

RESUME REPORT

PREDIKSI PEMAKAIAN DAYA LISTRIK

PRIMARY METHOD

Fuzzy Time Series

COMPARATIVE METHODS

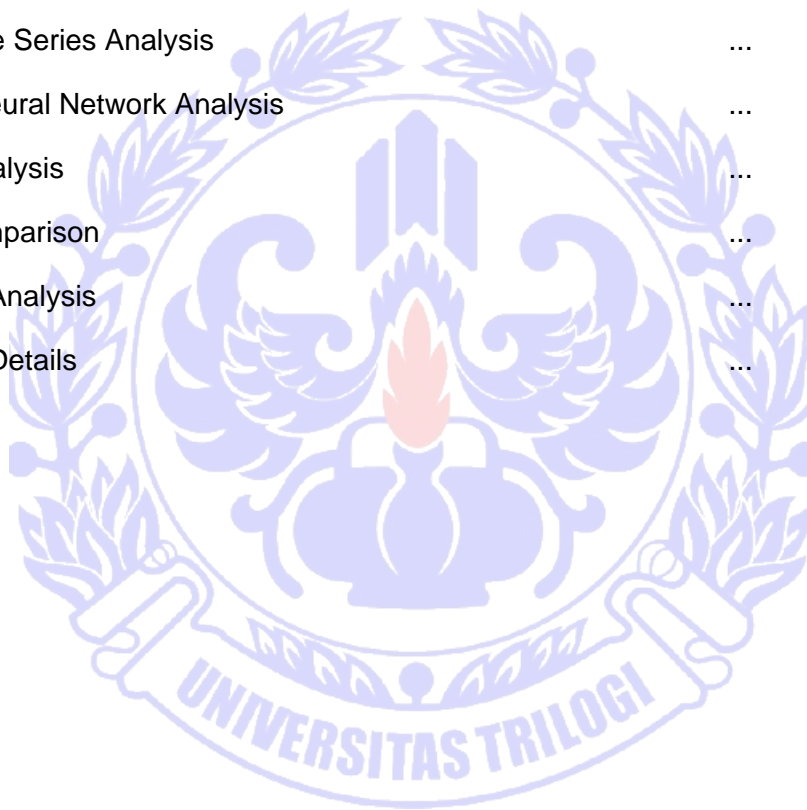
*Artificial Neural Network, dan Autoregressive
Integrated Moving Average*

[Generated: 16 January 2026, 06:14:57]

[Run ID: FAF7F113]

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1. Dataset Summary

Item	Value
Device	Unknown Device
Date Range	27/12/2025 - 04/01/2026
Total Rows	2,137
Start Time	27-12-2025 23:52:34
End Time	04-01-2026 10:02:35
Median Interval	300 seconds (5.0 min)

2. First 10 Rows

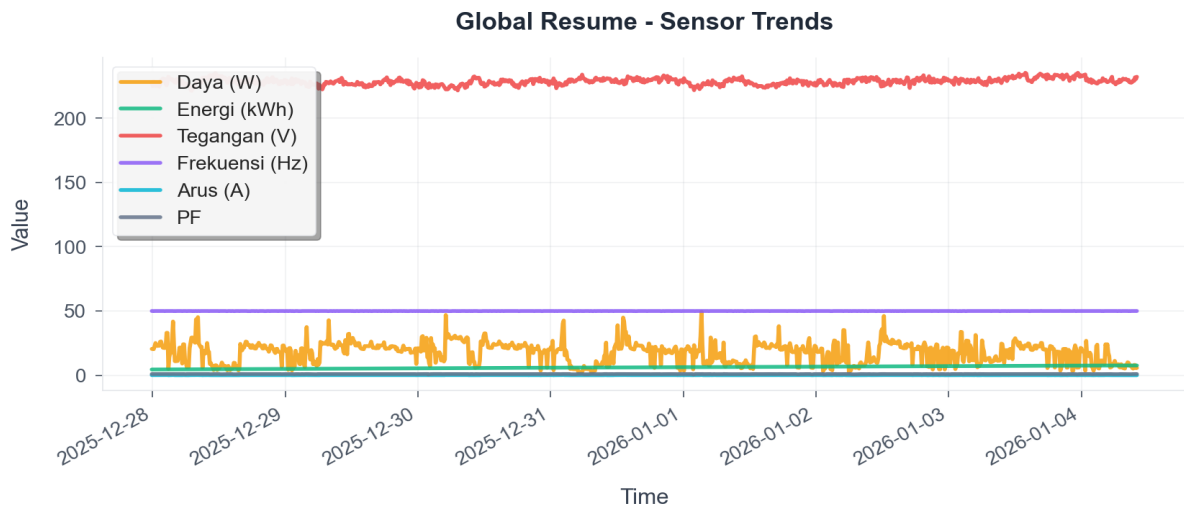
Timestamp	V (V)	A (A)	W (W)	kWh	Hz	PF
27-12-2025 23:52:34	227.30	0.093	20.50	4.4800	50.0	0.970
27-12-2025 23:57:34	225.70	0.093	20.50	4.4810	50.0	0.980
28-12-2025 00:02:34	225.00	0.093	20.40	4.4830	50.0	0.970
28-12-2025 00:07:34	227.60	0.093	20.40	4.4850	50.0	0.960
28-12-2025 00:12:35	228.60	0.092	20.30	4.4860	49.9	0.970
28-12-2025 00:17:34	225.90	0.104	22.60	4.4880	50.0	0.960
28-12-2025 00:22:34	226.40	0.103	22.50	4.4900	50.0	0.960
28-12-2025 00:27:34	225.20	0.103	22.40	4.4920	50.0	0.970
28-12-2025 00:32:34	225.10	0.119	25.10	4.4940	50.0	0.940
28-12-2025 00:37:34	225.80	0.108	22.90	4.4960	50.0	0.940

