Impact of 15-minutes Measurement Interval in Smart Metering on Peak Power Estimation and Network Capacity Planning

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Abstract— **This study examines the impact of transitioning from hourly to 15-minute metering intervals on peak power estimation, leveraging data from the first rollout of new generation smart meters by a Finnish Distribution System Operator (DSO). The analysis demonstrates that the switch to shorter metering intervals significantly influences peak demand estimates, with increases of up to 74.5% observed at certain metering points. The study also identifies that many electrical connections, based on 60-minute measurements, are oversized, as power demand often remains below 50% of the maximum capacity. Additionally, the research highlights the need for more accurate methods of estimating electrical connection requirements, as the introduction of 15-minute metering provides deeper insights into short-term power demands. These findings have significant implications for DSOs regarding network planning and tariff design optimization. As more 15-minute data become available, future studies will refine consumption profiles, contributing to more efficient grid management.**

Index Terms--**15-minute metering, Metering Intervals, Peak Power Demand, Power-based Tariff, Smart Meters.**

I. INTRODUCTION

The sizing of electrical connections, the design of electrical networks, and the structure of electricity markets and network tariffs have traditionally relied on hourly consumption data. This hourly metering interval has provided the foundation for assessing peak demand and determining grid capacity needs. However, with the transition to a 15-minute imbalance settlement period in Finland, Distribution System Operators (DSOs) have begun deploying smart meters capable of registering consumption at a higher resolution, such as 15-minute or even 1-minute intervals [1].

In Finland, the three largest DSOs have already announced their plans for new meter rollouts. Elenia's reform, which began in 2021, is expected to be completed by 2025, with the installation of 400,000 new meters [2]. Caruna plans to install new meters for all customers between 2027 and 2029, totaling 760,000 meters [3]. Helen Electricity Network Ltd. is upgrading its infrastructure with the installation of 420,000 new meters for customers in Helsinki between 2023 and 2029 [4], [5]. This transition is driven by regulatory requirements aimed at improving the accuracy of energy measurements and enabling a more responsive electricity market [6], [7].

In Finland, there are 77 DSOs [8], which typically charge small customers through a fixed monthly fee and a consumption-based volumetric rate. However, this consumption-based fee rarely aligns perfectly with peak power demands, which are the primary drivers of infrastructure costs. Approximately 90% of DSO expenses stem from maintaining and operating the network to meet peak loads at any given moment [9]. Some Finnish DSOs have recently extended power-based tariffs, which have long been used for larger customers, to small household-level customers as well. This tariff allows customers to influence their network service fees by limiting peak power demands [10]. Furthermore, in the new government proposal for the electricity market law update, there is an aim to promote the use of power-based tariffs across Finland and establish a uniform pricing structure among DSOs, while DSOs still have responsibility to determine the unit prices themselves [11].

Until recently, peak demand was measured only in hourly intervals. However, with the ongoing rollout of new smart meters, shorter metering intervals enable a more precise examination of peak demand in buildings. Given Finland's consumption patterns—cold winters, typical use of electric heating systems in residential and other buildings, and widespread use of saunas—this shift is expected to reveal higher peaks and increased variability, providing a more detailed view of electricity consumption profiles and peak power behavior. While buildings themselves continue to exhibit the same load profile, the availability of high-resolution data allows for a more precise analysis of short-term peak loads. In Finland [12], as well as in Sweden [13] and Norway [14], large-scale studies have examined building electricity load profiles using hourly data. However, research on metering intervals shorter than one hour has been relatively limited, particularly on a large scale. One notable exception is the study by Harsia et al., which analyzed six single-family houses' electricity

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consumption at 1 hour, 15-minutes, and 1-minute resolution. Compared to hourly average peak power, observed peak power increased averagely 14 % within 15 minutes interval and 34 % within 1-minute interval [15].

