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Comparative Operational Performance Assessment of 33 kV Distribution Feeders Using Load Profile Characteristics and Utilization Indices

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ABSTRACT

The operational performance of electricity distribution feeders is influenced by variations in load demand and the extent to which available network capacity is utilized. This study comparatively assessed the Ondo, Okitipupa and Ile-Oluji 33 kV distribution feeders using monthly peak and off-peak load-demand data for 2023–2025. The analysis employed an estimated two-period load factor, peak-to-off-peak demand ratio (PDR), coefficient of variation (CV), feeder utilization index (FUI), descriptive statistics and Pearson correlation. Ondo recorded the highest three-year mean peak demand (10.90 MW), whereas Ile-Oluji had the highest overall estimated load factor (0.76). Ondo also had the highest average PDR (2.72) and the greatest three-year peak-demand variability (CV = 22.28%). Relative to the maximum observed peak during the study period, the three-year mean FUI values were 74.17% for Ondo, 75.33% for Okitipupa and 76.84% for Ile-Oluji. Peak demand declined markedly on the Ondo feeder from a 2023 mean of 12.87 MW to 7.81 MW in 2025. The results demonstrate that feeder performance depends not only on peak-demand magnitude but also on the temporal distribution and stability of demand. Regular load monitoring, demand-side management, load balancing and timely network reinforcement are recommended.

Keywords: 33 kV distribution feeder; load factor; peak-to-off-peak demand ratio; feeder utilization index; load profile; distribution network.

INTRODUCTION

The reliable and efficient operation of electric power distribution networks is fundamental to economic development and societal well-being. Distribution feeders, as the primary infrastructure connecting bulk power supply to end-use customers, play a critical role in determining overall system performance, power quality, and energy delivery efficiency (Gellings, 2020). In developing economies such as Nigeria, where electricity distribution companies (DisCos) face persistent challenges of infrastructure inadequacy, technical losses, and growing demand, the need for systematic operational performance assessment of distribution feeders has become increasingly urgent (Adebayo & Ainah, 2024; Inyang *et al.*, 2025).

Load profiling and feeder performance characterization provide essential information for distribution system planners and operators (Yin & Lu, 2009). By understanding the temporal patterns of electricity demand, utilities can optimize maintenance schedules, improve demand forecasting accuracy, enhance capacity planning, and prioritize investment decisions. However, many distribution utilities in developing regions lack comprehensive load data and systematic analytical frameworks for feeder performance evaluation (Paudyal *et al.*, 2011).

Previous studies (Yin & Lu, 2009; Paudyal *et al.*, 2011; Dhakal & Ghimire, 2019) have examined various aspects of distribution feeder performance. Research on load factor analysis has demonstrated the relationship between

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feeder loading patterns and technical losses. Studies have also explored the impact of load factor on distribution network efficiency, showing that reducing peak demand and improving load factor can stabilize power distribution systems and yield cost savings (Islam *et al.*, 2025; Oskouei *et al.*, 2022; Jayasekara *et al.*, 2015). In the Nigerian context, several investigations have evaluated feeder performance in different DisCos, including the Ibadan Electricity Distribution Company (IBEDC) and the Benin Electricity Distribution Company (BEDC) (Ajewole *et al.*, 2019; Adesina *et al.*, 2024). However, comparative assessments of medium-voltage feeders using comprehensive operational indices remain limited.

This study addresses this gap by presenting a comparative assessment of operational performance for two 33 kV distribution feeders, OndoOkitipupa, within the BEDC network. Using monthly peak and off-peak load demand data for the year 2025, the study computes and analyses multiple performance indices, including load factor, peak-to-off-peak demand ratio, demand variability, coefficient of variation, and feeder utilization index. The analysis is performed using Microsoft Excel, enabling efficient data processing, statistical evaluation, computation of operational performance indices, correlation analysis, and graphical visualization.

MATERIALS AND METHODS

Study Area and Data Collection

The study focuses on the Ondo, Okitipupa and Ile-Oluji 33 kV distribution feeders operated by BEDC. The feeders supply residential, commercial and industrial consumers within their respective service areas. Monthly peak and off-peak demand data were obtained for January–December of 2023, 2024 and 2025. Peak demand represents the maximum recorded monthly demand, while off-peak demand represents the minimum recorded monthly demand. All demand values are expressed in megawatts (MW).