3. Last 10 Rows

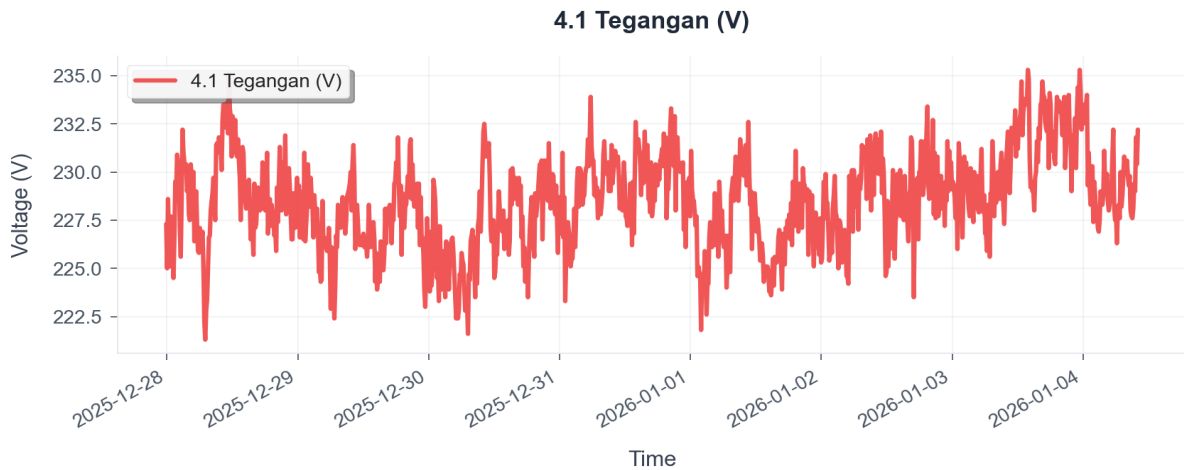
Timestamp	V (V)	A (A)	W (W)	kWh	Hz	PF
04-01-2026 09:17:35	227.90	0.025	5.30	7.6070	50.0	0.930
04-01-2026 09:22:35	229.40	0.024	5.20	7.6080	50.0	0.940
04-01-2026 09:27:35	229.30	0.025	5.30	7.6080	50.0	0.920
04-01-2026 09:32:35	229.00	0.036	8.00	7.6080	50.0	0.970
04-01-2026 09:37:35	228.80	0.036	7.90	7.6090	50.0	0.960
04-01-2026 09:42:35	231.80	0.035	8.00	7.6100	50.0	0.990
04-01-2026 09:47:35	230.30	0.037	8.00	7.6100	50.0	0.940
04-01-2026 09:52:36	230.40	0.026	5.50	7.6110	50.0	0.920
04-01-2026 09:57:36	230.40	0.026	5.50	7.6110	50.0	0.920
04-01-2026 10:02:35	232.20	0.025	5.70	7.6120	50.0	0.980

4. Global Resume

4.0 Overall



4.1 Tegangan (V)



Analisis Statistik Tegangan:

Statistik	Nilai	Tanggal
Rata-rata	228.49 V	-
Puncak (Tertinggi)	235.50 V	2026-01-03 13:27
Terendah	220.80 V	2025-12-30 07:17

Proses Matematis Tegangan:

$$Rata - rata : \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

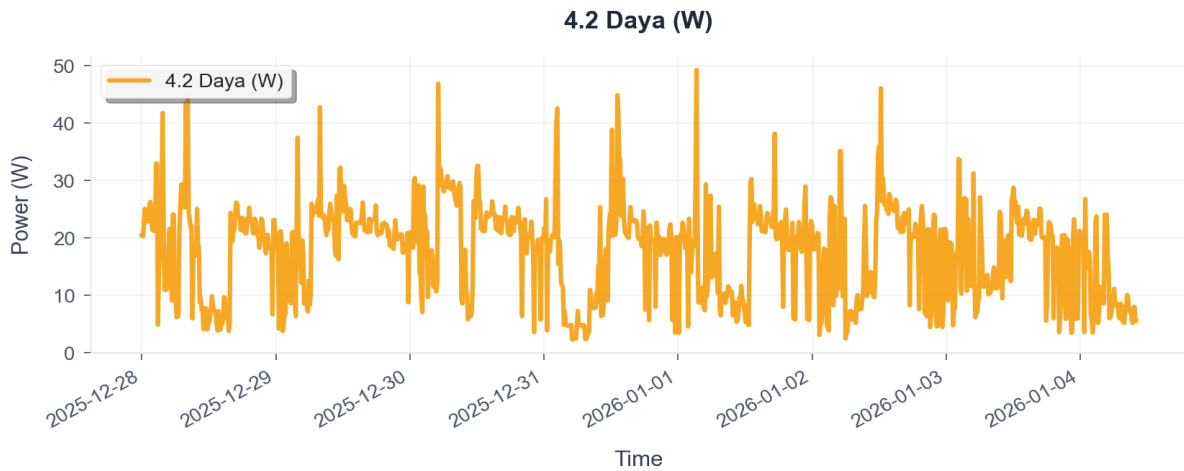
$$Puncak : \max(x) = \max\{x_1, x_2, \dots, x_n\}$$

$$Terendah : \min(x) = \min\{x_1, x_2, \dots, x_n\}$$

Statistik tegangan dihitung menggunakan metode: (1) rata-rata aritmetika untuk nilai tengah, (2) nilai maksimum untuk identifikasi puncak beban, (3) nilai minimum untuk analisis beban terendah. Tanggal dan waktu kejadian puncak serta

terendah dicatat untuk analisis temporal.

4.2 Daya (W)



Analisis Statistik Daya:

Statistik	Nilai	Tanggal
Rata-rata	17.62 W	-
Puncak (Tertinggi)	49.30 W	2026-01-01 03:17
Terendah	2.30 W	2025-12-31 05:02

Proses Matematis Daya:

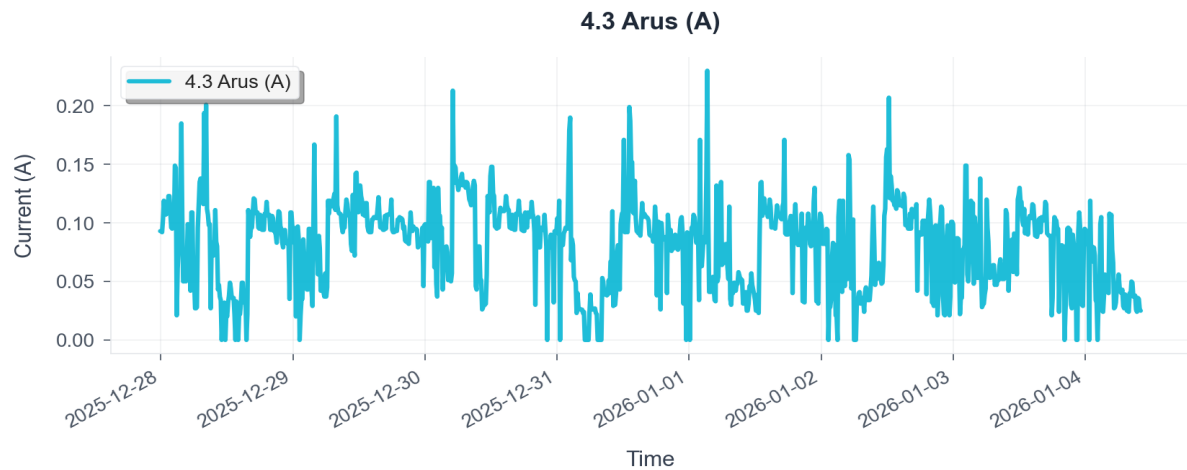
$$\text{Rata-rata} : \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