The implementation of shorter measurement intervals has far-reaching implications beyond the technical evaluation of load profile. For DSOs, understanding peak power at a more granular level is crucial for infrastructure planning, investment decisions, and tariff design. Traditionally, in larger buildings, DSO power-based tariffs have been based on hourly average peak demand measurements, with methods calculating charges, for example, from the highest hourly average power or the average of the two highest hourly values over the past 12 months [16]. The Finnish Energy Authority has recommended that power-based tariffs for small customers be determined using the average of the three highest hourly values within a month [17]. However, with the introduction of 15-minute metering periods, these peaks can now be observed more precisely, potentially influencing the billing practices in the future.

Additionally, the Terms of Network Service (VPE 2024) generally specify that electricity usage or generation at the point of consumption should not exceed the maximum current (fuse size) or the agreed maximum capacity outlined in the network or connection contract [18]. However, since only hourly average power has been measured in the past, and the typical connection size (fuse) at the electrical connection point can withstand short-term current surges much higher than the rated current, there has been no method to detect whether this maximum current has been exceeded for short durations.

This study provides one of the first insights from a one-year dataset of 15-minute consumption measurements across different customer types. By analyzing the effects of higher-resolution metering, we contribute to ongoing discussions on energy market development, tariff design, and grid optimization. The findings are particularly relevant for DSOs revising network pricing models and regulatory authorities balancing economic efficiency with consumer fairness. The primary objective is to quantify how peak power values change when shifting from hourly to 15-minute measurements, offering valuable insights into peak demand charges and infrastructure planning.

II. METHODOLOGY

This study utilizes actual 15-minute electricity consumption data. The data has been collected between November 2023 and October 2024 by a Finnish DSO managing networks in the Pirkanmaa, Keski-Suomi, and Pohjois-Pohjanmaa regions. The dataset consists of smart meter readings from 240 buildings, which were selected to represent a diverse range of electricity load profiles. These buildings are categorized into six types: detached houses (DH), row houses (RH), multi-dwelling buildings (MDB), industrial buildings (Ind.), commercial buildings (Com.), and agricultural buildings (Agri.).

The buildings are further divided into eight electrical connection size categories, ranging from 3×25 A to 3×160 A, as detailed in Table I. Notably, for multi-dwelling buildings and row houses, the dataset includes only the electricity consumption of common areas, such as corridor lighting, public saunas, and centralized HVAC systems.

TABLE I. BUILDINGS UTILIZED IN THE STUDY DIVIDED BY CONNECTION SIZES AND BULDING CATEGORIES

Connection size	**Buildings by the category**					
	***Apartment buildings*[1]**		***DH***	***Ind.***	***Com.***	***Agri.***
	RH	***MDB***				
3x25 A	-	-		-	-	-
3x35 A	-	-	30	-	-	-
3x50 A	10	10	30	-	-	10
3x63 A	-	10	-	-	10	10
3x80 A	-	-	-	-	30	-
3x100 A	-	-	-	20	10	-
3x125 A	10	10	-	10	-	-
3x160 A	-	-	-	20	10	-
Total	**20**	**30**	-	**50**	**60**	**20**
[1] *Data only of buldings common electricity consumption: corridor lighting, public saunas, centralized HVAC systems, etc.*						

This study examines how the transition from hourly to 15-minute metering affects registered peak power. The analysis follows a three-step approach. First, the highest annual values of quarter peak power ($P_{q_{max}}$) and hourly peak power ($P_{h_{max}}$) are compared to determine how much the peak power relatively increases when transitioning from an hour to 15-minute metering interval. In the second step, the hour in which $P_{q_{max}}$ occurs is examined in more detail by identifying its corresponding hourly power ($P_{h,q_{max}}$). This allows for an assessment of how much the registered peak power fluctuates within that hour. Finally, in the third step, the maximum capacity of each electrical connection is analyzed to evaluate how peak power relative to the installed connection capacity changes under the new metering interval.

