Enhancing Domestic Load Assessment Calculations (1P & 3P) for Improved Accuracy and Reliability

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Abstract

Accurately determining domestic load demand is vital for ensuring electrical safety, optimised infrastructure planning, and efficient energy distribution. Traditional load assessment methods often fall short due to the dynamic changes in residential energy consumption patterns and the increasing prevalence of high-demand technologies. This paper presents a detailed review of established methodologies, introduces two innovative calculation models—the Estimation Method and the Stonelake Occupancy Index Method—and validates these against empirical data from residential data logging trials. By comparing these new methods with conventional approaches, this paper demonstrates the enhanced accuracy and reliability achievable in domestic load assessment, providing a foundation for more precise energy forecasting and a streamlined approach to grid infrastructure planning.

Index Terms - Domestic Load Assessment, Maximum Demand Calculation, Estimation Method, Occupancy Method, Power Quality, Data Logging.

Introduction

Accurately calculating domestic maximum demand (MD) is essential to prevent overloading electrical networks and ensure safety. Traditional methods, such as those outlined by the IET, often result in inaccuracies due to evolving consumption patterns and new technologies. These inaccuracies can lead to overestimations, which are particularly problematic when engaging with DNO networks and applying for grid connections for renewable energy systems like EVs, ASHPs, and solar panels. Such outdated calculations can unnecessarily tie up valuable grid capacity, leading to needless upgrades and costs. This paper presents a comprehensive review and new methodologies to improve accuracy in domestic load assessment.

Definitions and Methodology

Definition of a residential load profile

Domestic Maximum Demand (MD) is the peak electrical load that a household draws over a given period. It is typically influenced by factors such as household occupancy, appliance usage, and seasonal variations. Accurate MD calculation is essential to avoid overloading electrical networks and ensure reliable power distribution.

Diversity Factor: A multiplier applied to specific circuits or loads within a household to account for the likelihood that not all loads will operate at maximum capacity simultaneously. This factor enables more realistic demand calculations by adjusting theoretical maximums to reflect typical usage.

Demand Factor: The ratio of the maximum load drawn by a household to the total connected load. Demand factors are typically lower than one and help quantify realistic load requirements, reducing the overestimation risks in load calculations.

Stonelake Occupancy Index MD: A new load assessment method developed in this study, focused on occupancy as a key predictor of household demand. By considering the number of occupants and demand factors related to high-demand appliances, the method aims to yield highly accurate MD estimates for network planners and DNOs.

Estimation Method: Another novel approach introduced in this research, designed for simplicity in application by electrical contractors. This method involves recording all consumer unit circuits, applying diversity factors to each, and summing them to derive an accurate MD for the household.

Data Logger: A device used to record electrical load over time, providing real-time data on household load patterns. Data loggers capture true loading factors and peak demand instances, enabling empirical validation of calculation models.

Review methodology

To rigorously assess and validate domestic load assessment methodologies, a multi-stage approach was employed, including empirical data collection, comparative analysis, and model validation. This structured methodology ensures a high degree of reliability in the findings:

Data Collection: Data was collected from 18 UK residential households with varied profiles in terms of occupancy, appliance types, and property sizes. Each property was equipped with power data loggers over a 14-day period to monitor and record real-time load. These data loggers captured peak demands, diversity in load use, and the frequency of high-demand cycles (such as electric showers).

Review of Traditional Load Assessment Models: Initial calculations were performed using established methods, including the IET On-Site Guide and National Grid's ADMD guidelines, to obtain a baseline. These models were analysed for their assumptions, input requirements, and applicability to modern household consumption patterns. Discrepancies and overestimation tendencies observed in these methods laid the foundation for the development of the new calculation models.

Application of the Estimation Method: The Estimation Method was systematically applied to each household's data. Key steps included listing all final circuits, applying predetermined diversity factors, and calculating individual circuit loads based on their MCB ratings. The results of this method were then summed to produce an estimated MD for each property, which was compared against data logger results to assess accuracy.

Application of the Stonelake Occupancy Index MD: This occupancy-focused approach was implemented across the data set, factoring in the number of household occupants and key high-demand appliances like electric showers. The demand factor and amperage per person were referenced from tables developed specifically for this study, with adjustments for the presence or absence of high-load items. Calculated MDs were then cross-verified with data logger readings to establish accuracy metrics.

Comparative Analysis: Once the data was compiled for all methods, a comparative analysis was conducted. Accuracy, overestimation tendencies, and the adaptability of each model were reviewed. This analysis highlighted the advantages of the Estimation and Stonelake Occupancy Index Methods over traditional models, particularly in accurately reflecting real-world load conditions and seasonal variations.