$$\text{Puncak} : \max(x) = \max\{x_1, x_2, \dots, x_n\}$$

$$\text{Terendah} : \min(x) = \min\{x_1, x_2, \dots, x_n\}$$

Statistik daya dihitung menggunakan metode: (1) rata-rata aritmetika untuk nilai tengah, (2) nilai maksimum untuk identifikasi puncak beban, (3) nilai minimum untuk analisis beban terendah. Tanggal dan waktu kejadian puncak serta terendah dicatat untuk analisis temporal.

4.3 Arus (A)



Analisis Statistik Arus:

Statistik	Nilai	Tanggal
Rata-rata	0.08 A	-
Puncak (Tertinggi)	0.23 A	2026-01-01 03:17
Terendah	0.00 A	2025-12-28 11:02

Proses Matematis Arus:

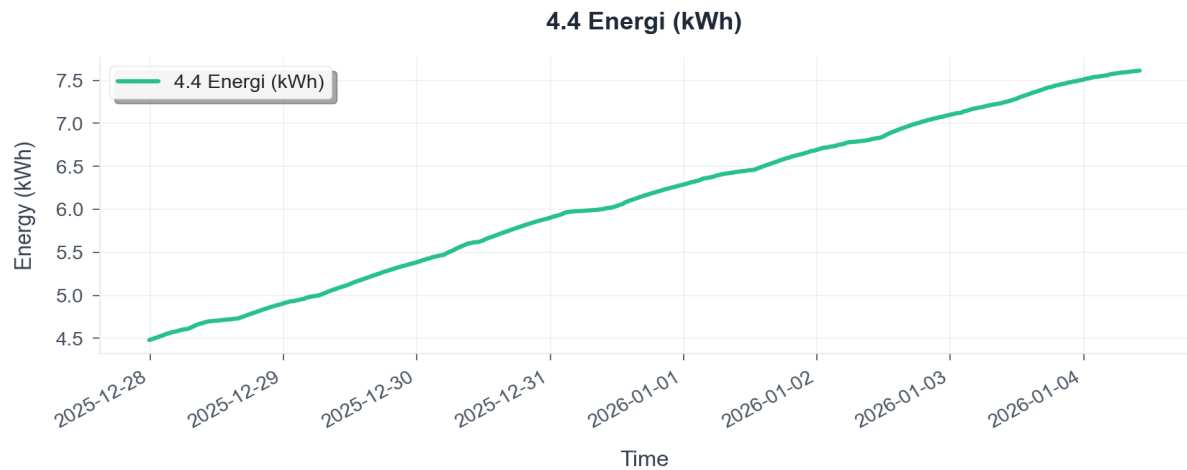
$$\text{Rata - rata : } \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

$$\text{Puncak : } \max(x) = \max\{x_1, x_2, \dots, x_n\}$$

$$\text{Terendah : } \min(x) = \min\{x_1, x_2, \dots, x_n\}$$

Statistik arus dihitung menggunakan metode: (1) rata-rata aritmetika untuk nilai tengah, (2) nilai maksimum untuk identifikasi puncak beban, (3) nilai minimum untuk analisis beban terendah. Tanggal dan waktu kejadian puncak serta terendah dicatat untuk analisis temporal.

4.4 Energi (kWh)



Analisis Statistik Energi:

Statistik	Nilai	Tanggal
Rata-rata	6.12 kWh	-
Puncak (Tertinggi)	7.61 kWh	2026-01-04 10:02
Terendah	4.48 kWh	2025-12-27 23:52

Proses Matematis Energi:

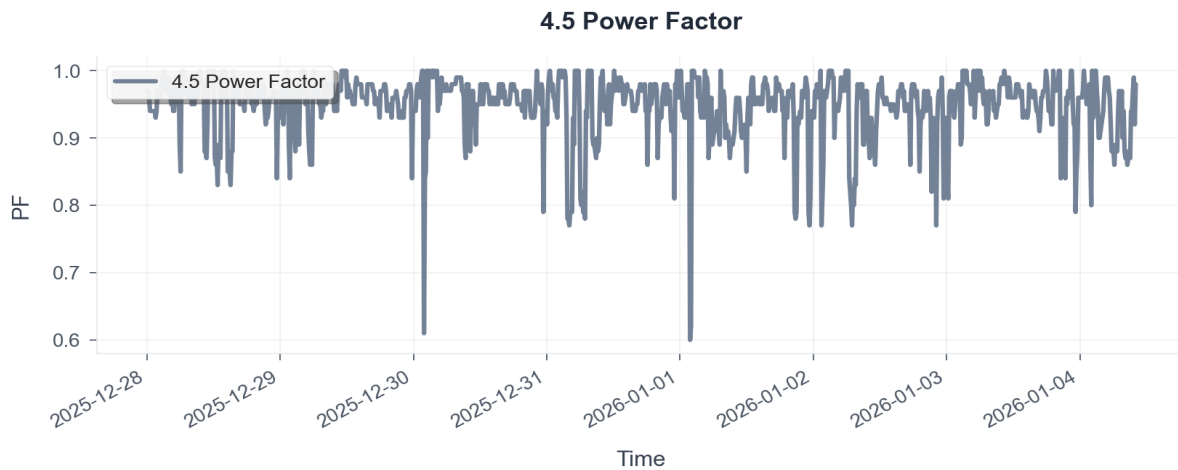
$$\text{Rata - rata : } \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

$$\text{Puncak : } \max(x) = \max\{x_1, x_2, \dots, x_n\}$$

$$\text{Terendah : } \min(x) = \min\{x_1, x_2, \dots, x_n\}$$

Statistik energi dihitung menggunakan metode: (1) rata-rata aritmetika untuk nilai tengah, (2) nilai maksimum untuk identifikasi puncak beban, (3) nilai minimum untuk analisis beban terendah. Tanggal dan waktu kejadian puncak serta terendah dicatat untuk analisis temporal.