Analysis begins by converting recorded 15-minute energy consumption data, E, in time t, from unit kWh to kW as average quarter power P_q (1). After conversion, average power between quarter and hour intervals are relatively comparable. After that, the quarter peak power $P_{q_{max}}$ was calculated to identify the highest average quarter-hour power over the year (2). To calculate the hourly peak power $P_{h_{max}}$, the dataset is processed by summing four consecutive consumption values within the same hour to obtain the hourly average power (3). While this comparison captures how annual peak power values change when transitioning from hourly to 15-minute metering, it does not reflect how the highest quarter peak power relates to the hourly power within the same period. Therefore, a third metric is introduced: the hourly power in the same hour where $P_{q_{max}}$ occurs, denoted as $P_{h,q_{max}}$. This value is calculated by identifying the time $t_{q_{max}}$, in which the quarter peak power ($P_{q_{max}}$) was recorded and summing the four consecutive quarter energy values (E) from consumption data within that hour (4). In (3) and (4), i represents the quarter interval within an hour, ranging from 0 to 3, and Δt is the 15-minute measurement interval.

$$P_q = \frac{E(t)}{0.25\text{h}} \tag{1}$$

$$P_{q_{max}} = \max_t P_q(t) \tag{2}$$

$$P_{h_{max}} = \max_t\left(\sum_{i=0}^{3} E(t + i \cdot \Delta t)\right) \tag{3}$$

$$P_{h,q_{max}} = \sum_{i=0}^{3} E(t_{q_{max}} + i \cdot \Delta t)) \tag{4}$$

To assess the impact of the shorter metering interval, the study evaluates how much the registered peak power increases when switching from hourly to 15-minute metering interval. This is quantified by two relative growth metrics. First, the relative annual peak power growth, ΔP_a measures how much the quarter peak power exceeds the hourly peak power (5). Second, the relative growth within the hour where $P_{q_{max}}$ occurs, ΔP_h, quantifies how much power fluctuates within that hour by comparing $P_{q_{max}}$ to the hourly power in the same hour, $P_{h,q_{max}}$ (6).

$$\Delta P_a = \frac{P_{q_{max}} - P_{h_{max}}}{P_{h_{max}}} \cdot 100\% \tag{5}$$

$$\Delta P_h = \frac{P_{q_{max}} - P_{h,q_{max}}}{P_{h,q_{max}}} \cdot 100\% \tag{6}$$

These relative changes in peak power values provide insights into how annual peak power estimates shift with 15-minute resolution and how hourly measurement smooths results by averaging out shorter peak demand moments. To provide a comprehensive view of the results, both average and median values were calculated for each comparison.

III. RESULTS

The results from steps one and two are shown in Fig. 1 and Fig. 2. In those figures, each circle represents the relative change at a single metering point. The data points are categorized by system sizes and building types. Black triangles represent the average values, while red squares indicate the median values.

At the top of both figures is presented relative annual peak power growth, ΔP_a, while the bottom of the figures presents the relative hourly peak power growth, ΔP_h, within the same hour where the quarterly peak power ($P_{q_{max}}$) occurred. These two results are separated because they illustrate how peak demands observed over the year do not occur at the same time when the metering interval changes. In contrast, comparing the same hour provides insight into how the 60-minute metering period smooths the results at that specific time.

From Fig. 1 and Fig. 2, we can see that the average relative growth of annual peak power (ΔP_a) varied along connection sizes as follows: In commercial buildings, peak power increased by 13.5–26.5%, in industrial buildings by 7.4–10.2%, in agricultural buildings by 11.2–20.9%, in apartment buildings' common consumption (row houses and multi-dwelling buildings) by 8.2–27.5%, and in detached houses by 15.0–24.4%. For the relative growth of hourly peak power (ΔP_h), which compares the highest quarter peak to the hourly power within the same hour, the observed increases in average values were as follows: Commercial buildings showed an increase of 20.8–51.4%, industrial buildings 14.8–19.6%, agricultural buildings 24.4–27.1%, apartment buildings' common consumption 15.4–55.4%, and detached houses 29.9–50.5%.

