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Time Interval Sensitivity Analysis of Residual Demand in South Korea: A Comparison of 1-Hour and 5-Minute Data Intervals

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1. Introduction

The global push for a carbon emission-free society is intensifying. The IPCC (Intergovernmental Panel on Climate Change) recommends global carbon neutrality by 2050 to keep global warming below 1.5 degrees Celsius [1]. The South Korean Presidential Committee on Carbon Neutrality has proposed two strategies to reach this milestone. However, these strategies have drawn critique due to their dependence on yet-to-exist or soon-to-be-available technologies [2]. Moreover, the strategies overlook the importance of load following technologies essential for stabilizing power from Variable Renewable Energy (VRE) sources, such as solar and wind.

Presently, options for carbon-neutral load following power are scarce, with hydropower standing out. However, innovations are on the horizon, like boron-free SMRs (Small Modular Reactor), hydrogen-fueled gas turbines, energy storage systems, and fuel cells, which might be viable if costs diminish. Carbon-captured natural gas is another potential avenue.

As the adoption of variable renewable energy surges, the necessity for load following plants that modulate power output becomes evident. Excess renewable energy production can escalate costs and decrease its environmental advantages, underscoring the importance of efficient energy storage solutions [3, 4, 5, 6, 7, 8]. Energy storage methods, including batteries and pumped hydro, are pivotal to compensate for renewable energy's inconsistency and to serve as backup during periods of reduced renewable output. Nonetheless, the current cost and capacity limitations of these solutions persist.

In order to plan for the challenging load following environment of the future, thorough analysis of the residual demand is crucial. High time resolution assessment is necessary but often times, data is very limited, especially for large scale grids. This study is a sensitivity study on the time interval.

2. Methods and Results

2.1 Methodology and Data Sources

Data of country scale grid with generation capacity in GW-scale is very scarce. However, KPX (Korea Power Exchange) has released the demand data with 5-min time interval on EPSIS (Electric Power Statistics Information System) [9]. Data can be easily accessed from the Korean public data portal (www.data.go.kr). Solar and wind generation data in the same time scale was released. Using the data of year 2022, the residual demand was obtained.

The residual demand can be obtained by subtracting solar and wind generation capacity from the demand. The profiles of the two renewable sources were obtained and the maximum solar and wind generation capacity was set as 18.476 GW and 1.708 GW respectively, as these were the installed capacities from the most recent report from KPX.

Four weeks were chosen to represent the four different seasons in Korea. The peak demand weeks of summer and winter were chosen while the minimum demand weeks were chosen to represent spring and fall.

Table I: Representative Week of Each Season

Season	Week
Spring	18
Summer	27
Fall	36
Winter	51

The demand curve had more than a hundred thousand data points but was not perfect. There were a few cavities in the data and the average of the neighboring data points was calculated to fill them.

2.2 Results & Discussions

The residual curve of 5 min. time interval and 1 hour time interval were compared for all four seasons. Summer residual demands are shown in Figs. 1 and 2. As can be anticipated, the 5 min interval curve is much sharper than the 1 hour interval curve.

