



Project Title:

AI/ML-Based IoT Framework for Wide-Area Energy Management System

B25RVP01

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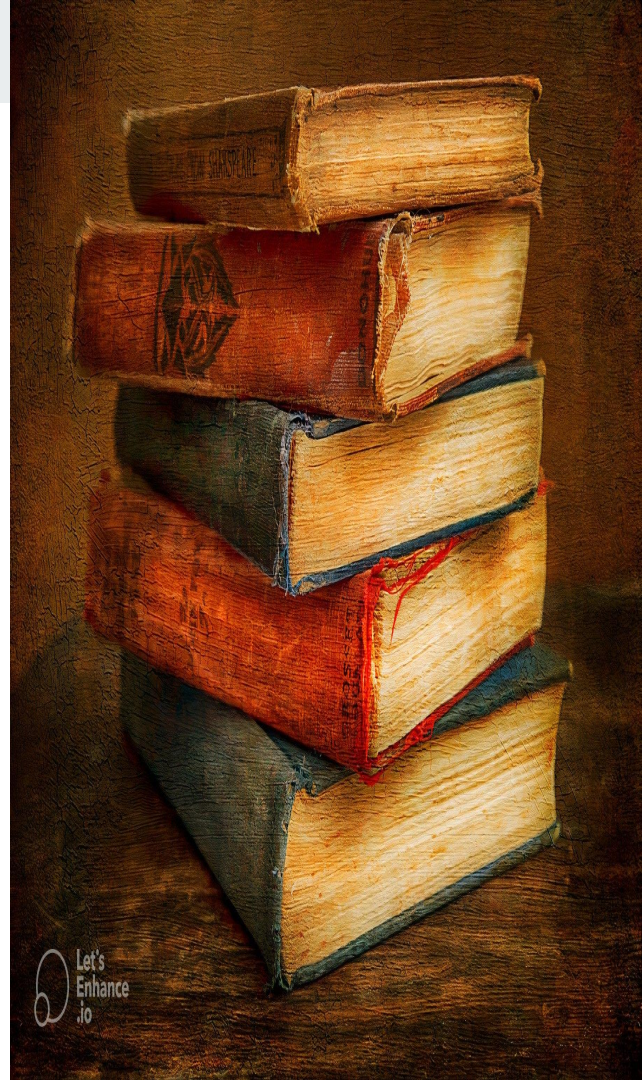
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1. ML MODELS



1.1 Data Set

Training Data: 1-year (Datetime vs Power)

Validation Data: 1 day (24 hourly points)

Target Column: Power in watts

Used For: Time series forecasting – predict next hour's power

Sample Training Data:

	Datetime	Power
0	2005-07-01 00:00:00	13981
1	2005-07-01 01:00:00	13162
2	2005-07-01 02:00:00	12699
3	2005-07-01 03:00:00	12464
4	2005-07-01 04:00:00	12599

Sample Validation Data:

	Datetime	Power
0	2006-07-01 00:00:00	12930
1	2006-07-01 01:00:00	12045
2	2006-07-01 02:00:00	11457
3	2006-07-01 03:00:00	11133
4	2006-07-01 04:00:00	10999