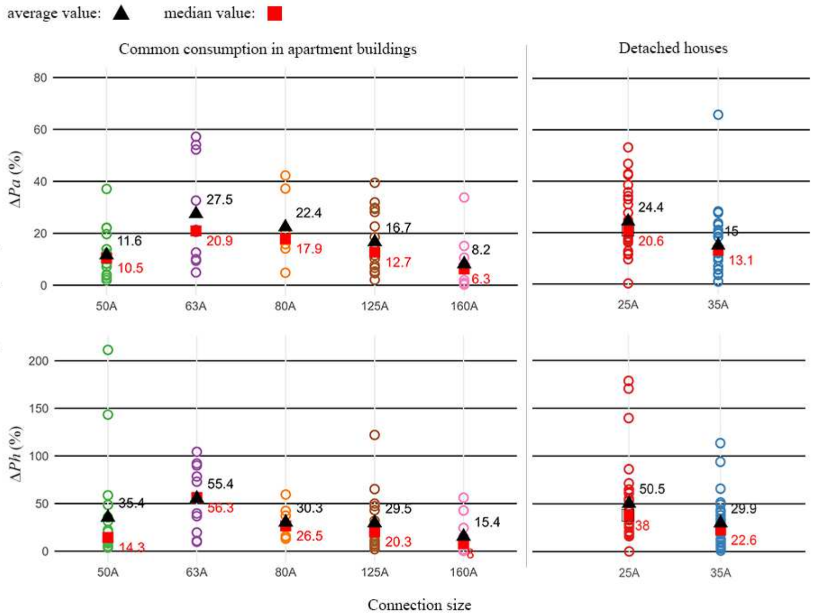

Figure 1. Relative growth in peak power for residential building categories by connection size.

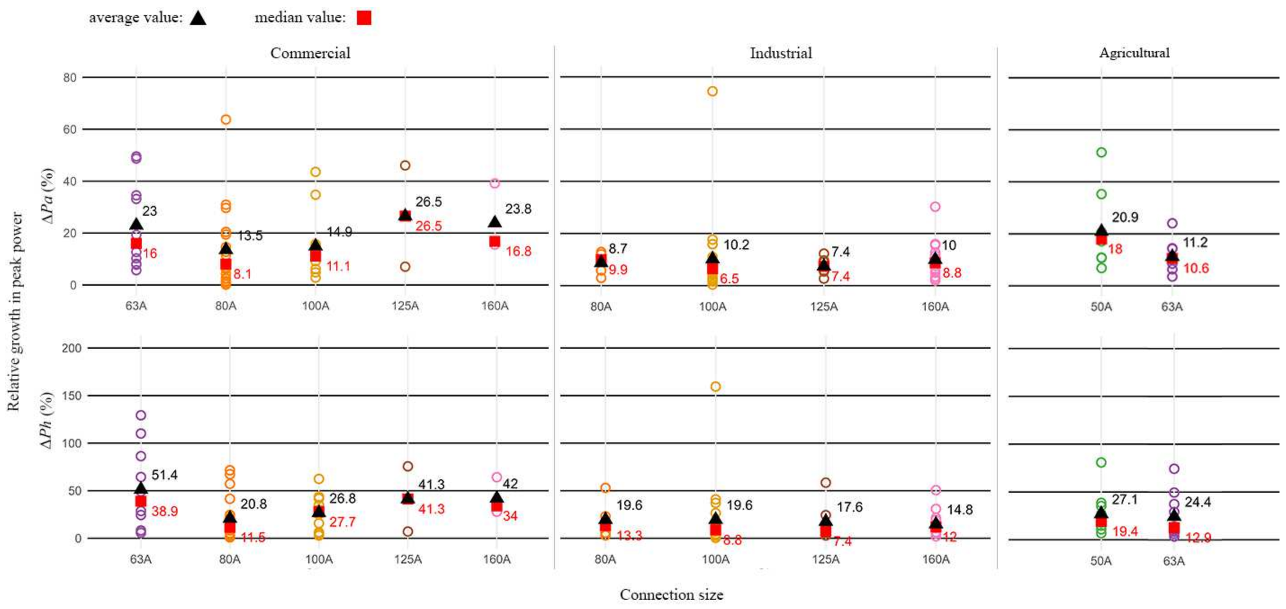

Figure 2. Relative growth in peak power for commercial, industrial, and agricultural buildings by connection size.

From Fig. 1 and Fig 2. we observe considerable variation when analyzing individual buildings. The highest relative growth in annual peak power reached 74.5%. At the same time, some metering points showed differences close to 0%. When focusing on the difference between hourly and 15-minute results within the same hour, individual metering points showed peak power growth reaching 211.4%, with many others falling between 150% and 200%.