Data Processing and Statistical Analysis

The data in Table 1 were organized and processed in Microsoft Excel. The analytical procedure comprised: (i) validation and checking of the recorded values; (ii) calculation of mean, standard deviation, minimum and maximum demand; (iii) computation of the operational indices defined below; (iv) Pearson correlation between peak and off-peak demand; and (v) graphical comparison of annual and monthly demand patterns.

Operational Performance Indices

Load Factor (LF): Because the available dataset contains only peak and off-peak observations for each month, the study estimates a two-period average load as the arithmetic mean of the peak and off-peak values.

Thus, LF=$\frac{P_{avg}}{P_{peak}}$.

This is an estimate based on the available two-point data and should not be interpreted as a conventional 24-hour load factor.

Peak-to-Off-Peak Demand Ratio (PDR): A higher ratio indicates a larger separation between peak and off-peak demand.

$$PDR=\frac{P_{peak}}{P_{off-peak}}$$

Coefficient of Variation (CV): The coefficient of variation normalizes the standard deviation by the mean:

$$CV=\frac{\sigma}{\mu}\times 100\%$$

where σ is the standard deviation and μ is the mean demand. Lower CV values indicate greater relative stability.

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Feeder Utilization Index (FUI): The feeder utilization index represents the ratio of actual load to the maximum recorded load:

$$FUI=\frac{P_{max}}{P_{actual}}\times 100\%$$

This index indicates how effectively the feeder capacity is being utilized throughout the year.

Table 1: Monthly Peak and Off-Peak Load Demand of the Three 33 kV Feeders, 2023–2025

Year	Month	Ondo Peak	Ondo Off	Okitipupa Peak	Okitipupa Off	Ile-Oluji Peak	Ile-Oluji Off
2023	January	12.0	5.0	6.0	2.0	7.0	3.0
2023	February	12.0	3.6	7.2	3.8	7.5	3.0
2023	March	12.0	6.0	6.4	2.4	6.5	2.5
2023	April	11.5	5.5	6.0	3.0	8.0	3.0
2023	May	13.0	4.0	5.6	1.5	6.5	2.0
2023	June	12.0	4.0	6.0	2.2	5.0	2.0
2023	July	13.0	3.0	7.0	3.6	6.5	1.5
2023	August	14.0	6.5	7.5	4.9	6.0	3.5
2023	September	12.9	6.2	7.0	6.0	8.0	3.7
2023	October	13.0	7.0	7.0	4.5	6.5	4.5
2023	November	14.3	6.9	8.0	4.9	8.0	5.0
2023	December	14.7	7.2	8.2	5.1	8.3	4.8
2024	January	10.0	7.0	7.1	2.9	7.2	3.6
2024	February	12.4	2.3	6.3	2.1	7.5	6.0
2024	March	12.0	2.0	5.8	2.0	5.5	3.0
2024	April	11.0	5.0	6.0	2.4	6.9	4.0
2024	May	12.0	5.2	8.0	4.7	6.5	4.5
2024	June	12.0	7.7	7.5	4.0	6.0	3.0
2024	July	11.6	5.3	5.0	2.5	7.0	3.2
2024	August	12.5	5.5	9.0	3.6	8.0	5.4
2024	September	11.5	6.9	8.0	5.0	6.0	4.5
2024	October	12.0	6.0	7.8	4.7	6.0	4.9
2024	November	13.5	7.6	8.0	5.6	7.4	5.3
2024	December	13.9	8.2	9.2	5.7	7.0	4.8
2025	January	7.9	2.9	6.8	3.7	4.7	2.1
2025	February	8.0	1.1	7.2	3.8	5.3	2.2
2025	March	7.1	2.8	6.4	2.4	4.9	1.9
2025	April	8.1	1.5	6.5	2.3	5.2	2.0
2025	May	7.1	2.4	6.5	2.5	5.3	2.2
2025	June	6.9	2.5	5.1	2.2	4.6	1.8
2025	July	6.6	2.5	4.7	2.6	4.8	2.1

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2025	August	8.1	3.0	6.3	3.2	5.7	2.9
2025	September	7.5	3.6	5.1	2.6	5.2	2.3
2025	October	8.6	4.1	8.7	3.8	6.1	3.2
2025	November	8.7	4.7	8.0	3.2	6.4	3.0
2025	December	9.1	5.3	8.6	5.9	6.6	3.9

Note: All values are in MW. Peak and off-peak denote the maximum and minimum recorded monthly demand, respectively.