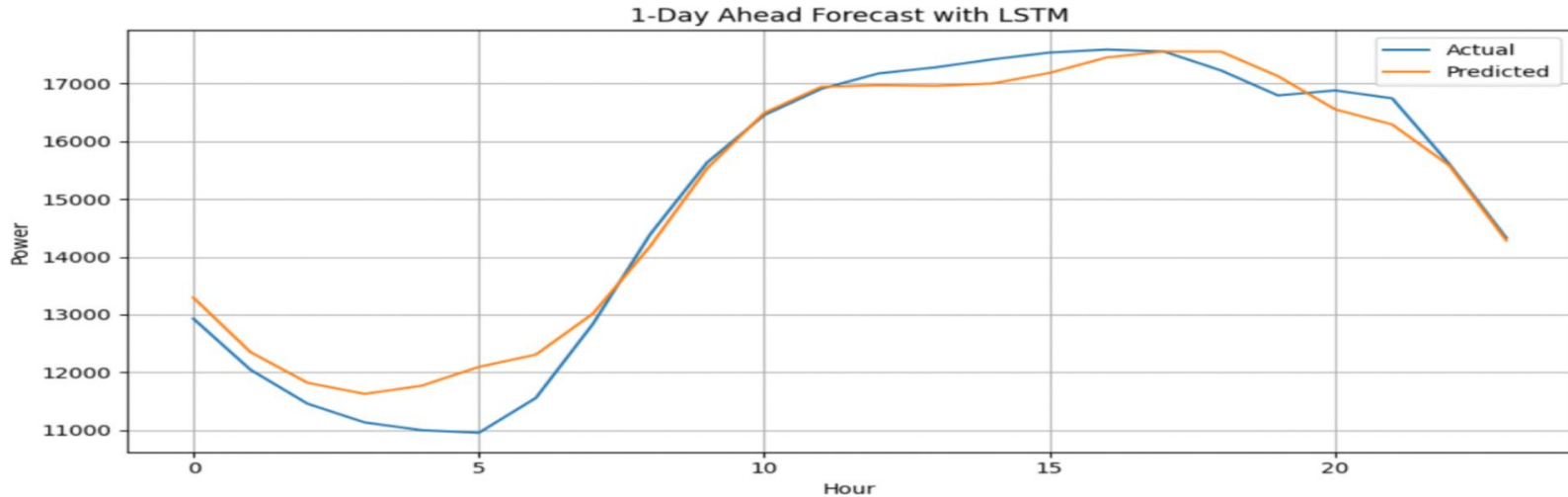
1.2 LSTM Model



- **Data Processing:**
 - Extracted Power, normalized (0 to 1)
 - Created sequences of last 24 hours to predict the next hour
- **Model:**
 - 1 LSTM layer (50 units), 1 Dense layer
 - Trained for 20 epochs, batch size 32
- **Prediction:**
 - Used both training + validation sequences
 - De-normalized output to get actual values
- **Metrics:**
 - $R^2 = 0.971$, MAE \approx 320 units

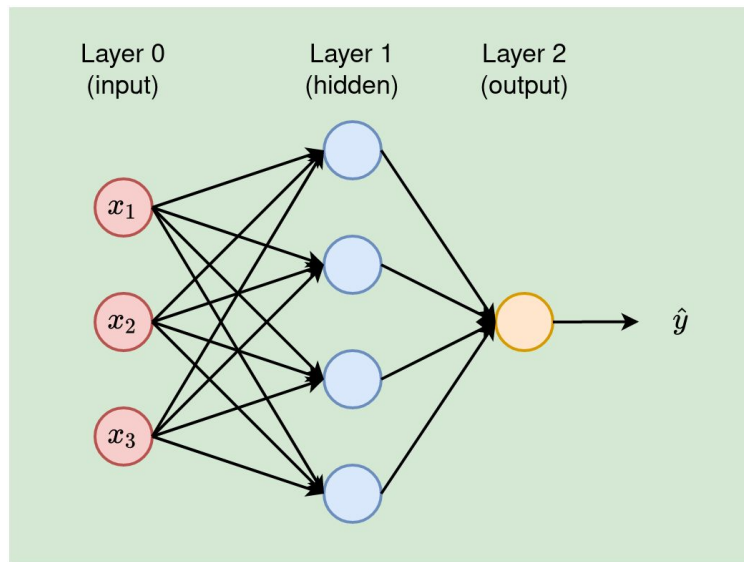
1.2 LSTM Model

273/273 — 1s 3ms/step — loss: 8.2837e-04
Epoch 20/20
273/273 — 1s 3ms/step — loss: 8.1529e-04
1/1 — 0s 65ms/step
Evaluation Metrics:
MAE: 320.24
MSE: 172412.79
RMSE: 415.23
MAPE: 2.42%
R²: 0.9718



1.3 FNN Model

- **Architecture:**
 - Input: 24 lag values
 - Hidden layers: Dense layers with ReLU
 - Output: 1 value
- **Training:**
 - Epochs = 50
 - Batch size = 32
- **Evaluation:**
 - $R^2 \approx 0.7733$
 - MAE ≈ 1037
 - It is the least performer compare to LSTM and XGBoost



1.3 FNN Model

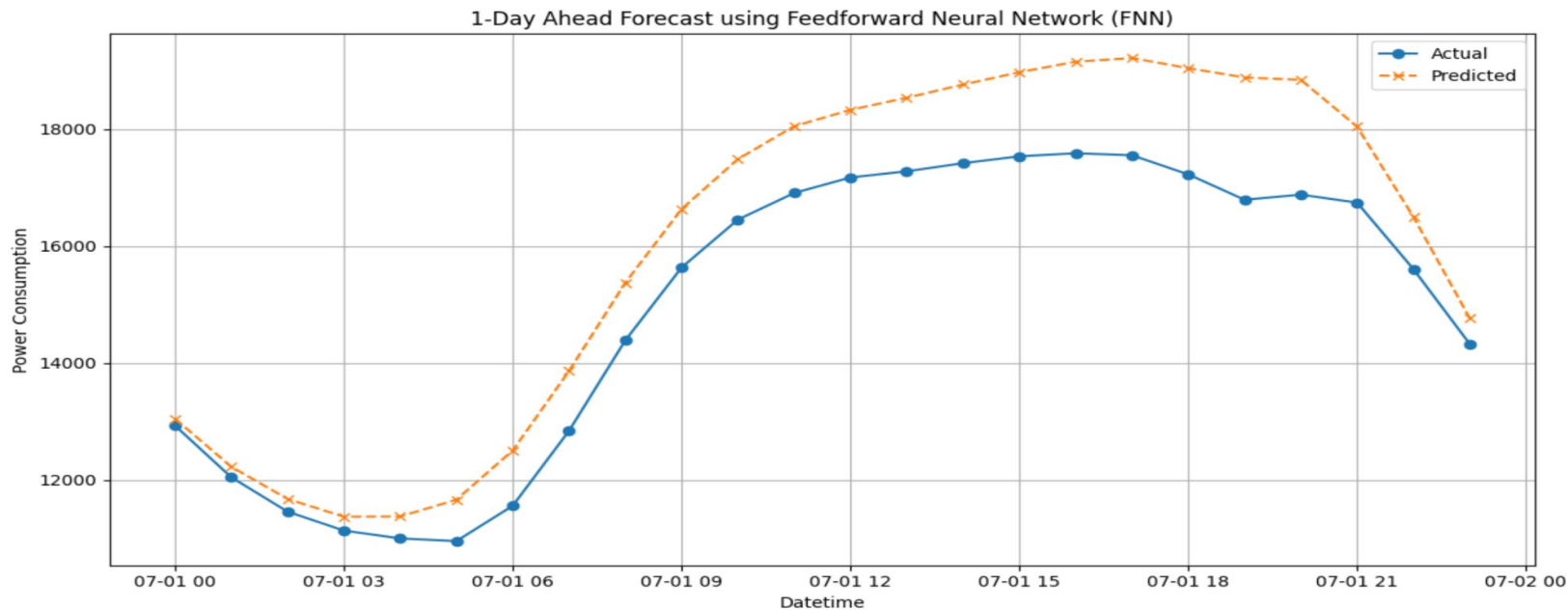
Evaluation Metrics:

MAE = 1037.6221

MSE = 1388160.8750

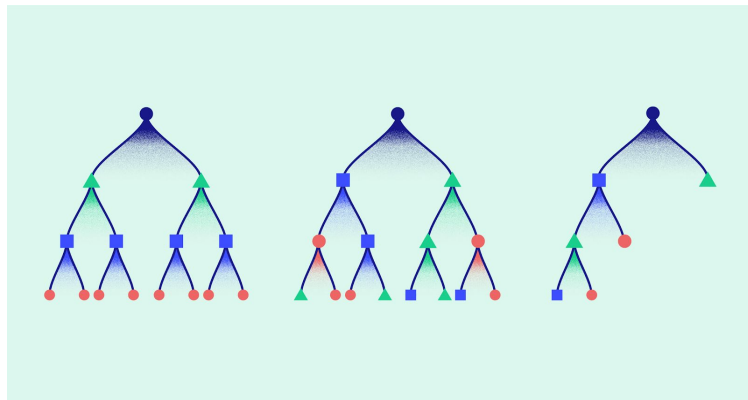
RMSE = 1178.2024

$R^2 = 0.7733$



1.4 XGBoost Model

- **Preprocessing:**
 - Merged training + testing into one DataFrame
 - Created lag features: lag1 to lag24 (past 24 hours)
- **Model:**
 - `XGBRegressor(n_estimators=100, max_depth=5, learning_rate=0.1)`
- **Evaluation:**
 - $R^2 \approx 0.989$
 - MAE ≈ 204 (better than LSTM)



1.4 XGBoost Model

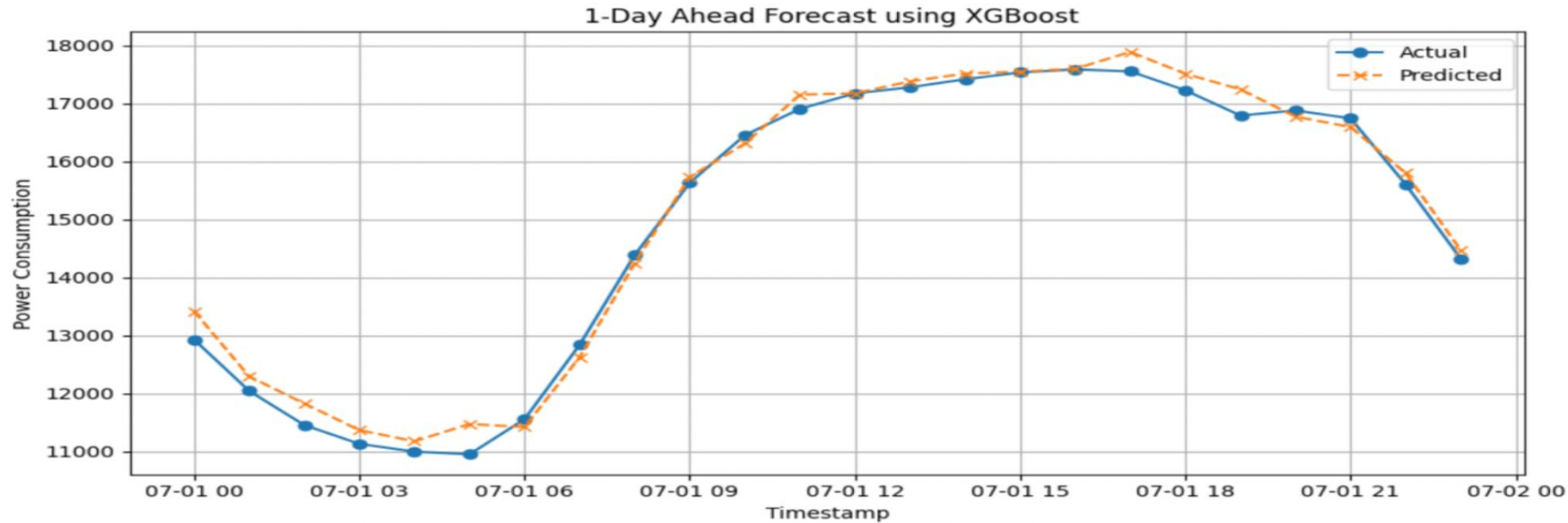
Evaluation Metrics for XGBoost Forecasting:

MAE : 204.76

RMSE : 248.66

R^2 : 0.9899

MAPE : 1.49%



2. Station S & IIITS

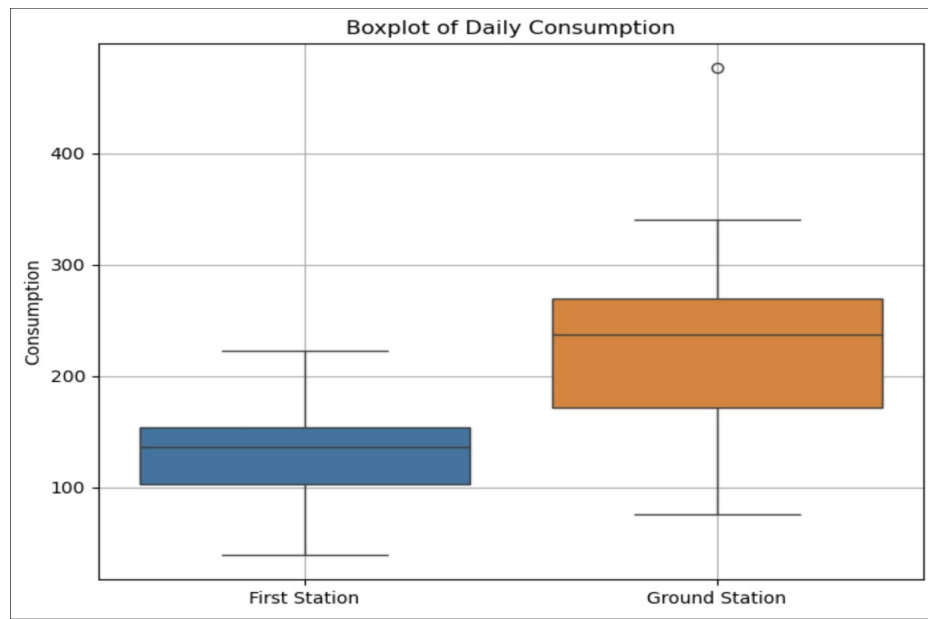
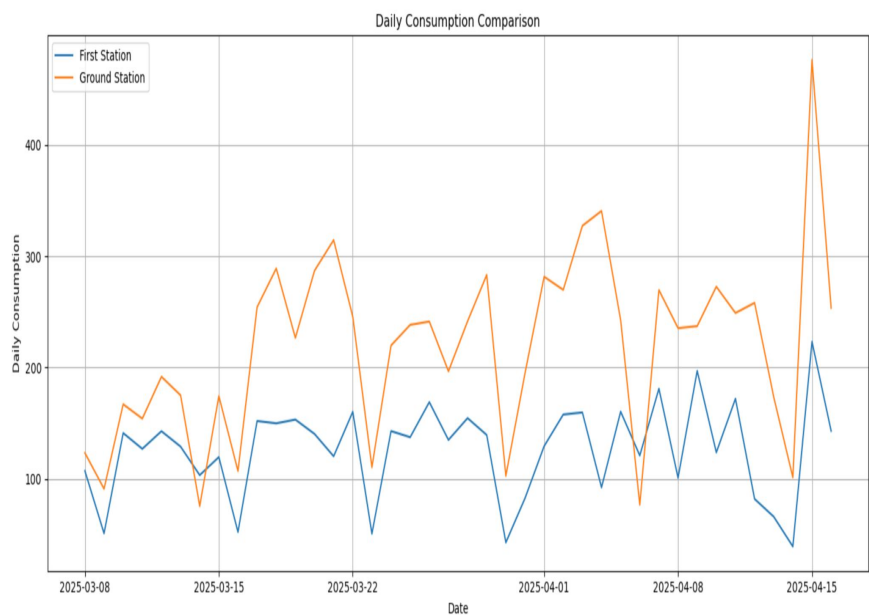
2.1 Data Preprocessing

1. Removed empty (null) values from the dataset.
2. Selected only the '**Energy**' column for analysis.
3. The data was recorded every 5 minutes, so we converted it to **1-hour intervals** by subtracting the minimum from the maximum value in each hour.
4. This gave us **24 energy values per day**.
5. The data used for this analysis ranges from **8th March to 17th April**.