4.5 Power Factor



4.6 Highest Current Points (Arus)

Rank	Timestamp	A (A)	W (W)	V (V)	Hz	kWh	PF
1	01-01-2026 03:17:38	0.230	49.30	224.20	50.0	6.3520	0.960
2	30-12-2025 05:07:37	0.215	47.40	221.90	50.0	5.4810	0.990
3	30-12-2025 05:02:36	0.213	46.90	222.40	50.0	5.4770	0.990
4	30-12-2025 06:57:37	0.212	47.00	223.00	50.0	5.5380	0.990
5	02-01-2026 12:12:39	0.210	46.90	225.70	50.0	6.8580	0.990

4.7 Lowest Current Points (Arus)

Rank	Timestamp	A (A)	W (W)	V (V)	Hz	kWh	PF
1	02-01-2026 06:07:39	0.000	3.70	229.10	50.0	6.7820	1.000
2	31-12-2025 05:27:38	0.000	2.30	231.00	50.0	5.9800	1.000
3	31-12-2025 05:22:37	0.000	2.50	230.30	50.0	5.9800	1.000
4	31-12-2025 05:17:37	0.000	2.60	231.00	50.0	5.9800	1.000
5	31-12-2025 05:12:38	0.000	2.50	231.70	49.9	5.9800	1.000

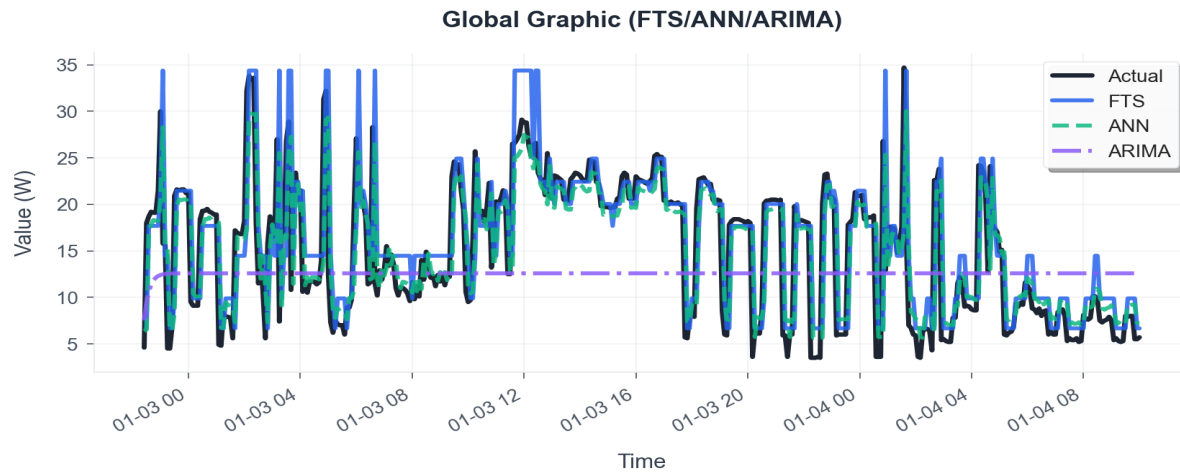
4.8 HOME Average Summary (Rata-rata)

Tanggal Awal	Tanggal Akhir	Jumlah Data	V_avg (V)	A_avg (A)	W_avg (W)	E (kWh)	Hz_avg	PF_avg
27/12/2025	04/01/2026	2,137	228.49	0.081	17.62	3.1320	50.0	0.948