RESULTS AND DISCUSSION

Descriptive Statistics and Load Characteristics

Table 2 summarizes the annual demand characteristics. Ondo had the highest mean peak demand in 2023 (12.87 MW) and 2024 (12.03 MW), while Okitipupa recorded 7.31 MW in 2024. In 2025, mean peak demand fell to 7.81 MW for Ondo, 6.66 MW for Okitipupa and 5.40 MW for Ile-Oluji.

Across the three-year period, Ondo had the highest overall mean peak demand (10.90 MW) and the widest peak-demand range (6.60–14.70 MW). Its three-year peak CV of 22.28% was also the highest, indicating greater relative variation than Okitipupa (16.89%) and Ile-Oluji (16.67%). Off-peak demand was also more variable for Ondo, with a three-year CV of 41.60%, compared with 36.32% for Okitipupa and 36.20% for Ile-Oluji.

Table 2: Annual Descriptive Statistics for the Three Feeders, 2023–2025

Year	Feeder	Peak Mean	Peak SD	Peak Min	Peak Max	Off-Peak Mean	Off-Peak SD	Off-Peak Min	Off-Peak Max
2023	Ile-Oluji	6.98	1.00	5.00	8.30	3.21	1.14	1.50	5.00
2023	Okitipupa	6.83	0.84	5.60	8.20	3.66	1.44	1.50	6.00
2023	Ondo	12.87	1.03	11.50	14.70	5.41	1.46	3.00	7.20
2024	Ile-Oluji	6.75	0.75	5.50	8.00	4.35	1.00	3.00	6.00
2024	Okitipupa	7.31	1.30	5.00	9.20	3.77	1.37	2.00	5.70
2024	Ondo	12.03	1.03	10.00	13.90	5.73	1.98	2.00	8.20
2025	Ile-Oluji	5.40	0.66	4.60	6.60	2.47	0.64	1.80	3.90
2025	Okitipupa	6.66	1.31	4.70	8.70	3.18	1.04	2.20	5.90
2025	Ondo	7.81	0.78	6.60	9.10	3.03	1.22	1.10	5.30

Note: SD = sample standard deviation. Values are in MW.

Three-Year Comparative Performance Summary

Table 3: Three-Year Comparative Operational Performance Indices

Feeder	Peak Mean	Peak SD	Peak CV (%)	Off-Peak Mean	Off-Peak SD	Off-Peak CV (%)	LF	PDR	FUI (%)	r
Ile-Oluji	6.38	1.06	16.67	3.34	1.21	36.20	0.76	2.09	76.84	0.67

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Okitipupa	6.93	1.17	16.89	3.54	1.28	36.32	0.75	2.13	75.33	0.76
Ondo	10.90	2.43	22.28	4.72	1.96	41.60	0.71	2.72	74.17	0.67

Ondo carried the greatest average peak load but had the lowest estimated overall load factor (0.71). Ile-Oluji recorded the highest estimated load factor (0.76), while Okitipupa was close at 0.75. Ondo also had the highest PDR (2.72), indicating the greatest average separation between peak and off-peak demand. The three-year FUI values were 74.17% for Ondo, 75.33% for Okitipupa and 76.84% for Ile-Oluji when each feeder is referenced to its own maximum observed peak during the study period.

3.3 Load Factor

The monthly load-factor estimates are shown in Table 4. Okitipupa and Ile-Oluji generally show closer peak/off-peak relationships than Ondo. The annual estimates for Ondo are 0.71, 0.74 and 0.69 in 2023, 2024 and 2025, respectively. Okitipupa records 0.76, 0.75 and 0.74, while Ile-Oluji records 0.73, 0.82 and 0.73. Ile-Oluji therefore has the highest annual estimate in 2024.