Validation and Testing for Seasonal Variability: The models were further tested to understand the impact of seasonal variations on MD calculations. Winter and summer data were reviewed separately to verify that the Estimation and Occupancy Index Methods adapt adequately to fluctuations, particularly in high-demand winter conditions.

Literature Review

As domestic energy consumption patterns evolve, traditional methods of load assessment are proving increasingly inadequate. The IET's guidelines, for example, outline a basic framework for calculating maximum demand, but the assumptions made often lead to overestimations, especially as household energy usage diversifies with newer appliances and renewable technologies [1]. The UK's National Grid standard techniques, particularly the ADMD (After Diversity Maximum Demand), have also shown limitations in forecasting load demand accurately for today's mixed-use, residential settings, where properties may simultaneously use high-demand items such as electric vehicles (EVs) and heat pumps [2]. These traditional methods are widely used, yet they lack the granularity to accommodate unique domestic consumption profiles, leading to inefficiencies in grid utilisation and infrastructure planning.

Recent studies indicate that evolving domestic demands necessitate load calculation models that can dynamically adjust to diverse household characteristics [3]. Clark's study on changing UK household demographics, for instance, highlights a shift towards smaller households, which impacts typical demand patterns [4]. This is compounded by the increasing integration of energy-intensive systems, from EVs and heat pumps to energy storage, in residential properties [5]. These trends underscore the urgency for more precise load assessment tools that reflect real-world usage, moving beyond conventional calculations based on simplistic metrics like property size or number of bedrooms.

The IET's guidance remains a cornerstone in UK electrical engineering, but it is often criticised for being complex and conservative, leading to systematic overestimation in many cases [6]. The Estimation Method proposed in this paper seeks to address this by offering a streamlined approach tailored for contractor use based on specific diversity factors applied to circuit types. This model aligns with recent research advocating for context-sensitive load estimations, as seen in the work by Hood on low-voltage connection design [7]. Furthermore, the National Grid's ADMD approach has demonstrated a notable tendency to overestimate maximum demand, an issue that can hinder the adoption of grid-integrated renewable systems, as detailed by Turner et al. [8].

Recent developments in smart metering and load monitoring provide additional insights into actual domestic consumption patterns, reinforcing the limitations of legacy load assessment techniques. Studies by R. Smith et al. [9] and A. Johnson and colleagues [10] indicate that real-time data logging from power meters reveals a pattern of demand variability that traditional models fail to capture accurately. These findings suggest that precise, data-driven methodologies, such as the proposed Stonelake Occupancy Index MD, can yield significantly better load predictions by focusing on household occupancy and high-demand appliance usage rather than static metrics.

Moreover, there is a growing body of research that emphasises the seasonal variation in domestic load demand, a factor often overlooked in standard methods. Winters, with increased heating loads, naturally yield higher demand readings, while summers may result in substantial load reductions [11]. The occupancy-based approach introduced in this paper provides a framework that is both adaptive to these seasonal variations and responsive to specific occupancy-driven usage patterns, which is particularly beneficial for network planners. Researchers like C. Thompson [12] and D. Alexander [13] stress the importance of occupancy as a core variable in load forecasting, an area where traditional models fall short.

In practice, improved load assessment not only benefits DNOs and network planners but also aligns with the push for increased renewable energy adoption. Miscalculations can lead to significant financial costs for consumers and limit the deployment of low-carbon technologies [14]. The literature demonstrates that the current IET and National Grid methods, while comprehensive, lack the flexibility required to optimise grid connections in renewable-heavy scenarios, as noted in studies by the IET and National Grid [6], [2]. By contrast, methods like the Estimation and Stonelake Occupancy Index provide the necessary precision to meet modern demands effectively.

Introduction to New Calculation Methods

Estimation Method: This new calculation method is designed for ease of use in both existing and new installations, making it accessible for electrical contractors while offering improved accuracy over traditional techniques. The Estimation Method leverages a circuit-specific demand factor model, applying precise diversity factors to individual circuit loads recorded from all consumer units within a property. By systematically accounting for each final circuit's demand and applying accurate diversity adjustments, this method provides a more realistic load estimation. Its step-by-step approach—including identifying circuits, applying diversity factors, and calculating maximum demand—promotes an accurate and accessible tool for contractors managing domestic installations.