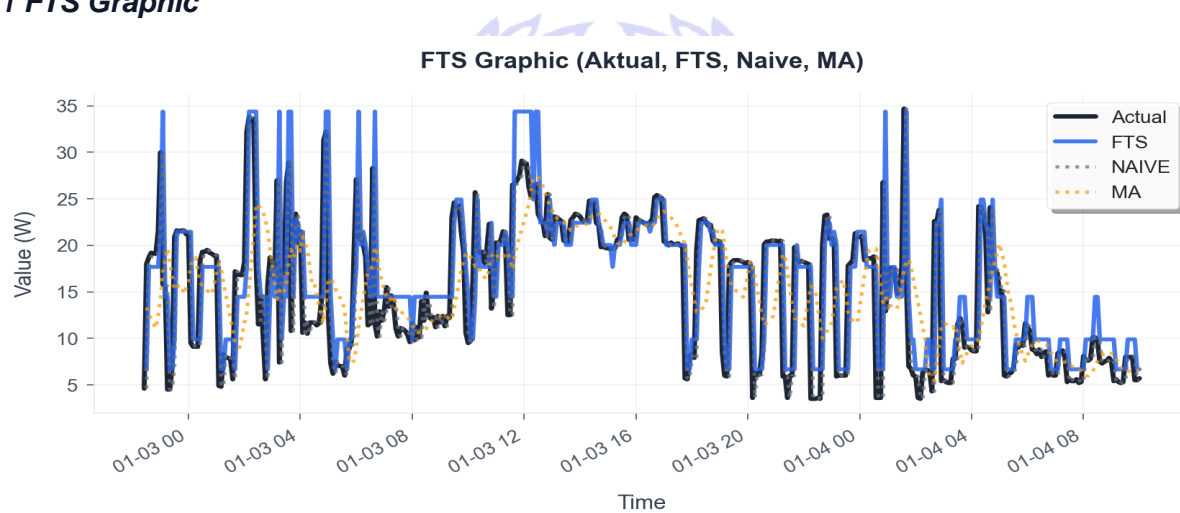
Energy method: **SENSOR_DELTA**

5. Resume Graphic (FTS/ANN/ARIMA)

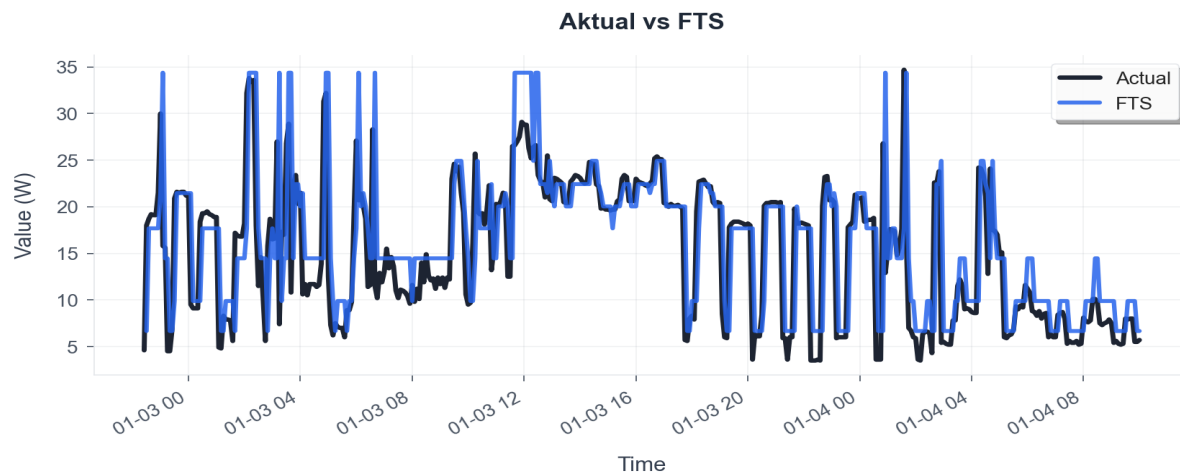
5.0 Global Graphic



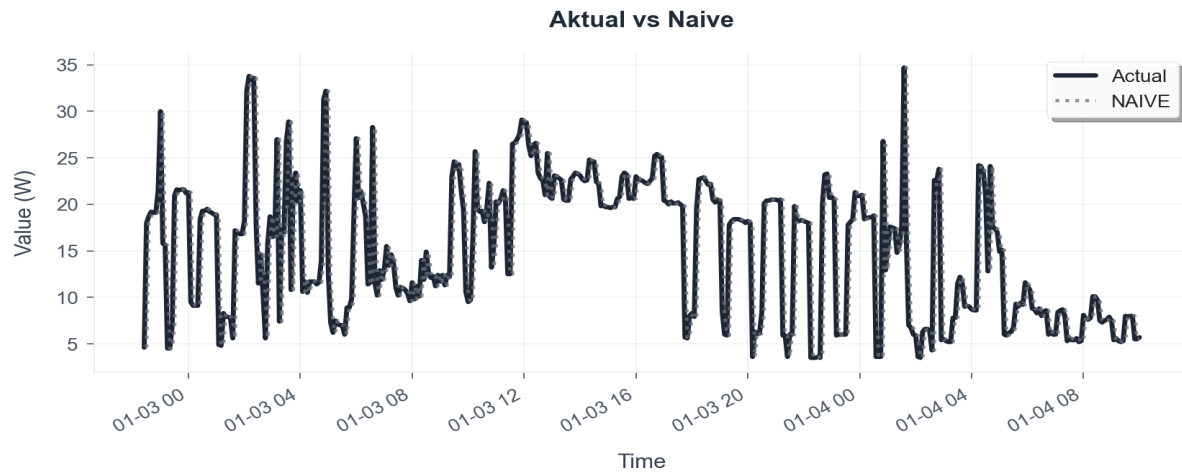
5.1 FTS Graphic



5.1.1 Grafik Aktual vs FTS



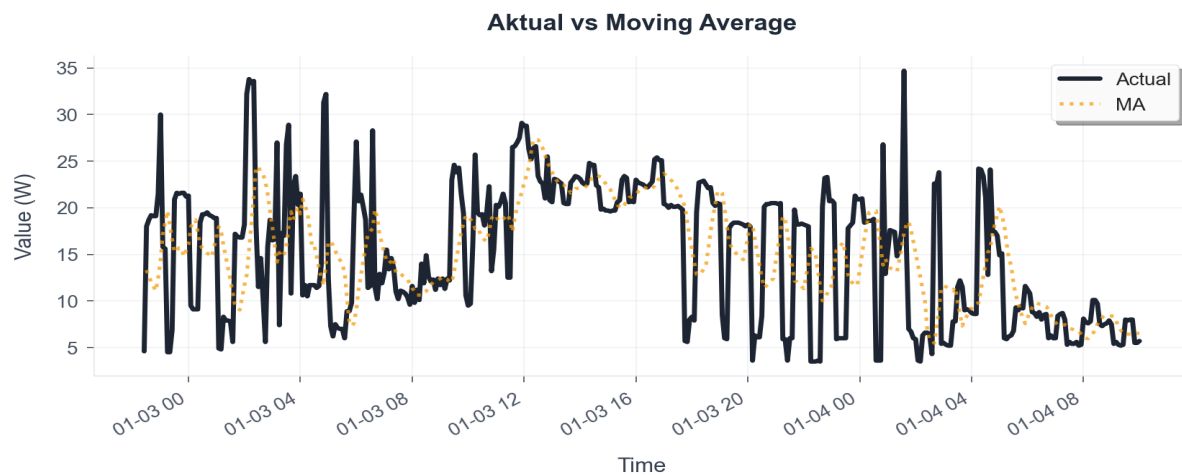
5.1.2 Grafik Aktual vs Naive



Perbandingan Detail Aktual vs Naive:

Tanggal/Waktu	Aktual	Naive
2026-01-04 09:40	8.00	nan
2026-01-04 09:45	8.00	4.60
2026-01-04 09:50	5.50	18.00
2026-01-04 09:55	5.50	18.70
2026-01-04 10:00	5.70	19.20

5.1.3 Grafik Aktual vs Moving Average

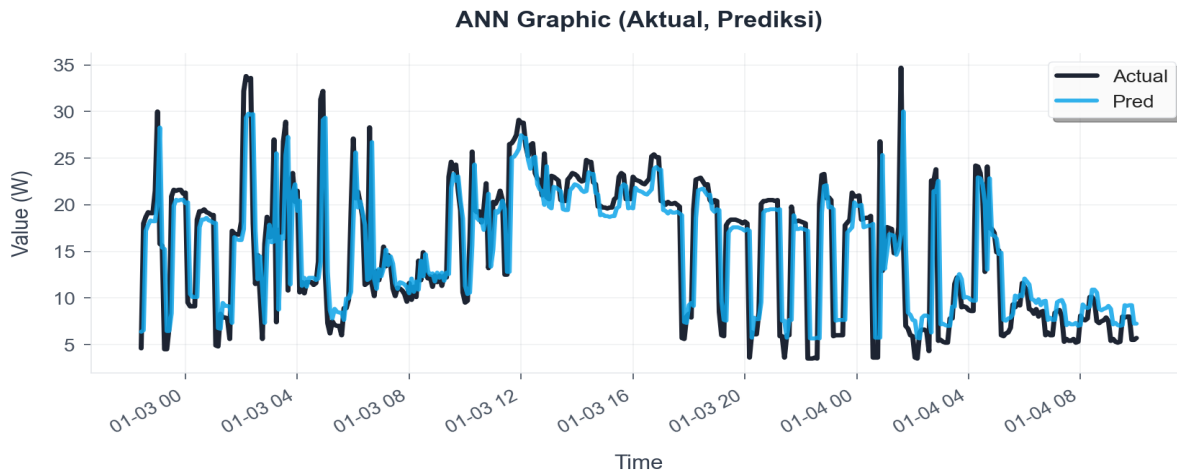


Perbandingan Detail Aktual vs Moving Average:

Tanggal/Waktu	Aktual	Moving Average
2026-01-04 09:40	8.00	nan
2026-01-04 09:45	8.00	13.31
2026-01-04 09:50	5.50	12.63

2026-01-04 09:55	5.50	12.06
2026-01-04 10:00	5.70	11.56

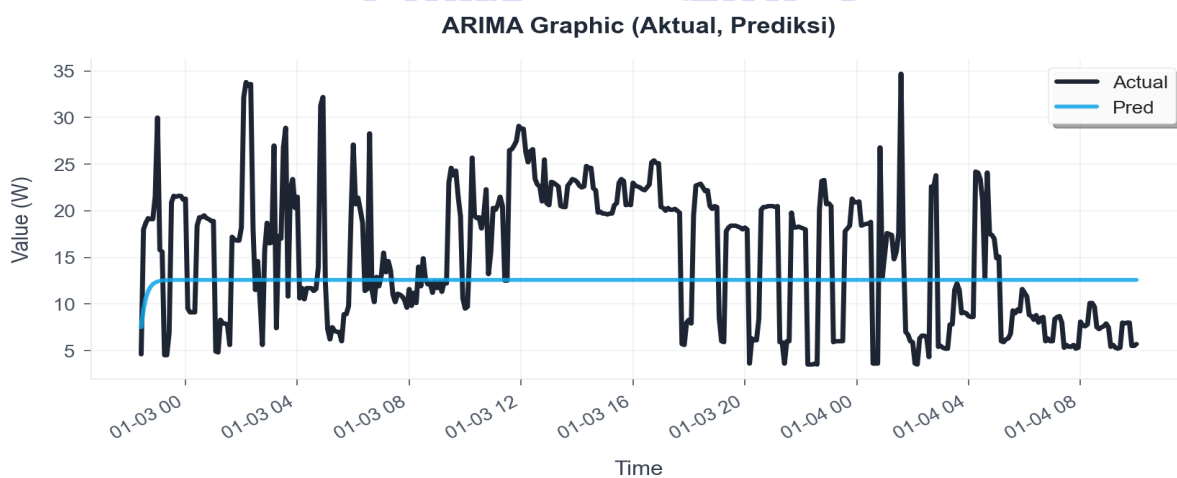
5.2 ANN Graphic



Perbandingan ANN (Aktual vs Prediksi):

Tanggal/Waktu	Aktual	ANN Predicted
2026-01-04 09:40	8.00	6.37
2026-01-04 09:45	8.00	6.53
2026-01-04 09:50	5.50	17.21
2026-01-04 09:55	5.50	17.86
2026-01-04 10:00	5.70	18.32

5.3 ARIMA Graphic



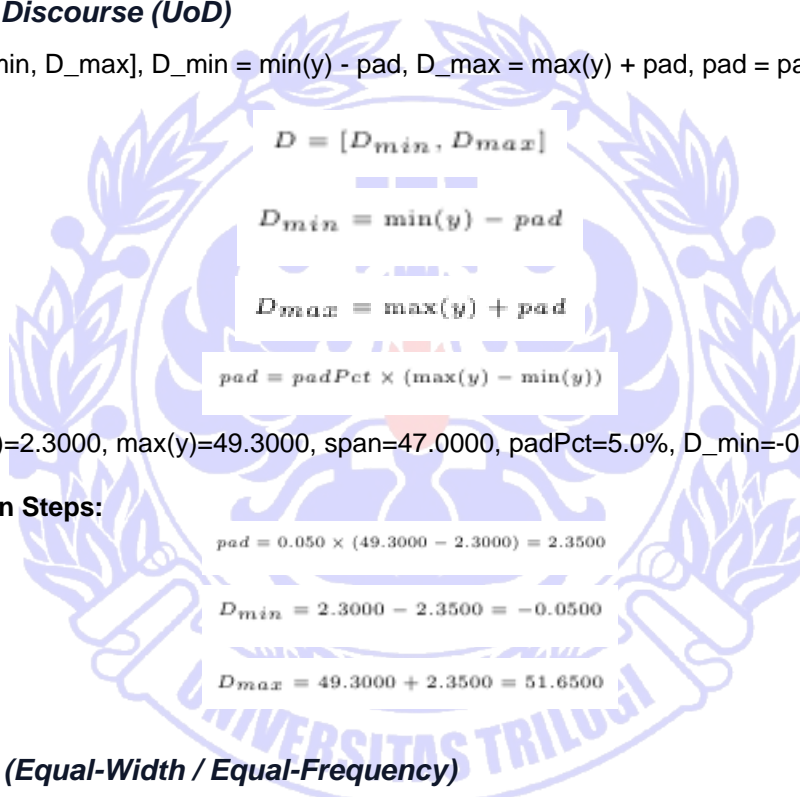
Perbandingan ARIMA (Aktual vs Prediksi):

Tanggal/Waktu	Aktual	ARIMA Predicted
2026-01-04 09:40	8.00	7.51
2026-01-04 09:45	8.00	9.44
2026-01-04 09:50	5.50	10.63
2026-01-04 09:55	5.50	11.37
2026-01-04 10:00	5.70	11.83

6. FTS Mathematical Documentation

6.1 Universe of Discourse (UoD)

Formula: $D = [D_{min}, D_{max}]$, $D_{min} = \min(y) - pad$, $D_{max} = \max(y) + pad$, $pad = padPct * (\max(y) - \min(y))$.



$$D = [D_{min}, D_{max}]$$

$$D_{min} = \min(y) - pad$$

$$D_{max} = \max(y) + pad$$

$$pad = padPct \times (\max(y) - \min(y))$$

Calculation: $\min(y)=2.3000$, $\max(y)=49.3000$, $span=47.0000$, $padPct=5.0\%$, $D_{min}=-0.0500$, $D_{max}=51.6500$