Table 4: Annual Estimated Load Factor by Feeder

Feeder	2023	2024	2025	Three-year mean
Ondo	0.71	0.74	0.69	0.71
Okitipupa	0.76	0.75	0.74	0.75
Ile-Oluji	0.73	0.82	0.73	0.76

These load-factor values are estimates derived from the two reported monthly demand points. Consequently, they are useful for comparative characterization but should not be used as substitutes for interval-based load factors in detailed loss, tariff or equipment-loading studies.

Peak-to-Off-Peak Demand Ratio

PDR quantifies the contrast between peak and off-peak demand. The three-year mean PDR is highest for Ondo (2.72), followed by Okitipupa (2.13) and Ile-Oluji (2.09). Ondo's highest monthly ratios occur in February 2025 (7.27), March 2024 (6.00), April 2025 (5.40) and February 2024 (5.39). Such high ratios indicate months in which off-peak demand was substantially lower than peak demand.

Table 5: Selected Extreme Monthly PDR Values

Feeder	Year	Month	PDR
Ondo	2025	February	7.27
Ondo	2024	March	6.00
Ondo	2025	April	5.40
Ondo	2024	February	5.39
Okitipupa	2023	May	3.73
Okitipupa	2024	August	2.50
Ile-Oluji	2023	April	2.67
Ile-Oluji	2025	March	2.58

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The PDR results support the load-factor comparison: higher peak-to-off-peak separation corresponds to lower estimated load-factor performance. Nevertheless, PDR should be interpreted as a demand-profile indicator rather than a direct measure of technical efficiency.

Demand Variability and Coefficient of Variation

The corrected analysis does not treat the earlier duplicated PDR table as a coefficient-of-variation table. Instead, CV is reported from the descriptive statistics. The three-year peak-demand CV values are 22.28% for Ondo, 16.89% for Okitipupa and 16.67% for Ile-Oluji. Off-peak CV values are higher for all three feeders: 41.60%, 36.32% and 36.20%, respectively. This indicates that minimum-demand conditions fluctuate more strongly than peak-demand conditions over the full study period.

Table 6: Annual Peak-Demand Coefficient of Variation (%)

Feeder	2023	2024	2025	Three-year CV
Ondo	7.99	8.56	9.99	22.28
Okitipupa	12.24	17.76	19.73	16.89
Ile-Oluji	14.28	11.13	12.31	16.67

Okitipupa shows a marked increase in annual peak-demand variability from 12.24% in 2023 to 19.73% in 2025. Ondo also increases from 7.99% to 9.99%, while Ile-Oluji remains comparatively stable. These differences imply that forecasting and capacity-planning strategies may need to be feeder-specific.

Feeder Utilization Index

FUI was calculated relative to the maximum peak demand observed for each feeder over 2023–2025. The reference maxima are 14.70 MW for Ondo, 9.20 MW for Okitipupa and 8.30 MW for Ile-Oluji. The annual mean FUI values show strong temporal differences, particularly on Ondo.

Table 7: Annual Mean Feeder Utilization Index (FUI)

Feeder	2023 (%)	2024 (%)	2025 (%)	Three-year mean (%)	Study-period peak (MW)
Ondo	87.53	81.86	53.12	74.17	14.70
Okitipupa	74.18	79.44	72.37	75.33	9.20
Ile-Oluji	84.14	81.33	65.06	76.84	8.30

Ondo's mean FUI falls sharply from 87.53% in 2023 to 53.12% in 2025 because its 2025 peak-demand levels are substantially below the 14.70 MW study-period maximum. Okitipupa remains comparatively stable, while Ile-Oluji shows a moderate reduction in 2025.

The FUI values should not be interpreted as percentages of the physical feeder ratings because the actual thermal or equipment ratings were not supplied in the dataset. The index is therefore most appropriate for identifying relative utilization within each feeder and comparing temporal changes in observed loading.

Annual and Monthly Load Trend

The annual mean peak-demand trend shows a pronounced reduction on Ondo, from 12.87 MW in 2023 to 7.81 MW in 2025. Okitipupa increases from 6.83 MW in 2023 to 7.31 MW in 2024 before declining slightly to 6.66 MW in 2025. Ile-Oluji decreases from 6.98 MW in 2023 to 5.40 MW in 2025 as shown in figure 1.