The ranges of relative and absolute peak power growth for different building categories are summarized in Table 2. The table presents both ΔP_a and ΔP_h showing variations across all connection sizes, categorized by buildings.

TABLE II. RELATIVE AND ABSOLUTE GROWTH RANGE IN PEAK POWER COMPARING QUARTER PEAK POWER TO HOURLY PEAK POWER

Building category	Range in ΔP_a		Range in ΔP_h	
	Relative (%)	*Absolute* (kW)	*Relative* (%)	*Absolute* (kW)
MDB & RH	0.3–57.2	0.0–17.5	0.3–211.4	0.0–28.3
DH	0.2–65.9	0.0–5.2	0.2–178.6	0.0–14.3
Com.	0.1–63.7	0.0–19.8	0.8–129.3	0.4–29.5
Ind.	0.4–74.5	0.2–19.1	0.4–159.4	0.2–27.4
Agri.	3.6–51.3	0.8–12.5	3.6–80.8	0.8-16.5

Fig. 3 presents the registered peak power of each metering point in relation to the maximum capacity of the electrical connection, which should not be exceeded. Each circle represents one metering point, categorized by connection size. The average values are indicated by triangles, and median values by squares. The top graph shows the relative capacity utilization based on hourly peak power ($P_{h_{max}}$), while the bottom graph presents the same metric using quarter peak power ($P_{q_{max}}$).

From Fig. 3, we can observe that the average capacity use across different connection sizes varied from 45.4% to 65% with hourly peak power, and from 51.1% to 73% with quarter peak power. Additionally, there are metering points where the maximum capacity is exceeded, with more occurrences in the 15-minute period. Highest point was 129 % with hourly peak power and 139.7% with quarter peak power. This is possible because main fuses can temporarily withstand overloads without disconnecting the current; a standardized fuse in Finland typically requires 1.6 times the rated current to trip within an hour [19]. It is also noteworthy that in each connection size, there are multiple metering points where the peak power is less than 25% of the available capacity.

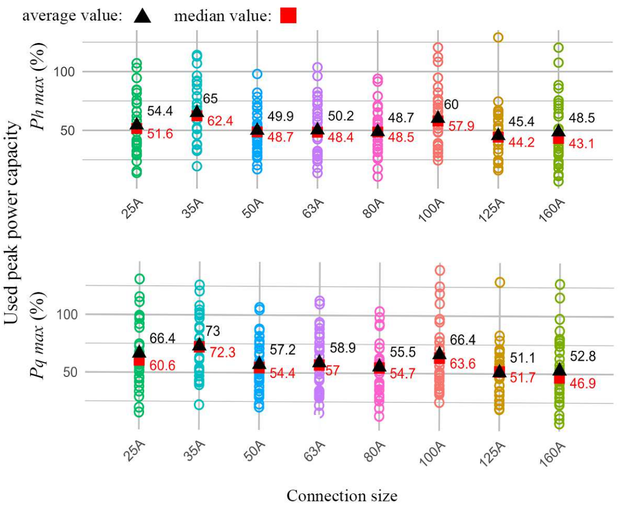

Figure 3. Utilized peak power capacity as a percentage of the maximum electrical connection capacity by connection size.

IV. DISCUSSION

This study provides important early insights into building peak power estimation with metering intervals shorter than one hour. The findings indicate that when transitioning to a 15-minute metering interval, the annual peak power increase across different building types and connection sizes averaged between 7.4% and 27.5% compared to hourly peak power. At the same time, significant variability was observed across individual metering points: some buildings showed increases of over 74.5%, while others exhibited minimal differences, indicating more stable peak power levels in certain customers. This variability implies that if future power tariffs are based on shorter intervals, the impact on different customers could vary significantly.

Building upon earlier hourly measurement-based load profiles in Nordic countries, this study extends the work of Harsia et al., which focused on a small sample of single-family homes in Finland. Their case study highlighted in addition to 15 minutes resolution the effect of even 1-minute resolution on peak power, showing considerable variation between buildings, particularly influenced by heating solutions and electric sauna heaters [15]. Our study expands on these findings by analyzing a larger dataset that includes various building types, reaffirming the need for further research to understand why and how the impact of shorter metering periods differs between similar buildings.