LaTeX Calculation Steps:

$$pad = 0.050 \times (49.3000 - 2.3000) = 2.3500$$

$$D_{min} = 2.3000 - 2.3500 = -0.0500$$

$$D_{max} = 49.3000 + 2.3500 = 51.6500$$

6.2 Partitioning (Equal-Width / Equal-Frequency)

Formula: $w = (D_{max} - D_{min}) / n$; $A_i = [D_{min} + (i-1)w, D_{min} + iw]$, $A_n = [D_{min} + (n-1)w, D_{max}]$.

$$w = \frac{D_{max} - D_{min}}{n}$$

$$A_i = [D_{min} + (i-1)w, D_{min} + iw]$$

$$A_n = [D_{min} + (n-1)w, D_{max}]$$

$$mid(A_i) = \frac{lo_i + hi_i}{2}$$

Method=equal-frequency, $n=9$, width=5.7444

LaTeX Calculation Steps:

$$w = \frac{51.6500 - -0.0500}{9} = 5.7444$$

$$A_1 = [-0.0500, 5.6944)$$

$$A_2 = [5.6944, 11.4389)$$

⋮

$$A_9 = [45.9056, 51.6500]$$

ID	Lower	Upper	Midpoint
A1	-0.0500	6.6000	3.2750
A2	6.6000	9.8000	8.2000
A3	9.8000	17.5000	13.6500
A4	17.5000	19.7000	18.6000
A5	19.7000	20.8000	20.2500
A6	20.8000	22.3000	21.5500
A7	22.3000	23.5000	22.9000
A8	23.5000	25.8000	24.6500
A9	25.8000	51.6500	38.7250

6.3 Fuzzification

Proses Fuzzification: Mengkonversi nilai numerik menjadi label linguistik berdasarkan interval partisi.
Formula: $L_t = A_i$ jika y_t berada pada interval $[lo_i, hi_i)$.

$$L_t = A_i, \text{ jika } y_t \in [lo_i, hi_i)$$

Definisi Interval:

Interval	Batas Bawah	Batas Atas	Label
Interval 1	-0.050	6.600	A1
Interval 2	6.600	9.800	A2
Interval 3	9.800	17.500	A3
Interval 4	17.500	19.700	A4
Interval 5	19.700	20.800	A5
Interval 6	20.800	22.300	A6
Interval 7	22.300	23.500	A7
Interval 8	23.500	25.800	A8
Interval 9	25.800	51.650	A9

Contoh Perhitungan Fuzzification:

Timestamp	Nilai Aktual (y_t)	Kondisi	Label (L_t)
27-12-2025 23:50:00	20.500	$19.700 \leq 20.500 < 20.800$	A5
27-12-2025 23:55:00	20.500	$19.700 \leq 20.500 < 20.800$	A5
28-12-2025 00:00:00	20.400	$19.700 \leq 20.400 < 20.800$	A5
28-12-2025 00:05:00	20.400	$19.700 \leq 20.400 < 20.800$	A5

28-12-2025 00:10:00	20.300	$19.700 \leq 20.300 < 20.800$	A5
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6.4 Fuzzy Logical Relationship (FLR)

Proses Fuzzy Logical Relationship (FLR): Membentuk hubungan logis antara label linguistik consecutive.

Formula: $FLR = \{(L_{t-1}, L_t)\}$ atau $A_i \rightarrow A_j$.

$$A_i \rightarrow A_j$$

$$FLR = \{(L_{t-1}, L_t)\}$$

Contoh Perhitungan FLR:

t	L_{t-1}	L_t	FLR
2	A5	A5	$A5 \rightarrow A5$
3	A5	A5	$A5 \rightarrow A5$
4	A5	A5	$A5 \rightarrow A5$
5	A5	A5	$A5 \rightarrow A5$
6	A5	A7	$A5 \rightarrow A7$

Daftar FLR yang Terbentuk:

No	Relation
1	$A5 \rightarrow A5$
2	$A5 \rightarrow A5$
3	$A5 \rightarrow A5$
4	$A5 \rightarrow A5$
5	$A5 \rightarrow A7$
6	$A7 \rightarrow A7$
7	$A7 \rightarrow A7$
8	$A7 \rightarrow A8$
9	$A8 \rightarrow A7$
10	$A7 \rightarrow A7$

... 1700 relasi lainnya ...

6.5 Fuzzy Logical Relationship Group (FLRG)

Proses FLRG: Mengelompokkan FLR berdasarkan antecedent yang sama.

Formula: $A_i \rightarrow \{A_j\}$ dengan $\text{support} = \text{count}(A_i \rightarrow A_j) / \text{total}(A_i)$.

$$A_i \rightarrow \{A_{j_1}, A_{j_2}, \dots\}$$

$$\text{support}(A_i \rightarrow A_j) = \frac{\text{count}(A_i \rightarrow A_j)}{\sum_j \text{count}(A_i \rightarrow A_j)}$$

Group	Next States (Support)
A1	A1 (66.1%), A2 (16.7%), A3 (5.4%), A5 (5.4%), A4 (3.2%), A6 (2.2%), A7 (1.1%)

A2	A2 (57.2%), A1 (16.6%), A3 (12.8%), A6 (4.3%), A4 (3.2%), A5 (2.7%), A7 (1.6%), A8 (1.1%), A9 (0.5%)
A3	A3 (63.4%), A2 (12.9%), A4 (10.8%), A1 (3.1%), A9 (2.6%), A8 (2.6%), A7 (2.1%), A5 (1.5%), A6 (1.0%)
A4	A4 (64.1%), A3 (9.4%), A5 (8.9%), A1 (7.3%), A6 (3.6%), A9 (3.1%), A2 (2.6%), A7 (0.5%), A8 (0.5%)
A5	A5 (60.3%), A4 (13.0%), A6 (8.7%), A7 (7.1%), A2 (3.3%), A9 (3.3%), A1 (2.7%), A3 (1.1%), A8 (0.5%)
A6	A6 (57.9%), A7 (11.1%), A5 (10.0%), A8 (10.0%), A4 (3.7%), A2 (2.6%), A9 (2.1%), A3 (1.6%), A1 (1.1%)
A7	A7 (56.4%), A8 (16.6%), A6 (11.6%), A5 (6.1%), A9 (2.8%), A3 (2.2%), A2 (2.2%), A1 (1.7%), A4 (0.6%)
A8	A8 (55.6%), A7 (16.2%), A9 (11.6%), A6 (9.1%), A3 (2.5%), A4 (1.5%), A5 (1.5%), A2 (1.5%), A1 (0.5%)
A9	A9 (74.7%), A8 (15.2%), A3 (2.5%), A6 (2.0%), A5 (2.0%), A7 (1.5%), A1 (1.0%), A4 (0.5%), A2 (0.5%)

6.6 Forecasting (Cheng Method)

Proses Forecasting (Cheng Method): Memprediksi nilai berdasarkan FLRG dengan weighted average.