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The monthly series show year-to-year and within-year fluctuations rather than a uniform monotonic pattern as shown in figure 2, 3 and 4. Some fourth-quarter observations are relatively high, but the pattern is not identical across all years and feeders. The dataset therefore supports evidence of temporal variation but does not, by itself, establish causes such as weather, outages, customer composition or operational switching.

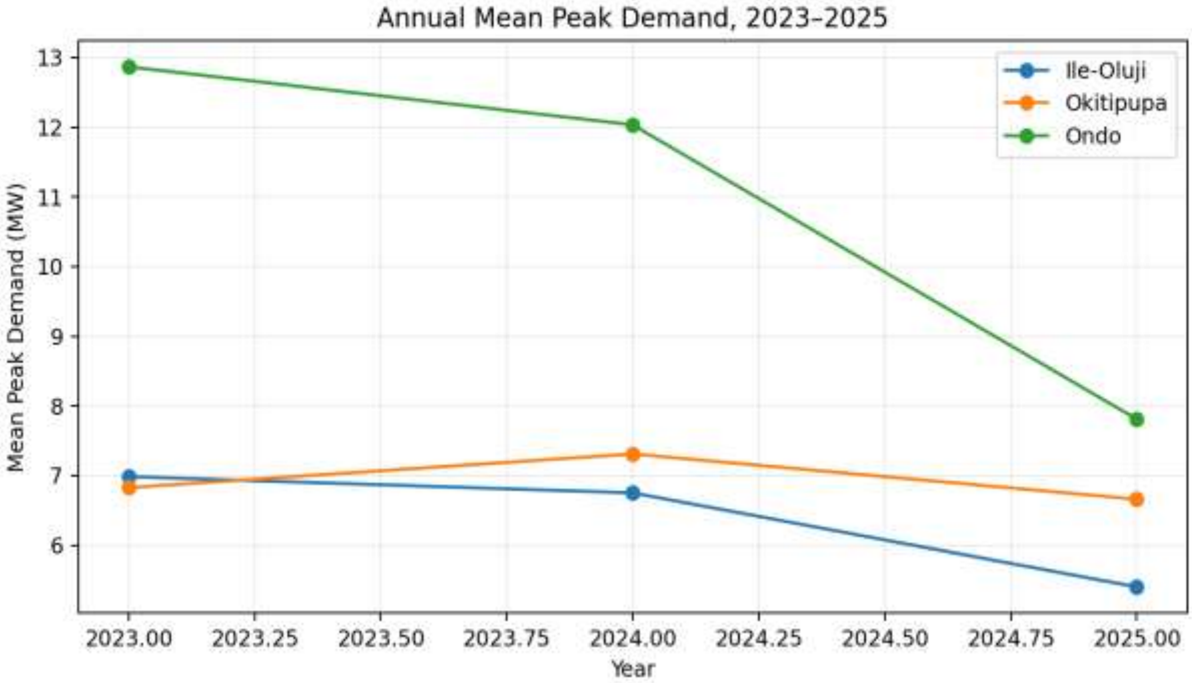

Figure 1: Annual Mean Peak Demand of the Three Feeders, 2023–2025.