These results offer valuable new insights for DSOs, helping to refine network planning and tariff structures. Additionally, this understanding of 15-minute metering intervals benefits market participants, including electricity suppliers, by supporting more accurate day-ahead market bidding and balance management. However, further studies are needed to better understand the power behavior of different customer types at shorter metering intervals. Identifying the most power-intensive loads behind these meters and exploring ways to mitigate peak power will be crucial for providing lower fees to customers and reducing the investment burden on DSOs.

The main limitations of this study are the reliance on only one year of data and the relatively approximate understanding of customer behavior. Since this study provides early insights from the first rollouts of the new generation of smart meters, future studies with larger datasets, longer periods, and a better understanding of individual customer behavior would be beneficial. With such data, it would be possible to create more detailed 15-minute consumption profiles, including specific electrical loads and operating environments. This would allow for the development of more accurate consumption profiles that reflect real-world conditions more precisely, further enhancing the understanding of how shorter metering periods impact peak demand and grid planning.

V. CONCLUSION

This study provided valuable insights into the relative growth of measured peak power when the metering interval was changed from hour to 15-minutes, using the first rollout of new generation smart meters by DSOs. When comparing the highest measured annual hour- and quarter-peak powers across various building types and connection sizes, the quarter-peak powers were, on average, 7.4% to 27.5% higher than the hour-peak powers for each category. The smallest growth was 0.1%, while the highest reached 74.5%, indicating significant variation across individual customers. When quarter-peak power was compared to the average hourly power at the same moment, the average increase in peak power ranged from 14.8% to 55.4%, with variations between customers ranging from 0.2% to 211.4%.

In the final phase of the study, we examined electrical connection capacity usage across different customer sizes. Our results show that for approximately half of the customers, power demand based on hourly resolution is less than 50% of maximum capacity. This suggests that many electrical connections, originally sized based on hourly consumption data, are overestimated, leading to unnecessarily high fees for DSOs and customers. Moreover, the 15-minute metering interval provide more detailed insights into actual power usage, helping to better plan for short-term power needs. By improving these methods, we can ensure cost-effective solutions for both DSOs and customers while minimizing the risk of overcurrent situations.

The findings emphasize the need to refine electrical connection sizing methods and peak power estimation models to account for shorter metering intervals. While this study focused on peak power differences between hourly and 15-minute metering over one year, further research is needed to identify which electrical loads contribute to short-term peak demands and how they can be managed. As more 15-minute data from smart meters becomes available, updating existing load profiles to reflect these shorter intervals and linking them with detailed customer type information will enable more accurate grid planning. Additionally, integrating large-scale 15-minute resolution data with insights from electrical loads, weather conditions, and time-based consumption patterns can further refine load profiling, ultimately leading to more cost-efficient and resilient distribution networks.

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work the authors used ChatGPT-4o to improve readability and language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

REFERENCES

[1] Fingrid Oyj, “Energy Authority confirms changes to the terms and conditions for balance responsible parties and balancing service providers in relation to the 15-minute imbalance settlement period.” Accessed: Jan. 02, 2025. [Online]. Available: https://www.fingrid.fi/en/news/news/2023/energy-authority-confirms-changes-to-the-terms-and-conditions-for-balance-responsible-parties-and-balancing-service-providers-in-relation-to-the-15-minute-imbalance-settlement-period/

[2] Elenia Oy, “Elenia has already installed more than 300,000 new smart electricity meters for its customers.”