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 894 entries, 0 to 893
Data columns (total 4 columns):
#   Column      Non-Null Count  Dtype
---  -
0   Date        894 non-null    object
1   Hour        894 non-null    int64
2   Energy      894 non-null    float64
3   Datetime    894 non-null    datetime64[ns]
dtypes: datetime64[ns](1), float64(1), int64(1), object(1)
memory usage: 28.1+ KB
None
```

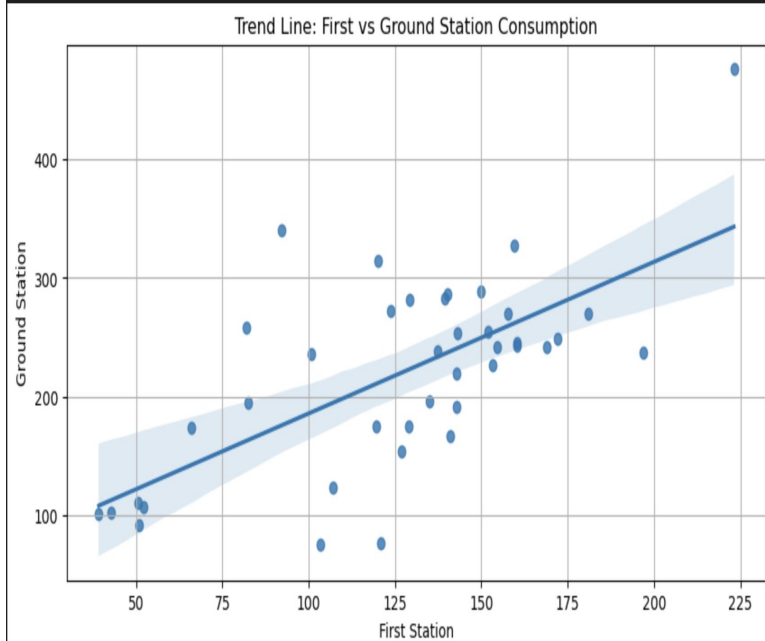
2.2 Data Analysis

STATION S GROUND AND FIRST FLOOR DAILY ENERGY CONSUMPTION



2.2 Data Analysis

Correlation between First and Ground Station consumption: 0.662



--- Basic Info ---

First Station:

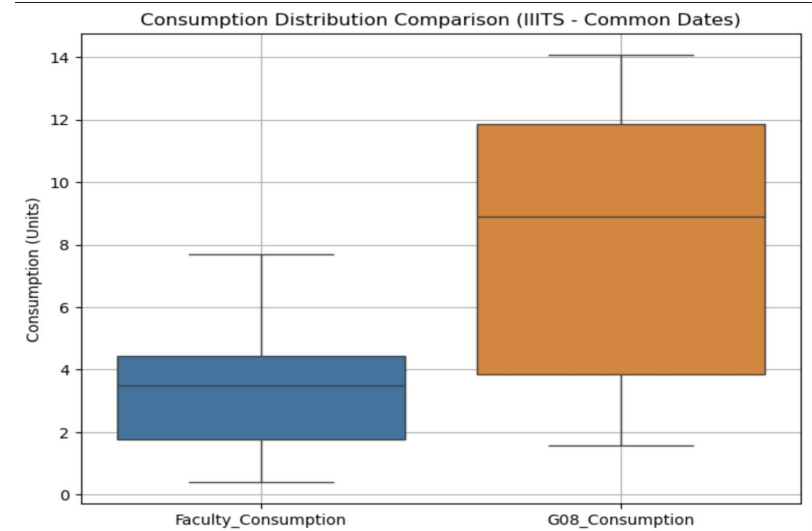
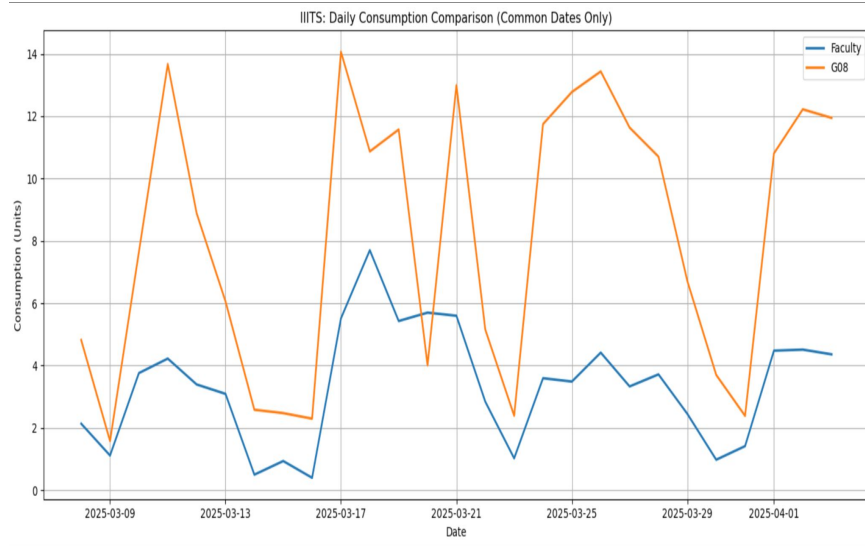
	Date	Daily_Energy_Consumption
count	40	40.000000
mean	2025-03-27 12:00:00	126.252550
min	2025-03-08 00:00:00	39.190000
25%	2025-03-17 18:00:00	102.660250
50%	2025-03-27 12:00:00	136.147500
75%	2025-04-06 06:00:00	153.510000
max	2025-04-16 00:00:00	223.165000
std	NaN	42.920159

Ground Station:

	Date	Daily_Energy_Consumption
count	40	40.000000
mean	2025-03-27 12:00:00	219.206475
min	2025-03-08 00:00:00	75.426000
25%	2025-03-17 18:00:00	171.833500
50%	2025-03-27 12:00:00	237.718500
75%	2025-04-06 06:00:00	269.594000
max	2025-04-16 00:00:00	476.295000
std	NaN	82.971121

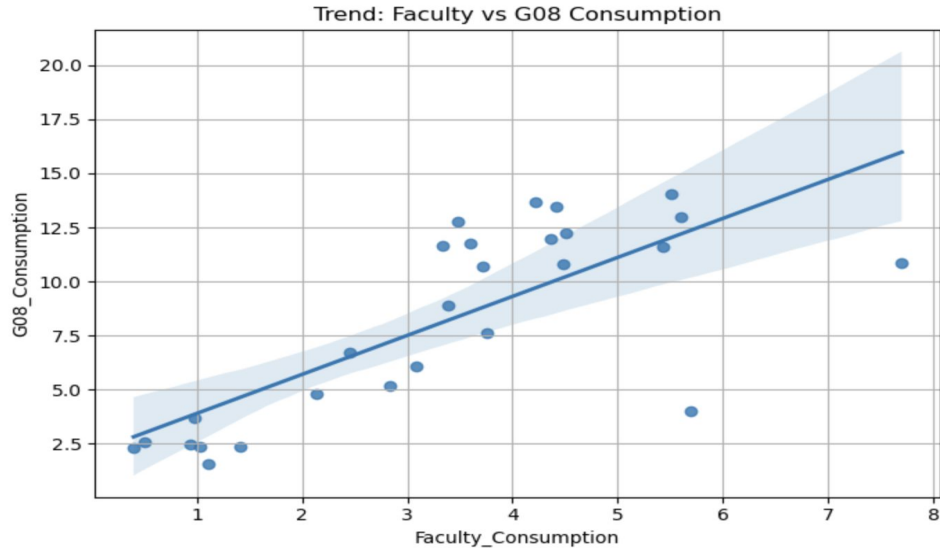
2.2 Data Analysis

IIITS FACULTY WING AND G08 DAILY ENERGY CONSUMPTION



2.2 Data Analysis

Correlation between Faculty and G08 consumption: 0.763