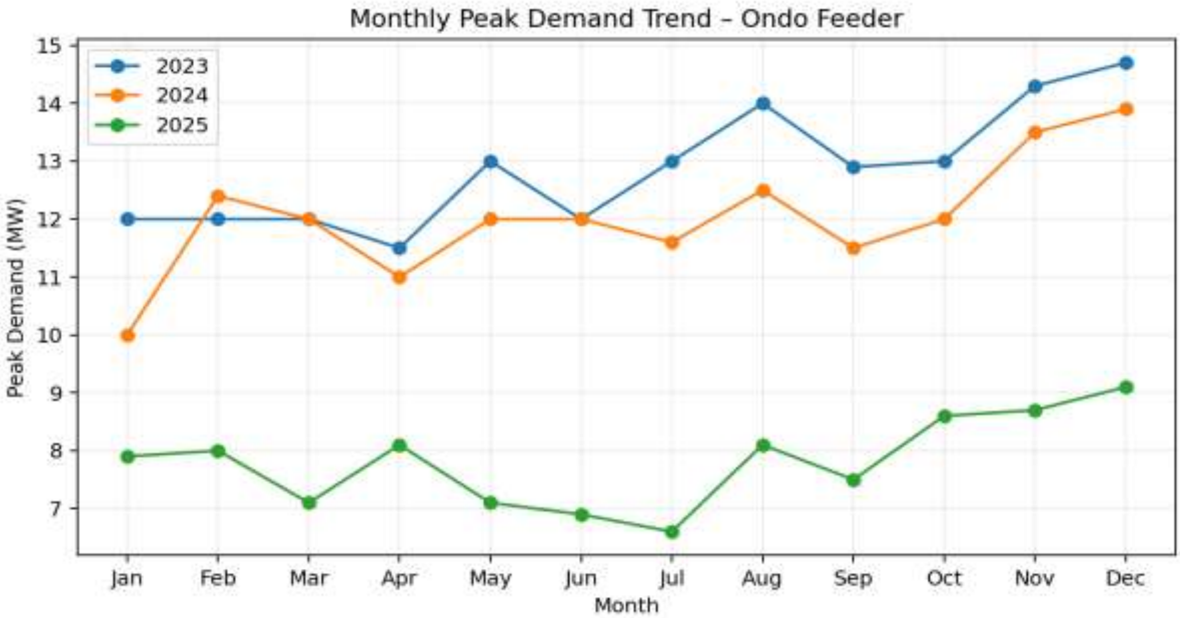

Figure 2: Monthly Peak Demand Trend for Ondo, 2023–2025.

For the Ondo feeder, the monthly series shows year-to-year and within-year fluctuations rather than a uniform monotonic trend. Fourth-quarter demand is generally stronger than the middle of the year for several observations, but the pattern is not identical in every year. Consequently, the data support seasonal variation but do not justify attributing the changes to a single cause without customer-class, outage, weather or operational records.

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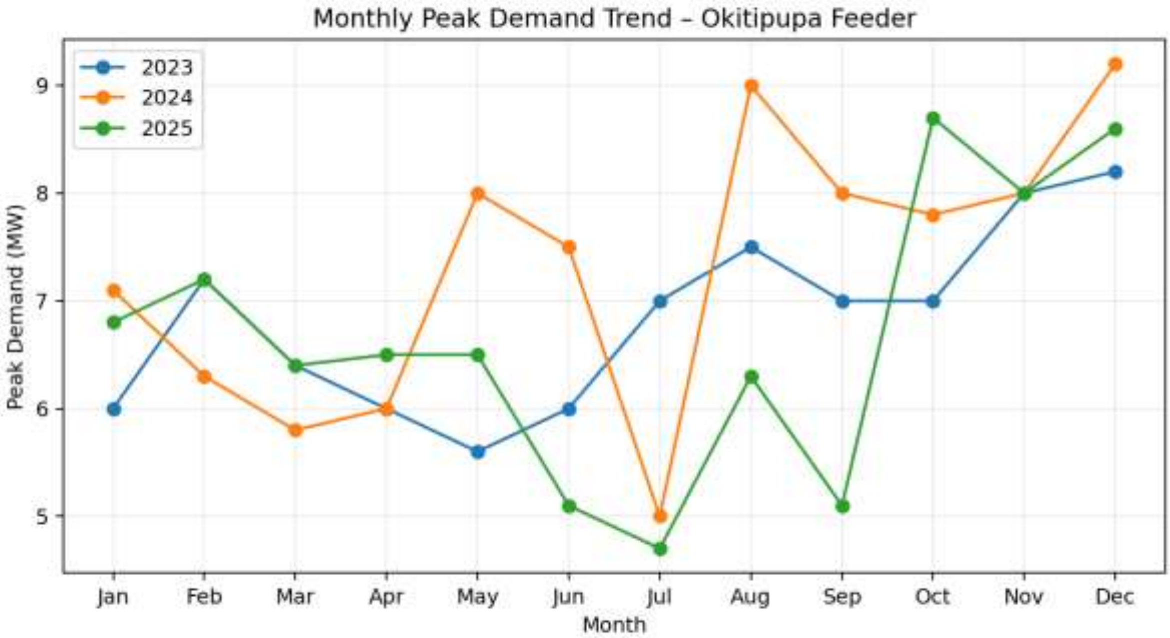

Figure 3: Monthly Peak Demand Trend for Okitipupa, 2023–2025.