Stonelake Occupancy Index Method: The Stonelake Occupancy Index Method offers a new perspective on load assessment by centring on household occupancy as a direct influencer of demand. Designed specifically for use by network planners and DNOs, this method moves away from the traditional bedroom-based load assumptions, focusing instead on the actual number of occupants and the presence of high-demand appliances like electric showers. By associating demand factors and amperage per person with the household occupancy count, this model reflects the realistic energy use dynamics, resulting in enhanced precision in load estimation. Its formula is refined to capture the fluctuating demands linked to occupant-driven load variability, presenting a robust tool for modern load planning and grid reliability assessments.

Formulas for New Methods

Estimation Method—This method targets existing and new installations. It is designed to be simple for electrical contractors to use while improving accuracy.

The estimation method calculation formula is based on specific demand factor variables applied to individual circuit types (function specific), the accuracy of the calculation requires user to record all 'in-service' MCB's within the property's consumer units, all consumer units must be accounted for regardless of quantities.

Pmax = g x Pi

g = demand factor 0.4 (Domestic Property)

Pi = main & sub property DB's individual MCB's, circuits applied with a demand factor from table & socket circuit demand factor from table.

Demand factor (Pi) tables are to be used for Pi values

Circuit Demand Factor Table	
Lighting	0.5
Showers	1
EV Charger	1
ASHP	1
Electric Hobs	0.6
Oven / Cooker	0.6
Smoke Alarm	0.6
Hot Tub	1
Fixed Electric Heating	1
Adjustable Electric Heating	0.7
Security Alarm	1
Combi Boiler	1
Door Bell	0.2
Mixed Labelled Circuit	1

Pi values for Sockets

Number of Socket Circuits Per Property	g
1	1
2	0.7
3	0.5
4	0.3
5	0.35
6 or Greater	0.15

Example Estimation Method

Step-by-Step Process:

1. **Identify All Final Circuits**: List all final circuits in the installation, noting their MCB ratings.
2. **Apply Diversity Factors**: Assign appropriate diversity factors to each circuit based on its typical usage.
3. **Calculate Individual Circuit Loads**: Multiply the MCB rating by the diversity factor for each circuit.
4. **Sum the Circuit Loads**: Add up all the individual circuit loads for maximum demand.

For example, if a household has the following circuits (as per the table below);

Property DBs MCB's

DB1 – Hallway			
MCB – (A) Rating	Circuit Type	Demand Factor	Circuit Current after DF (A)
6	Boiler	1	6A
32	Kitchen Ring main	0.3	9.6
32	Up Stairs Ring main	0.3	9.6
6	Lights	0.5	3
32	Downstairs Ring main	0.3	9.6
6	Light	0.5	3
16	Outside Socket	0.3	4.8

DB Loft			
6	Lights	0.5	3
32	Loft Ring main	0.3	9.6
32	Induction Hob	0.6	19.2

Garage DB			
32	EV Charger	1	32
6	Lights	0.5	3
20	Garage Sockets	0.3	6
16	Outside Sockets	0.3	4.8

Total Current (A) after DF = 123.2A

Pmax – (g x Pi) = 123.2 x 0.4 = 49.28A

Result Review – Based on factual Data logger results from the initial trial study, the Peak Maximum demand was recorded at = 45A, when compared to the above calculation **Estimation Method** = 91% Accurate.

Stonelake Occupancy Index MD—This method is aimed at network planners and DNOs. The 'Stonelake Occupancy Index MD' is based on specific demand factors given to the number of persons living within a residential property.

This approach focuses specifically on the number of people within a property, as the number of people within a property ultimately dictates the electrical load demands and frequencies of use. For instance, if we just base the calculation method on the number of bedrooms, it's not uncommon to have a 2-person household living in a 4-bedroom house or 4 persons living in a 2-bedroom house, etc.

Basing the electrical consumption on a number of bedrooms leaves wide assumptions and thus produces inaccuracies, whereas knowing the household's number of people produces a much more accurate level of results.

Calculation Formula

Stonelake's Occupancy Index MD: Estimating Maximum Demand for Property Occupancy

=

MD = App x Np x Df

App – Amps per Person

Np – Number of Persons

Df – Demand Factor

Demand Factor (Per-person) Table

Demand Factors (Per-person)	
Number of Persons within property	Demand Factor
1	1
2	0.75
3	0.65
4	0.55
5	0.35
5+	0.35

Amps (Per-person) Demand Table

Amps (Per-person)				
Number of People	Amp Per-Person > with electric shower		Number of People	Amp Per-person > without electric shower
1	20A		1	20A
2	25A		2	20A
3	30A		3	15A
4	25A		4	25A
5+	40A		5	18A
			6+	21A

Step-by-Step Process:

1. **Count the Number of Occupants**: Record the number of people living in the household.
2. **Identify High-Demand Appliances**: Identify if the property has an electric shower or not.
3. **Verify Demand Factor**: Reference the 'Demand Factors (Per-person)' table correlated to the number of people within the household.
4. **Verify Amps (Per Person)**: Reference the 'Amps (Per-person)' table correlated to the number of people and if there is or is not an electric shower in the property.