--- DESCRIPTIVE STATISTICS (Common Dates Only) ---

Faculty Consumption (Common Dates):

count	27.000000
mean	3.336111
std	1.855421
min	0.398000
25%	1.774000
50%	3.486000
75%	4.446500
max	7.701000

Name: Faculty_Consumption, dtype: float64

G08 Consumption (Common Dates):

count	27.00000
mean	8.11663
std	4.37884
min	1.57800
25%	3.85450
50%	8.88700
75%	11.84750
max	14.06800

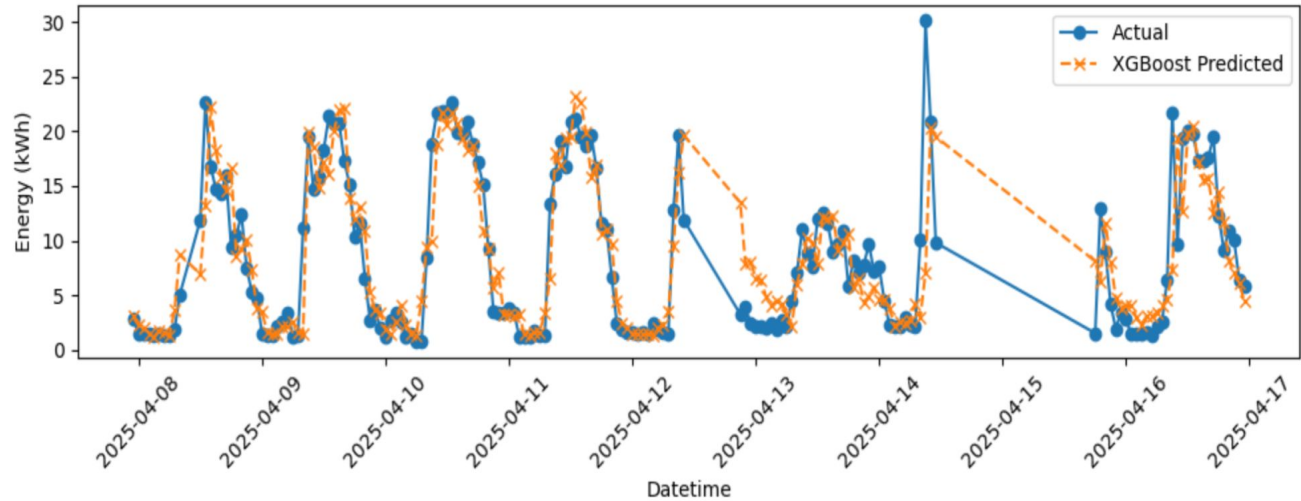
Name: G08_Consumption, dtype: float64

2.3 XGBoost Model

XGBoost Regression Evaluation Metrics:

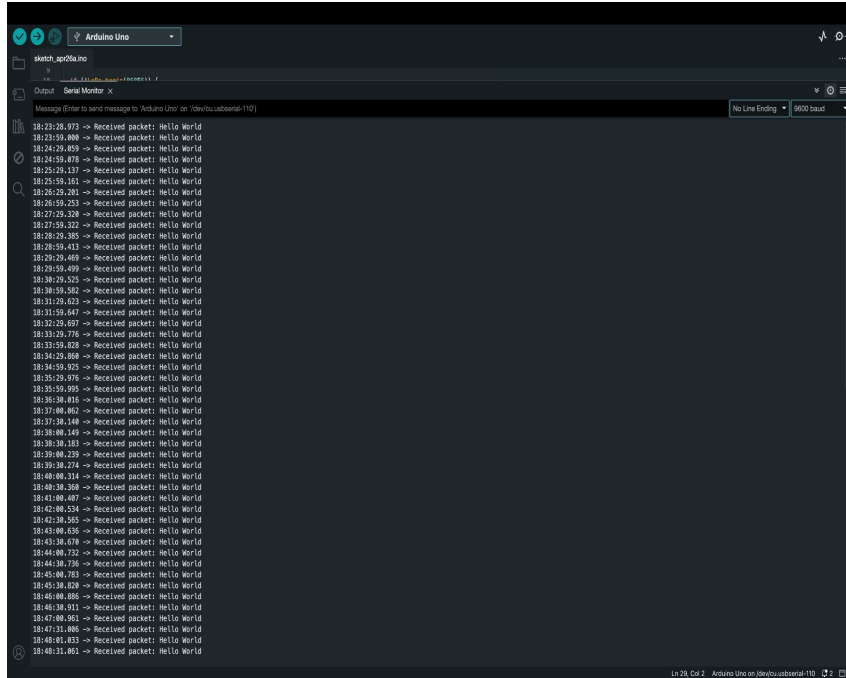
R² Score : 0.7307
MAE : 2.37 kWh
MSE : 13.94 (kWh)²
RMSE : 3.73 kWh

XGBoost - Actual vs Predicted Energy (kWh)
R² = 0.7307, RMSE = 3.73 kWh



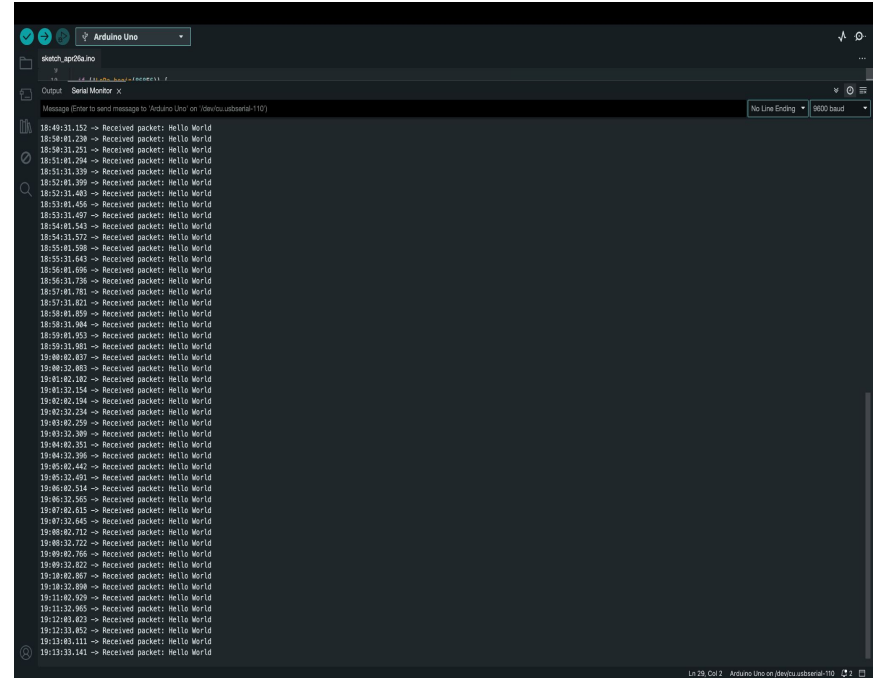
Date	Hour	Energy (in kWh)
2025-03-08	0	2.10500000000047
2025-03-08	1	2.125
2025-03-08	2	2.13599999999951
2025-03-08	3	2.12799999999997
2025-03-08	4	2.125
2025-03-08	5	1.735000000000058
2025-03-08	6	1.39599999999973
2025-03-08	7	1.326000000000002
2025-03-08	8	3.64899999999943
2025-03-08	9	5.287000000000026
2025-03-08	10	7.103000000000007
2025-03-08	11	7.19899999999961
2025-03-08	12	6.99700000000003
2025-03-08	13	6.439000000000031
2025-03-08	14	6.746000000000001
2025-03-08	15	6.610999999999988
2025-03-08	16	5.569999999999971
2025-03-08	17	5.399999999999964
2025-03-08	18	5.159000000000056
2025-03-08	19	4.557999999999999
2025-03-08	20	1.445000000000062
2025-03-08	21	3.310999999999969
2025-03-08	22	2.475999999999966
2025-03-08	23	2.037999999999956
2025-03-09	0	1.957999999999963

3.Lora Range Test