For the Okitipupa feeder, the monthly series shows year-to-year and within-year fluctuations rather than a uniform monotonic trend. Fourth-quarter demand is generally stronger than the middle of the year for several observations, but the pattern is not identical in every year. Consequently, the data support seasonal variation but do not justify attributing the changes to a single cause without customer-class, outage, weather or operational records.

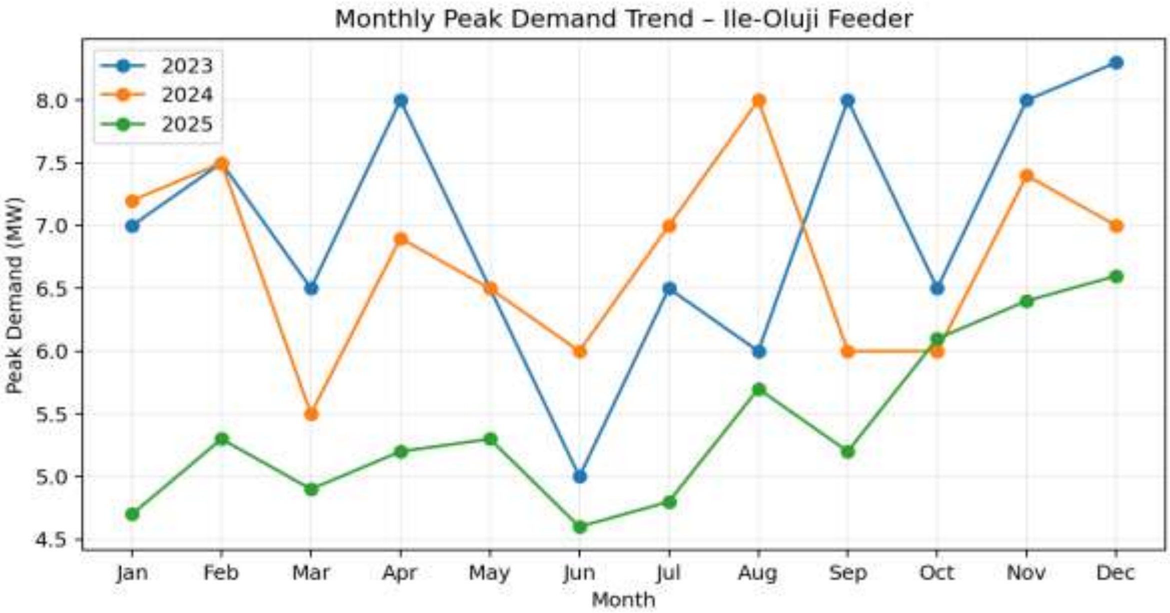

Figure 4: Monthly Peak Demand Trend for Ile-Oluji, 2023–2025.

For the Ile-Oluji feeder, the monthly series shows year-to-year and within-year fluctuations rather than a uniform monotonic trend. Fourth-quarter demand is generally stronger than the middle of the year for several observations, but the pattern is not identical in every year. Consequently, the data support seasonal variation but do not justify attributing the changes to a single cause without customer-class, outage, weather or operational records.

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Monthly Load-Factor and Utilization Highlights

The monthly load-factor results reveal substantial within-year variation. For Ondo, the estimated monthly LF ranges from 0.57 to 0.85; Okitipupa ranges from 0.63 to 0.93; and Ile-Oluji ranges from 0.62 to 0.91. Okitipupa reaches its highest estimated monthly LF in September 2023 (0.93), while Ondo reaches 0.85 in January 2024 and Ile-Oluji reaches 0.91 in October 2024.

The FUI series also identifies periods of relatively high observed peak loading. Ondo reaches 100% of its study-period reference maximum in December 2023, while Ile-Oluji also reaches 100% in December 2023. Okitipupa reaches 100% in December 2024. Conversely, Ondo's monthly FUI falls to 44.90% in July 2025, its lowest observed value during the study period.