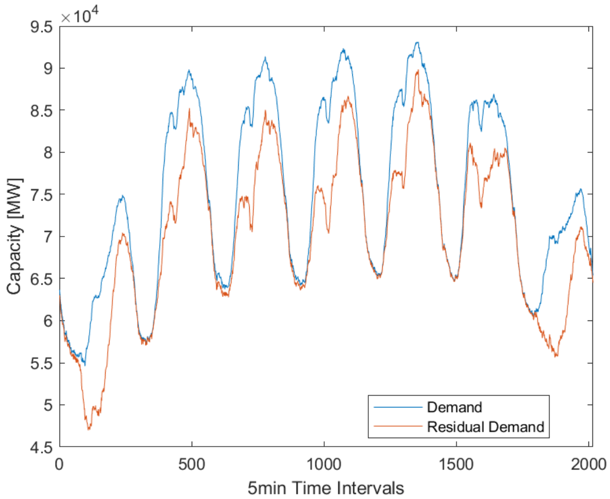

Fig. 1. Summer Demand and Residual Demand curve on 5 min time intervals

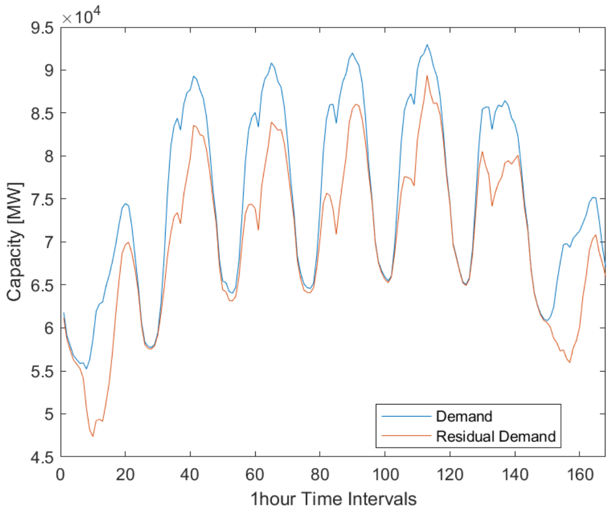

Fig. 2. Summer Demand and Residual Demand curve on 1 hour time intervals

Table II: Time Interval Sensitivity of Maximum Ramp Up Rate

	5 min Intervals [MW/min]	1 hour Intervals [MW/min]	Difference [MW/min]
Spring	216.9401	108.3111	108.629
Summer	203.1031	83.21627	119.8868
Fall	220.3585	120.3281	100.0304
Winter	234.2267	142.0515	92.1752

Table III: Time Interval Sensitivity of Maximum Ramp Down Rate

	5 min Intervals [MW/min]	1 hour Intervals [MW/min]	Difference [MW/min]
Spring	-177.502	-101.523	75.97831
Summer	-227.03	-66.3669	160.6635
Fall	-243.178	-96.2314	146.9466
Winter	-330.735	-96.8414	233.8938

Table III: Time of Maximum Ramp Up Rates

	5 min Intervals	1 hour Intervals
Spring	15:55	17:00
Summer	13:10	08:00
Fall	08:05	08:00
Winter	08:10	08:00

Table IV: Time of Maximum Ramp Down Rates

	5 min Intervals	1 hour Intervals
Spring	7:30	8:00
Summer	17:05	00:00
Fall	17:05	09:00
Winter	17:05	12:00

Although the difference may not seem dramatic on the figures, the numbers cannot be overlooked. Tables I and II show the ramp rate differences. The maximum ramp up rate difference between the two time intervals occurred in summer with almost 120MW/min difference.

The difference is even bigger on the maximum ramp down rate. The biggest difference occurred in winter with a value bigger than 230MW/min.

It is clear that an assessment based on a 1-hour interval curve cannot capture the exact load following specs required. Numbers can be severely underestimated as the volatility is diffused.

Tables III and IV show the time period of maximum ramp rates. It shows that the time do not match all the time. This means that actual discrepancies will be larger than the figures shown above.

The results from this study are similar from that of Deane [10]. Although the VRE was limited to wind generation in the study, both studies show similar results. Higher temporal resolution is crucial in power system modeling especially when VRE proportion increases.

This study shows that volatility is greater than anticipated when higher temporal resolution modeling is performed. If we are to pursue deeper penetration of VREs, it is necessary to invest more on flexible energy sources and energy storage methods. To maintain the objective of reducing carbon emission, flexible sources must be from low carbon sources. SMRs with flexibility standards higher than conventional plants are being developed. These may play a crucial role in our grids in the future.

3. Summary and Future Works

Sensitivity study was performed on the residual demand with different time intervals. Most high resolution studies performed are based on 1 hour time interval data. However, the high volatility of both the demand curve and VRE (variable renewable energy) can cause large discrepancies between minute and hour scale data. In case of South Korea, the maximum difference was 234MW/min. Considering that the peak demand is a little over 90GWs, this difference is significant and should be thoroughly assessed when studying for future load following necessities.

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