```
sketch_ap00a.ino
Output Serial Monitor X
Message (Enter to send message to Arduino Uno on /dev/ttyUSB0-110)
No Line Ending 9600 baud

18:23:28.973 -> Received packet: Hello World
18:23:59.808 -> Received packet: Hello World
18:24:29.859 -> Received packet: Hello World
18:24:59.878 -> Received packet: Hello World
18:25:29.137 -> Received packet: Hello World
18:25:59.161 -> Received packet: Hello World
18:26:29.201 -> Received packet: Hello World
18:26:59.253 -> Received packet: Hello World
18:27:29.328 -> Received packet: Hello World
18:27:59.322 -> Received packet: Hello World
18:28:29.395 -> Received packet: Hello World
18:28:59.413 -> Received packet: Hello World
18:29:29.469 -> Received packet: Hello World
18:29:59.499 -> Received packet: Hello World
18:30:29.525 -> Received packet: Hello World
18:30:59.582 -> Received packet: Hello World
18:31:29.632 -> Received packet: Hello World
18:31:59.647 -> Received packet: Hello World
18:32:29.697 -> Received packet: Hello World
18:32:59.778 -> Received packet: Hello World
18:33:29.828 -> Received packet: Hello World
18:34:29.868 -> Received packet: Hello World
18:34:59.925 -> Received packet: Hello World
18:35:29.978 -> Received packet: Hello World
18:35:59.995 -> Received packet: Hello World
18:36:29.918 -> Received packet: Hello World
18:37:00.862 -> Received packet: Hello World
18:37:30.140 -> Received packet: Hello World
18:38:00.149 -> Received packet: Hello World
18:38:30.181 -> Received packet: Hello World
18:39:00.239 -> Received packet: Hello World
18:39:30.274 -> Received packet: Hello World
18:40:00.214 -> Received packet: Hello World
18:40:30.368 -> Received packet: Hello World
18:41:00.407 -> Received packet: Hello World
18:42:00.534 -> Received packet: Hello World
18:42:30.565 -> Received packet: Hello World
18:43:00.636 -> Received packet: Hello World
18:43:30.678 -> Received packet: Hello World
18:44:00.732 -> Received packet: Hello World
18:44:30.736 -> Received packet: Hello World
18:45:00.783 -> Received packet: Hello World
18:45:30.828 -> Received packet: Hello World
18:46:00.886 -> Received packet: Hello World
18:46:30.931 -> Received packet: Hello World
18:47:00.961 -> Received packet: Hello World
18:47:31.006 -> Received packet: Hello World
18:48:01.033 -> Received packet: Hello World
18:48:31.061 -> Received packet: Hello World
```