Table 8: Selected Monthly Performance Extremes

Indicator	Feeder	Highest observation	Lowest observation
Estimated LF	Ondo	0.85 (Jan. 2024)	0.57 (Feb. 2025)
Estimated LF	Okitipupa	0.93 (Sep. 2023)	0.63 (May 2023)
Estimated LF	Ile-Oluji	0.91 (Oct. 2024)	0.62 (Jul. 2023)
PDR	Ondo	7.27 (Feb. 2025)	1.43 (Jan. 2024)
PDR	Okitipupa	3.73 (May 2023)	1.17 (Sep. 2023)
PDR	Ile-Oluji	4.33 (Jul. 2023)	1.22 (Oct. 2024)
FUI	Ondo	100.00% (Dec. 2023)	44.90% (Jul. 2025)
FUI	Okitipupa	100.00% (Dec. 2024)	51.09% (Jul. 2025)
FUI	Ile-Oluji	100.00% (Dec. 2023)	55.42% (Jun. 2025)

Taken together, these results show that no single index fully describes feeder performance. A feeder can have a relatively high utilization level while also experiencing substantial peak/off-peak separation, or it can have lower observed utilization while maintaining a more stable demand profile.

Correlation Analysis

Pearson correlation was used to assess the association between monthly peak and off-peak demand. The three-year coefficients are positive for all feeders, with Okitipupa showing the strongest relationship ($r = 0.762$), followed by Ile-Oluji ($r = 0.672$) and Ondo ($r = 0.666$). Thus, months with relatively high peak demand generally tend to have higher off-peak demand, although the strength of this association differs among feeders.

Table 9: Pearson Correlation between Peak and Off-Peak Demand

Feeder	2023	2024	2025	2023–2025
Ondo	0.540	0.169	0.570	0.666
Okitipupa	0.842	0.814	0.731	0.762
Ile-Oluji	0.588	0.755*	0.936	0.672

The annual correlation values reproduced here are based on the reported analysis; the asterisk is only a visual marker and does not denote a significance test. Statistical significance was not claimed because inferential test statistics and p-values were not provided. The relatively weak Ondo correlation in 2024 suggests that changes in peak demand that year were less closely mirrored by changes in off-peak demand.

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Overall Operational Interpretation

The comparative results show three distinct operational patterns. Ondo is characterized by the highest demand magnitude, the highest PDR and the greatest three-year variability, indicating a comparatively pronounced peak/off-peak contrast. Okitipupa shows the strongest peak/off-peak correlation and relatively stable three-year FUI, although its annual peak-demand variability increased toward 2025. Ile-Oluji has the highest overall estimated load factor and FUI, suggesting a relatively balanced relationship between peak and off-peak demand within the limits of the available data.

These findings are descriptive rather than causal. The dataset contains demand observations but does not include feeder ratings, voltage profiles, technical-loss measurements, outage records, customer-class composition or power-factor information. Accordingly, conclusions about physical capacity adequacy, efficiency losses or reliability should be confirmed with additional operational data.

CONCLUSION AND RECOMMENDATION

Conclusion

This study assessed the comparative operational performance of the Ondo, Okitipupa and Ile-Oluji 33 kV distribution feeders using monthly load-profile characteristics and utilization indices over the period 2023–2025.

The results established that all three feeders exhibited significant temporal variations in loading. The load-factor analysis showed differences in the consistency of demand across feeders and months. The PDR analysis demonstrated that peak demand was substantially higher than off-peak demand during selected periods, indicating uneven temporal distribution of feeder loading. The FUI analysis further showed considerable variation in feeder utilization, with some feeders approaching their maximum observed loading during selected months and operating at substantially lower utilization levels during others.

The combined indicators provide evidence that feeder operational performance is influenced not only by the magnitude of maximum demand but also by the temporal distribution and consistency of demand. The results therefore support the use of multiple load-based indicators for distribution-feeder performance assessment.

Recommendations

The feeders should be monitored regularly to identify changes in load demand. Load should be properly balanced among the feeders to reduce excessive loading. Demand during peak periods should be reduced where possible, while customers should be encouraged to use some electrical appliances during off-peak periods. Feeders experiencing high loading should be upgraded when necessary. The available capacity of underutilized feeders should also be used more effectively. Regular collection and analysis of load data should be encouraged to support proper distribution network planning. Further studies should include voltage levels, power losses, and feeder reliability.

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