Accessed: Jan. 31, 2025. [Online]. Available: https://www.elenia.fi/en/news/elenia-has-already-installed-more-than-300000-new-smart-electricity-meters-for-its-customers

[3] Aidon Oy, “Caruna, Finland’s largest DSO, signs a contract with Aidon for the renewal of 760,000 electricity meters.” Accessed: Jan. 31, 2025. [Online]. Available: https://aidon.com/caruna-finlands-largest-dso-signs-a-contract-with-aidon-for-the-renewal-of-760000-electricity-meters/

[4] Aidon Oy, “Helen Electricity Network transferred metering tasks to Aidon One.” Accessed: Jan. 31, 2025. [Online]. Available: https://aidon.com/helen-electricity-network-transferred-metering-tasks-to-aidon-one/

[5] Helen Sähköverkko Oy, “Tietoa etäluentamittareista.” Accessed: Jan. 31, 2025. [Online]. Available: https://www.helensahkoverkko.fi/yksityisasiakkaat/tietoa-sahkonkulutuksesta/tietoa-etaluentamittareista

[6] Valtioneuvoston asetus sähköntoimitusten selvityksestä ja mittauksesta 767/2021, 2021. [Online]. Available: https://www.finlex.fi/fi/laki/ajantasa/2021/20210767

[7] Sähkömarkkinalaki 588/2013, 2013. [Online]. Available: https://www.finlex.fi/fi/laki/ajantasa/2013/20130588

[8] Energiavirasto, “Verkkotoiminnan luvanvaraisuus.” Accessed: Jan. 29, 2025. [Online]. Available: https://energiavirasto.fi/verkkotoiminnan-luvanvaraisuus

[9] I. Lehto, “Tärkeä tietää sähkönjakelusta,” Energiateollisuus ry, 2023. [Online]. Available: https://energia.fi/wp-content/uploads/2020/09/tarkea-tietaa-sahkonjakelusta-2023.pdf

[10] A. Rautiainen et al., “Reforming distribution tariffs of small customers – targets, challenges and impacts of implementing novel tariff structures,” *CIRED - Open Access Proceedings Journal*, vol. 2017, no. 1, pp. 2857–2860, Oct. 2017, doi: 10.1049/oap-cired.2017.0887.

[11] “HE 197/2024 - Hallituksen esitys eduskunnalle laeiksi sähkömarkkinalain ja sähköntoimitussopimusten vertailuvälineestä annetun lain muuttamisesta,” 2024. [Online]. Available: https://www.finlex.fi/fi/esitykset/he/2024/20240197

[12] A. Mutanen, K. Lummi, and P. Järventausta, “Load models for electricity distribution price regulation,” presented at the 25th International Conference and Exhibition on Electricity Distribution (CIRED2019), Madrid, Spain, Jun. 2019. [Online]. Available: https://www.cired-repository.org/items/40d74a21-c8f5-47b8-8501-4ee539025012

[13] V. Fransson, H. Bagge, and D. Johansson, “Impact of variations in residential use of household electricity on the energy and power demand for space heating – Variations from measurements in 1000 apartments,” *Applied Energy*, vol. 254, p. 113599, Nov. 2019, doi: 10.1016/j.apenergy.2019.113599.

[14] L. Pedersen, “Load Modelling of Buildings in Mixed Energy Distribution Systems,” Doctoral thesis, Fakultet for ingeniørvitenskap og teknologi, 2007. Accessed: Jan. 29, 2025. [Online]. Available: https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/233327

[15] P. Harsia et al., Opas pientalojen suunnitteluun: Sähkötehojen hallinta osana rakennuksen energiatehokkuutta. Tampereen yliopisto, 2019. [Online]. Available: https://trepo.tuni.fi/handle/10024/117897

[16] K. Lummi, A. Mutanen, and P. Järventausta, “Upcoming changes in distribution network tariffs – potential harmonization needs for demand charges,” 2019, [Online]. Available: https://www.cired-repository.org/bitstream/20.500.12455/519/1/CIRED%202019%20-%201680.pdf

[17] Energiavirasto, “Energiaviraston suosituksia verkkopalvelumaksujen harmonisoiduksi rakenteeksi,” Sep. 2021. [Online]. Available: https://energiavirasto.fi/-/suositukset-sahkon-verkkopalvelumaksujen-harmonisoinnista

[18] Energiateollisuus ry, “Terms of network service 2024,” 2024. [Online]. Available: https://energia.fi/julkaisut/verkkopalveluehdot-vpe-2024-myos-ruotsiksi-ja-englanniksi/

[19] SFS-EN 60269-1: *Pienjännitevarokkeet. Osa 1: Yleiset vaatimukset*, SFS ry, 2008.