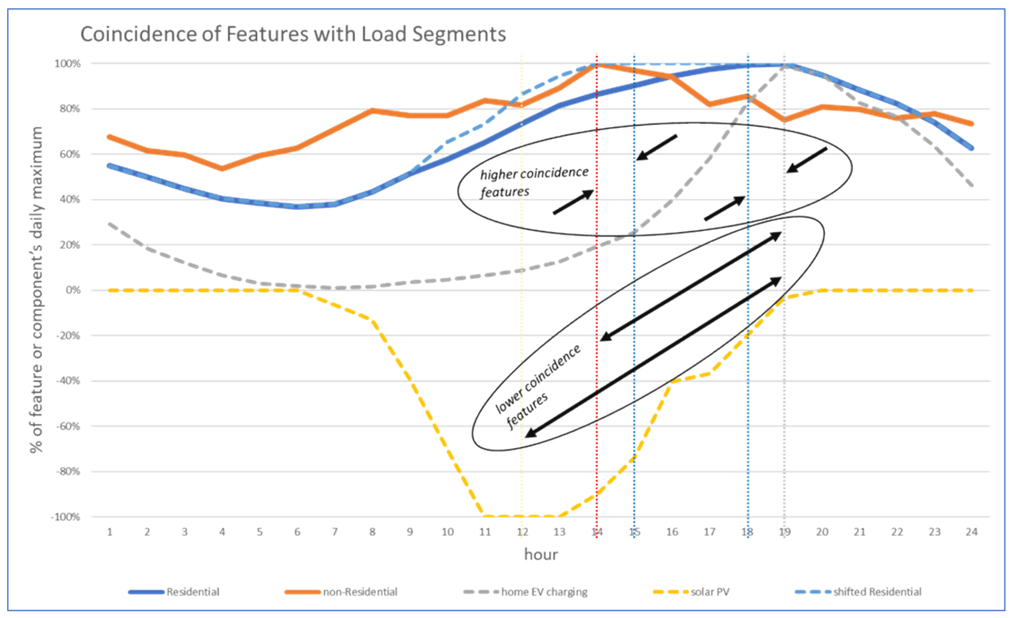