Formula: $\hat{y}_{t+1} = \frac{\sum(\text{support}_j \times \text{midpoint}_j)}{\sum(\text{support}_j)}$.

Fallback: Jika FLRG tidak ditemukan, gunakan $\hat{y}_{t+1} = \text{midpoint}$ dari interval aktual.

$$\hat{y}_{t+1} = \frac{\sum_j \text{support}(L_t \rightarrow A_j) \text{mid}_j}{\sum_j \text{support}_j}$$

$$\hat{y}_{t+1} = \text{mid}(L_t) \quad (\text{fallback})$$

Contoh Perhitungan Forecasting:

Interval	Batas	Midpoint
A1	[-0.050, 6.600)	3.275
A2	[6.600, 9.800)	8.200
A3	[9.800, 17.500)	13.650
A4	[17.500, 19.700)	18.600
A5	[19.700, 20.800)	20.250
A6	[20.800, 22.300)	21.550
A7	[22.300, 23.500)	22.900
A8	[23.500, 25.800)	24.650
A9	[25.800, 51.650)	38.725

Hasil Prediksi vs Aktual:

t	Timestamp	Actual (W)	Pred (W)
2	02-01-2026 22:30:00	18.000	6.665
3	02-01-2026 22:35:00	18.700	17.684
4	02-01-2026 22:40:00	19.200	17.684
5	02-01-2026 22:45:00	19.100	17.684
6	02-01-2026 22:50:00	19.100	17.684

7	02-01-2026 22:55:00	21.500	17.684
8	02-01-2026 23:00:00	30.000	21.464
9	02-01-2026 23:05:00	15.800	34.385
10	02-01-2026 23:10:00	15.600	14.467
11	02-01-2026 23:15:00	4.500	14.467

LaTeX Calculation Example:

Example calculation for $t = 1$:

$$\hat{y}_{t+1} = \sum_j \text{support}(L_t \rightarrow A_j) \times \text{mid}_j$$

$$\hat{y}_1 = -W$$

(detailed FLRG lookup omitted for brevity)

6.7 Evaluation Metrics

Formula: $MAE = \text{mean}(|y - \hat{y}|)$, $RMSE = \sqrt{\text{mean}((y - \hat{y})^2)}$, $MAPE = \text{mean}(|(y - \hat{y})/y|) * 100$.

$$MAE = \frac{1}{n} \sum_{t=1}^n |Y_t - \hat{Y}_t|$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{t=1}^n (Y_t - \hat{Y}_t)^2}$$

$$MAPE = \frac{100\%}{n} \sum_{t=1}^n \left| \frac{Y_t - \hat{Y}_t}{Y_t} \right|$$

Metric	Value
MAE	3.3094
RMSE	5.5432
MAPE (%)	30.86

LaTeX Calculation Steps:

$$n = 428 \text{ (test samples)}$$

$$MAE = \frac{1}{428} \sum_{t=1}^{428} |Y_t - \hat{Y}_t| = 3.3094$$

$$RMSE = \sqrt{\frac{1}{428} \sum_{t=1}^{428} (Y_t - \hat{Y}_t)^2} = 5.5432$$

$$MAPE = \frac{100\%}{428} \sum_{t=1}^{428} \left| \frac{Y_t - \hat{Y}_t}{Y_t} \right| = 30.86\%$$

6.8 Baseline Models Comparison

Metodologi Baseline Models: Perbandingan dengan model sederhana untuk evaluasi performa FTS.

Formula Matematis Baseline:

$$\text{Naive Method} : \hat{y}_{t+1} = y_t$$

$$\text{Moving Average} : \hat{y}_{t+1} = \frac{1}{w} \sum_{i=0}^{w-1} y_{t-i}$$

$$MAE = \frac{1}{n} \sum_{t=1}^n |y_t - \hat{y}_t|$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{t=1}^n (y_t - \hat{y}_t)^2}$$

Model	MAE	RMSE	MAPE (%)	Deskripsi
FTS (Chen)	3.3094	5.5432	30.86	Fuzzy Time Series
Naive	2.5272	5.1240	22.35	$y(t+1) = y(t)$
Moving Average	4.9935	6.6354	49.75	$y(t+1) = \text{mean}(\text{window})$

6.9 Sensitivity Analysis

Metodologi Sensitivity Analysis: Analisis perubahan parameter dan evaluasi robustness model FTS.

Formula Sensitivity Metrics:

$$\Delta MAPE = MAPE_{FTS} - MAPE_{Baseline}$$

$$\text{Relative Error} = \frac{|MAPE_{FTS} - MAPE_{Baseline}|}{MAPE_{Baseline}} \times 100\%$$

$$\text{Improvement Ratio} = \frac{MAPE_{Baseline} - MAPE_{FTS}}{MAPE_{Baseline}} \times 100\%$$

$$\text{Performance Index} = \frac{1}{1+RMSE} \times 100\%$$

Case	MAPE (%)	Delta (%)	Improvement (%)	Status
pad = 10%	29.73	-1.13	1.13%	Better
n = 11	30.09	-0.77	0.77%	Better
method = equal-width	32.85	1.99	-	Worse

7. Model Configuration

Model	Config Summary
FTS	n=9, method=equal-frequency, pad=5%, split=80%
ANN	epoch=100, neuron=16, layers=1, lr=0.01
ARIMA	order=(1, 1, 1)

8. Performance Results

Model	MAE	RMSE	MAPE (%)	Rank
FTS	3.3094	5.5432	30.86	2
ANN	2.9029	4.8343	27.10	1
ARIMA	6.7084	7.7408	55.08	3

Best Model: ANN

9. Sensitivity Analysis

Case	MAPE (%)	Delta (%)
pad = 10%	29.73	-1.13
n = 11	30.09	-0.77
method = equal-width	32.85	1.99

Best Case: pad = 10%

10. Auto-Generated Caption

Analisis perbandingan FTS Cheng, ANN, dan ARIMA pada Unknown Device periode 27/12/2025 - 04/01/2026 dengan 2137 titik data. FTS parameter $n=9$, method=equal-frequency, pad=5% memberi MAPE=30.86%. Model terbaik: ANN (MAPE=27.10%). Sensitivity menyarankan pad = 10% (improve 1.13%).