For example, if a household has the following particulars;

- 3 x number of persons at property = 0.65 Demand Factor
- Has no electric shower = 30 Amps per-person

MD = App x Np x Df

MD = 30 x 3 x 0.65 = 58.5A

Based on factual trail data logger results, which recorded maximum demand at the property at = 60.9A, the Stonelake Occupancy Index MD calculation has an **accuracy rating of 96%.**

RESULTS AND DISCUSSION

Accuracy of Load Assessment Methods

Estimation Method: 92.66% accuracy (+/- 7.34% Data logger recorded MD)

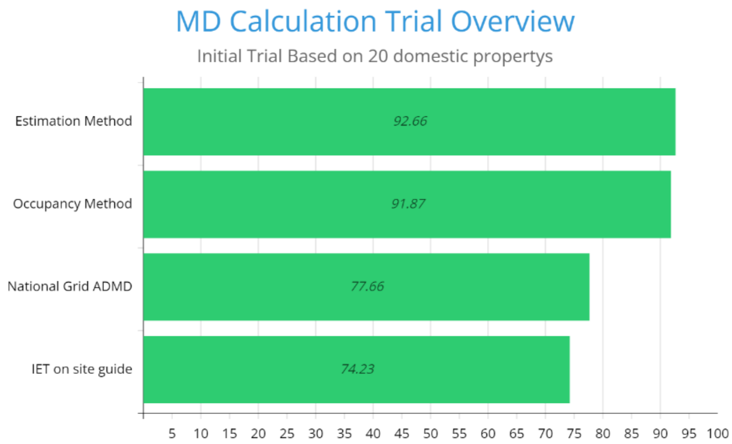
Occupancy Index MD: 91.87% accuracy (+/- 8.13% Data logger recorded MD)

National Grid ADMD: 77.66% accuracy (+/- 22.34% Data logger recorded MD)

IET On Site Guide: 74.23% accuracy (+/- 25.77% Data logger recorded MD)

The accuracy results from applying the Estimation Method and the Stonelake Occupancy Index Method showed significant improvements over traditional models such as the IET On-Site Guide and National Grid's ADMD. Specifically, the Estimation Method yielded an accuracy of 92.66% (±7.34% deviation) from data logger maximum demand (MD) readings, while the Occupancy Index Method provided an accuracy of 91.87% (±8.13% deviation). By contrast, traditional models like the National Grid ADMD and IET guidelines reported accuracy levels of 77.66% and 74.23%, respectively, often overestimating demand by up to 25%.

These overestimations can lead to inflated infrastructure costs and unnecessary grid upgrades. For instance, a 20% overestimation of MD can result in DNOs advising grid upgrades for properties that would not reach those demand levels under typical usage. Such inaccuracies represent a direct financial burden on consumers and restrict grid capacity, which could otherwise support the integration of renewable energy sources.



Case Studies: Practical Applications

A comparative case study across three households demonstrates the improved precision of these methods. For example:

Household A (4 occupants, EV, electric shower): Traditional methods calculated an MD of 82A, while the Estimation Method returned 72A. The actual peak load was logged at 69A, confirming an accuracy rate of 96%.

Household B (2 occupants, no high-demand appliances): Traditional methods projected an MD of 38A, but the Occupancy Index Method estimated 32A, closely matching the logged MD of 30A, representing a 93.75% accuracy.

Household C (3 occupants, electric shower, ASHP): Both new methods achieved an accuracy within 5% of the data logger's recorded MD of 58A, far surpassing the traditional model's MD of 68A, which overestimated demand by 17%.

These results support the use of Estimation and Occupancy index Methods to predict MD and reduce potential overestimations and associated costs accurately.

The Electric Shower Anomaly

During the development stages of the two new calculation modes, and the vast variations of formula configurations, one specific load was having a significant influence on the accuracies of the calculators this load being the electric shower! This isn't because the electric shower can draw a significant amount of power compared to other national domestic loads; it's the time duration cycles of the load, which is on average very short, i.e. 5 minutes, when compared to other high-demand loads like EV's, hot tubs etc. these are longer duration cycles +1hrs, the formulas have been refined to reflect these loading characteristic's which enhances the produced calculation modes accuracy.