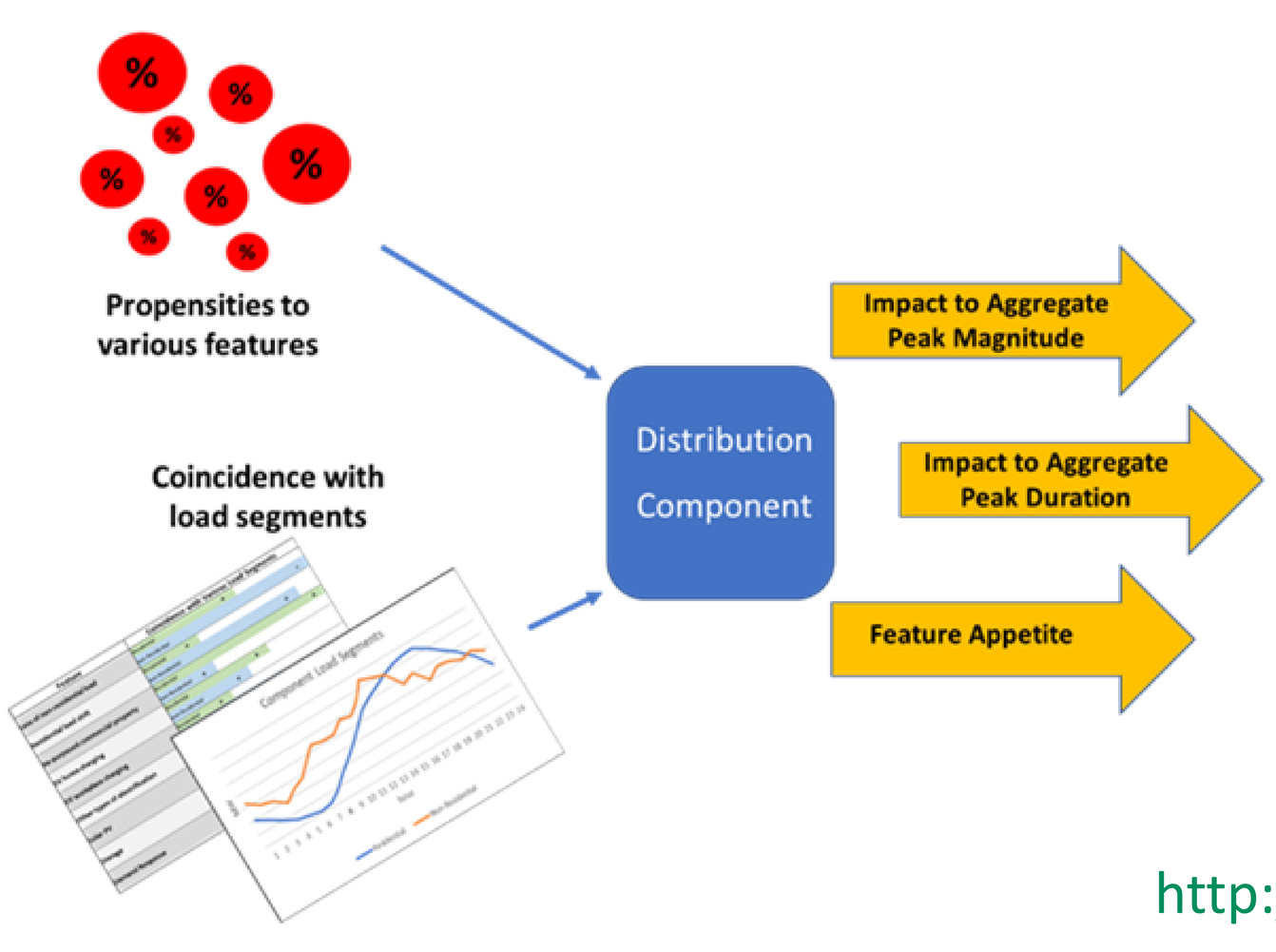
Discussion