```
sketch_ap00a.ino
Output Serial Monitor X
Message (Enter to send message to Arduino Uno on /dev/ttyUSB0-110)
No Line Ending 9600 baud

18:49:31.152 -> Received packet: Hello World
18:50:01.238 -> Received packet: Hello World
18:50:31.251 -> Received packet: Hello World
18:51:01.274 -> Received packet: Hello World
18:51:31.139 -> Received packet: Hello World
18:52:01.399 -> Received packet: Hello World
18:52:31.483 -> Received packet: Hello World
18:53:01.456 -> Received packet: Hello World
18:53:31.497 -> Received packet: Hello World
18:54:01.543 -> Received packet: Hello World
18:54:31.572 -> Received packet: Hello World
18:55:01.598 -> Received packet: Hello World
18:55:31.643 -> Received packet: Hello World
18:56:01.696 -> Received packet: Hello World
18:56:31.736 -> Received packet: Hello World
18:57:01.781 -> Received packet: Hello World
18:57:31.821 -> Received packet: Hello World
18:58:01.859 -> Received packet: Hello World
18:58:31.904 -> Received packet: Hello World
18:59:01.953 -> Received packet: Hello World
18:59:31.981 -> Received packet: Hello World
19:00:02.037 -> Received packet: Hello World
19:00:32.083 -> Received packet: Hello World
19:01:02.182 -> Received packet: Hello World
19:01:32.154 -> Received packet: Hello World
19:02:02.194 -> Received packet: Hello World
19:02:32.234 -> Received packet: Hello World
19:03:02.259 -> Received packet: Hello World
19:03:32.389 -> Received packet: Hello World
19:04:02.351 -> Received packet: Hello World
19:04:32.396 -> Received packet: Hello World
19:05:02.442 -> Received packet: Hello World
19:05:32.491 -> Received packet: Hello World
19:06:02.514 -> Received packet: Hello World
19:06:32.565 -> Received packet: Hello World
19:07:02.615 -> Received packet: Hello World
19:07:32.645 -> Received packet: Hello World
19:08:02.712 -> Received packet: Hello World
19:08:32.722 -> Received packet: Hello World
19:09:02.766 -> Received packet: Hello World
19:09:32.822 -> Received packet: Hello World
19:10:02.887 -> Received packet: Hello World
19:10:32.898 -> Received packet: Hello World
19:11:02.929 -> Received packet: Hello World
19:11:32.965 -> Received packet: Hello World
19:12:02.913 -> Received packet: Hello World
19:12:32.952 -> Received packet: Hello World
19:13:03.111 -> Received packet: Hello World
19:13:33.141 -> Received packet: Hello World
```


3.Lora Range Test

LoRa Range Test -C Block, A Block and Station-S

Data Interval:30 sec

Location:

- 1.Water Sump-From 6:25 to 6:27
- 2.DB Panel Room-From 6:28 to 6:31
- 3.A1 Energy Meter-From 6.33 to 6:40
- 4.Station-S(In/Out)-From 6:46 to 6:57
- 5.Return From Station-S to Campus-From 6:57 to 7:12

Inference:

- 1.NO data packet is lost
- 2.NO Bit Reversal
- 2.Data Comes seamlessly every 30 sec



4. Future works

1. Develop a **custom hardware solution** for improved efficiency, scalability, and cost-effectiveness.
2. Deploy a **complete IoT framework** with real-time analytics and an advanced dashboard for energy management.





THANK YOU