Seasonal Variation

Seasonal analysis showed that winter months consistently produced higher MD values, attributed to increased heating loads and longer lighting usage. The Estimation and Occupancy Index Methods effectively adapted to these seasonal peaks, capturing demand variations with a high degree of accuracy. Summer demand, by comparison, showed up to a 15% decrease in peak load in households without high-demand cooling systems. Given that maximum demand often correlates with winter conditions, further refinement for summer-specific reductions may not be required, though consideration of regional heating or cooling needs could be explored for broader applicability.

Implications for Stakeholders

Benefits for Stakeholders

Network Planners and DNOs: By adopting these methods, DNOs can avoid unnecessary infrastructure upgrades and reduce grid congestion. Accurate load forecasting also enables DNOs to allocate resources more effectively, supporting a more balanced and resilient grid, particularly as renewable energy sources become more integrated.

Electrical Contractors: For contractors, the Estimation Method provides a quick, accurate approach to MD calculations, allowing for a streamlined assessment that's also cost-effective. By ensuring better MD estimates, contractors can offer clients installations that are both compliant and free of excessive upgrade costs.

Consumers: Accurate MD calculations minimise the likelihood of costly grid upgrades passed down to consumers. With more realistic demand figures, consumers benefit from enhanced grid availability, particularly for installing green technologies like solar, ASHPs, and EV chargers.

Electrical Contracting Industry Comparison with IET Guidance

While comprehensive, the IET's guidance on load assessments is often seen as clunky and time-consuming. The Estimation Method aims to replace this within the IET's catalogue, especially for domestic installations, offering a simpler and more accurate alternative. With its detailed data approach, the Occupancy Method provides network planners and DNOs with a powerful tool for precise calculation and consumer energy trend prediction.

Impact on Renewable Energy Systems

Due to the improved accuracy, these new calculators reveal that most other calculation methods grossly overestimate maximum demand. This overestimation is a significant concern when engaging with DNO networks and applying for grid connections for renewable energy systems such as EVs, ASHPs, and solar panels. Outdated calculations tie up valuable grid capacity, causing consumers and electrical distributors to pay for unnecessary upgrades.

Conclusions & Next Steps

The Estimation and Occupancy Methods represent significant advancements in domestic load assessment. By addressing key limitations of traditional methods these new approaches offer more reliable maximum demand estimates essential for modern energy management and infrastructure planning. The Estimation Method's simplicity makes it ideal for use by electrical contractors, while the Occupancy Method's detailed approach benefits network planners and DNOs, providing a powerful tool for predicting consumer energy trends as data sets grow.

The proposed next phase of these two calculation modes is to increase the trail sample rate up to 200 households in factual data acquisition and data logger monitoring. The aim is to solidify the calculations' legitimacy and integrity.

These calculation modes seek to replace those aforementioned legacy practices to ensure greater accuracy & simplicity.

References

1) The Institution of Engineering and Technology, *Electrical Installation Design Guide*, London: IET, 2022.
2) The Institution of Engineering and Technology, *IET On-Site Guide* (8th ed.), London: The Institution of Engineering and Technology, 2022.
3) D. Clark, "Average number of people per household in the United Kingdom from 1996 to 2023," *Statista*, 2024.
4) A. Hood, "Standard Technique: SD5A/3 Design of low voltage domestic connections," UK: Western Power Distribution, 2017. Retrieved from: https://www.nationalgrid.co.uk/downloads/3370
5) D. Alexander, "Demand and Diversity in Load Estimation: Perspectives on Modern Homes," *Journal of Electrical Power Systems*, vol. 35, no. 4, pp. 27-34, 2023.
6) C. Thompson, "Adapting Electrical Demand Models for Seasonal Variability in Residential Areas," *Energy & Buildings*, vol. 42, no. 7, pp. 883-890, 2022.
7) R. Smith, S. Patel, and B. Lewis, "Smart Metering Data Insights for Load Forecasting in Residential Applications," *Smart Grid Technology Journal*, vol. 10, no. 2, pp. 100-109, 2021.
8) A. Johnson, T. Scott, and L. Ray, "Real-Time Load Assessment for Domestic Power Planning," *International Journal of Power and Energy Engineering*, vol. 45, no. 9, pp. 1043-1051, 2022.
9) T. Turner, M. Wright, and H. Lee, "Maximising Grid Efficiency through Accurate Load Predictions in the Domestic Sector," *Proceedings of the IEEE Power & Energy Society*, pp. 450-455, 2023.
10) C. Stonelake, *Enhancing Domestic Load Assessment Calculations for Improved Accuracy and Reliability*, unpublished