- Propensity toward a certain feature can be assigned to a component based on customer mix, regulatory policy, area demographics, and historical trends, among other criteria. In general, a high coincidence feature will tend to produce a change in segment load magnitude, while a low coincidence feature can result in a change in segment peak load duty cycle.
- **Impact to Aggregate Load Magnitude:** Aggregate load magnitude is perhaps the parameter most familiar to distribution planners. When it exceeds an equipment limit, a solution is warranted. Often a peak magnitude forecasted above a thermal or operating limit will drive system reinforcement and capital expenditure. A second, more subtle scenario involving aggregate load magnitude can occur when features impact the minimum load that equipment will experience.
- **Impact to Aggregate Load Peak Duration** With historic peak hour planning, the duration of load peaks can often be overlooked. Many times, load profile parameters—including peak duration—that are used to calculate equipment ratings are not re-examined over time to look for changes, although extended duty cycles can have significant effects on equipment capabilities.





- **Feature Appetite** In traditional peak hour planning, it is common to compare forecasted peak hour load on a component with the peak hour forecasted contingency load. Advancements in planning and operating tools that allow for utilizing time series data sets to process possible load transfers in real time will produce great visibility into dynamic component appetites that vary throughout the day and across the seasons.



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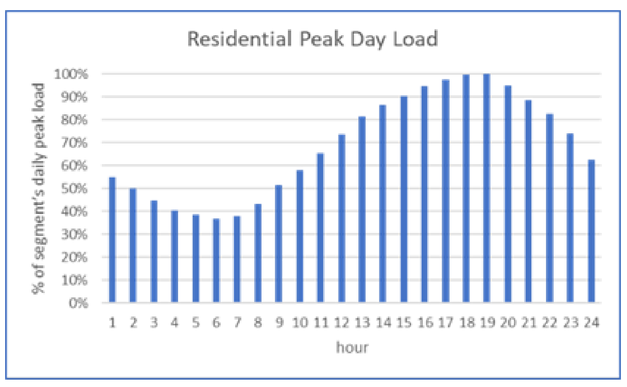
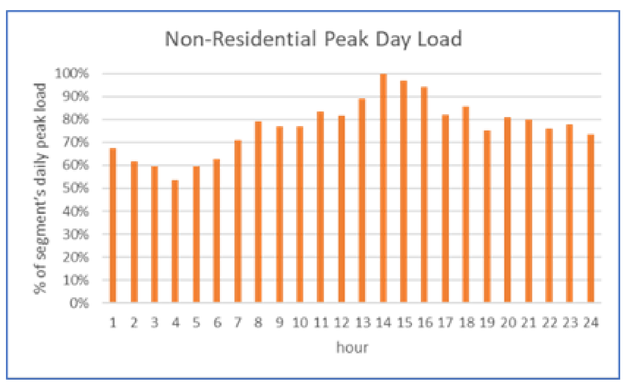
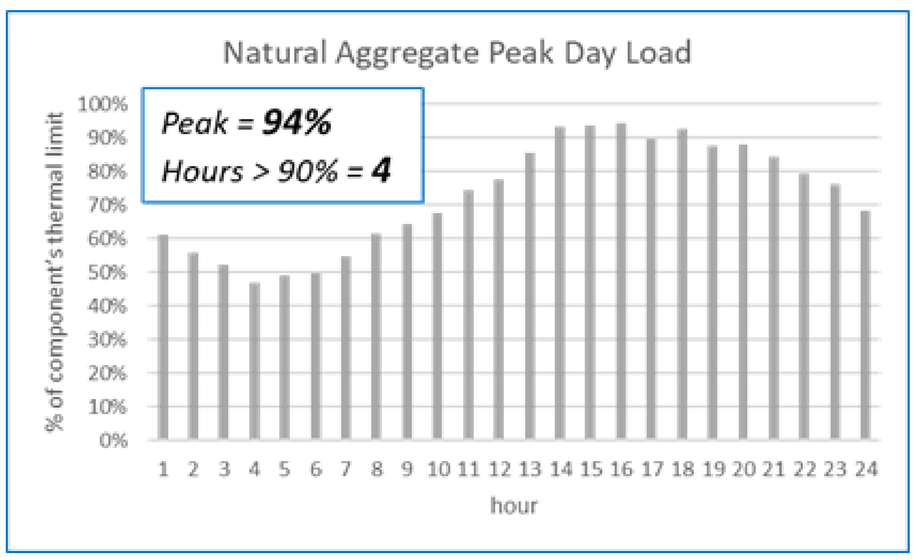
Conclusion

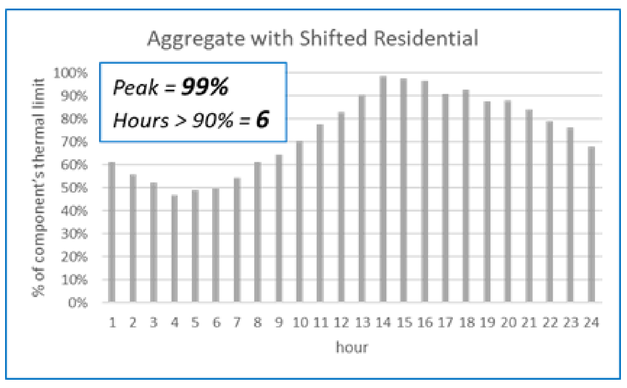
- An example 12kV circuit that serves both residential and non-residential load is used to illustrate the methodology. The pre-pandemic peak day segment and the resultant aggregate load profiles are shown below:

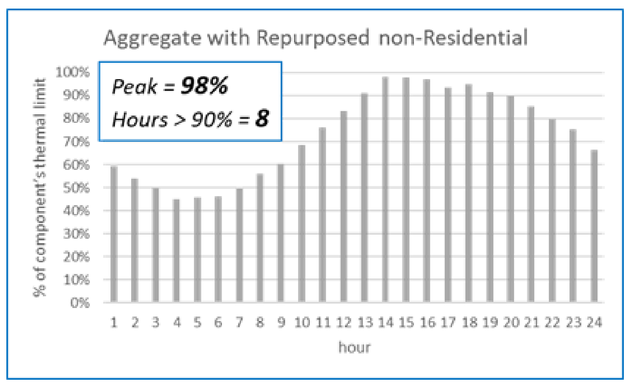


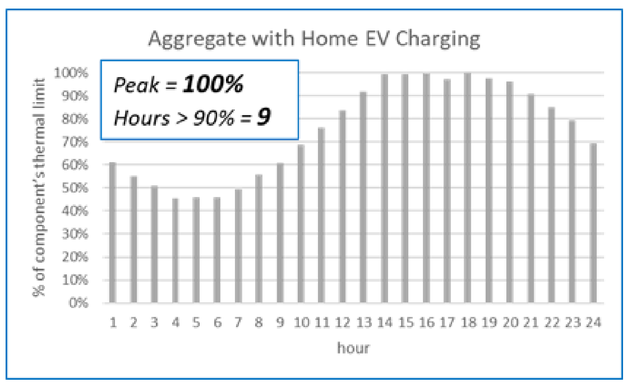


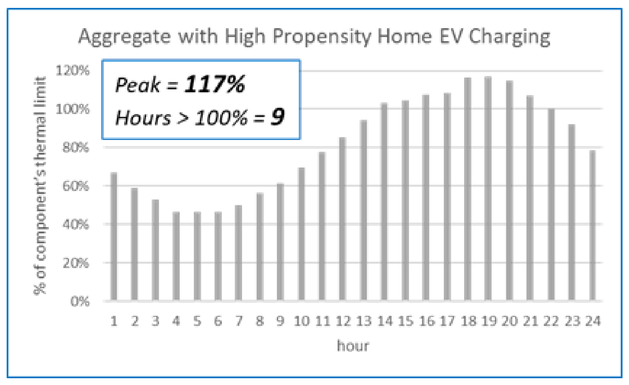


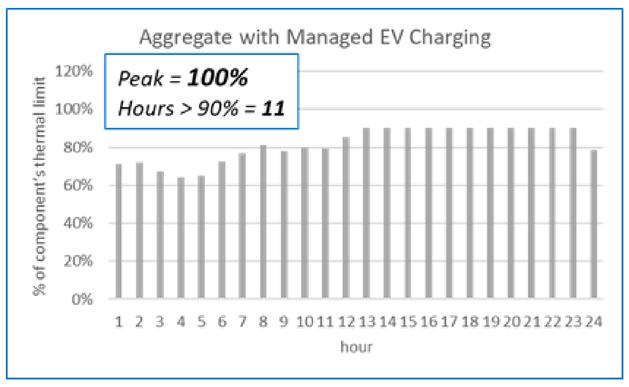
- Following the proposed methodology, scenarios can be created for such a component by summing the daily time series data sets of load segments and the features expected to be experienced by the component, scaled to reflect propensity. Scenarios should encompass all variables that are pertinent including peak days, different seasons, minimum load days, weekdays and weekends, as well as different output profiles for DER that may be included. Possible results are shown below:











- The rapidly evolving risk environment and changes in technology and grid capabilities suggest that distribution grid planners will need to develop new capabilities and tools to adequately predict changes over all planning horizons.
- Some features can transpire very rapidly while others occur over years. Identifying components with high propensities for potential risk factors like residential load shifting or pure non-residential load loss require particular vigilance.
- As near-, medium- and long-term time series forecasts are assembled for distribution system components, available appetite for various features can be incorporated into relief and operating strategies, adding resilience to grid design.