EECE 693 - Energy Demand Forecasting

Shafik Houeidi, Ounsi Kanaan, Hassan Miskawi
Electrical and Computer Engineering, American University of Beirut

Problem Statement

Forecasting household energy demand is critical for grid stability, resource allocation, and sustainable planning. Modern consumption data exhibit non-linear patterns, multiple seasonalities, and long-range dependencies due to renewable integration and electric vehicle adoption, challenging traditional forecasting methods.

Performance Comparison (Test Set)

Lower values are better.

Model	RMSE (kW)	MAE (kW)
ARIMA	0.750	0.620
Single-Layer LSTM	0.577	–
Bi-LSTM + Attn (24h)	0.520	0.380
Stacked LSTM (12h)	0.540	0.370
Transformer (Standard)	0.811	0.581
Hybrid LSTM–Transf.	0.0093	0.0058

Dataset & Features

- **Source:** IHEPC dataset (UCI ML Repo)
- **Target:** Global Active Power (kW).
- **Exogenous:** Temp, Humidity, Holiday (France).
- **Features:** Lags (1h, 24h, 168h), Calendar (hour, day, month).

Model Architectures

Baselines & LSTMs:

- ARIMA(0,1,3): Classical baseline.
- Single-layer LSTM (1h look-back).
- Stacked Bi-LSTM + Attention (24h look-back).
- Stacked LSTM (12h look-back).

Standard Transformer:

- Encoder-decoder (MH=4, $d_{model} = 64$, L=3).

Evaluation Metrics

Key metrics quantify prediction error (kW):

- **RMSE:** Penalizes larger errors. $\sqrt{\frac{1}{N}\sum(\hat{y}_i - y_i)^2}$
- **MAE:** Average absolute difference. $\frac{1}{N}\sum|\hat{y}_i - y_i|$

Conclusion

The proposed **Hybrid LSTM–Transformer** model effectively combines architecture strengths:

- Achieved lowest error (**RMSE** 0.0093 kW, **MAE** 0.0058 kW).
- Outperformed standalone LSTMs and standard Transformer.
- Captured local (LSTM) global (Transformer) dependencies.
- Promising for complex time series forecasting.

Proposed Hybrid LSTM–Transformer Architecture

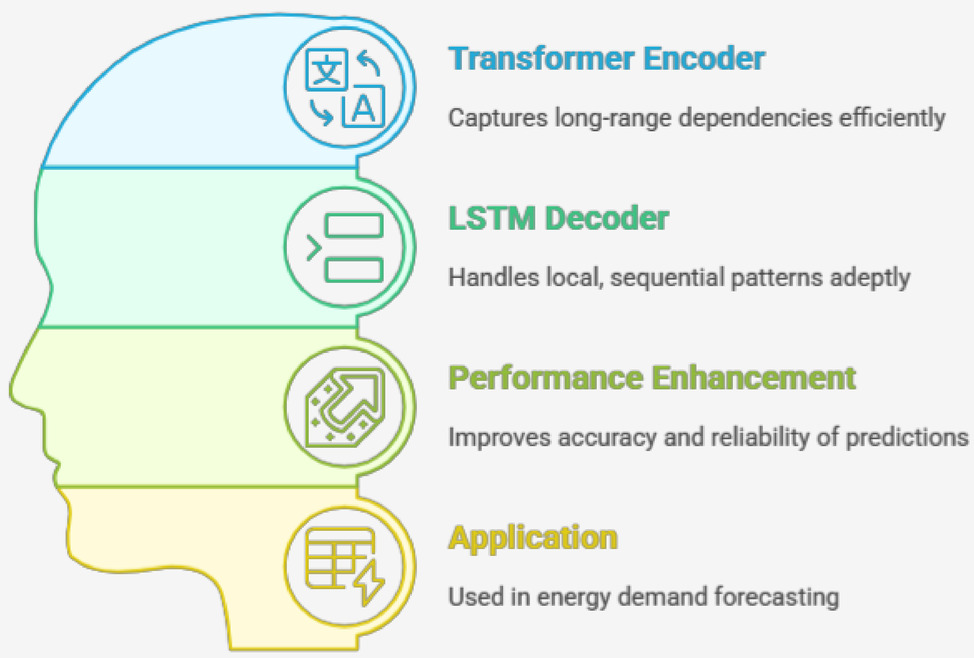

Figure 1: Hybrid model: parallel LSTM (local patterns) Transformer (global dependencies) branches fused for final forecast.

Prediction Samples

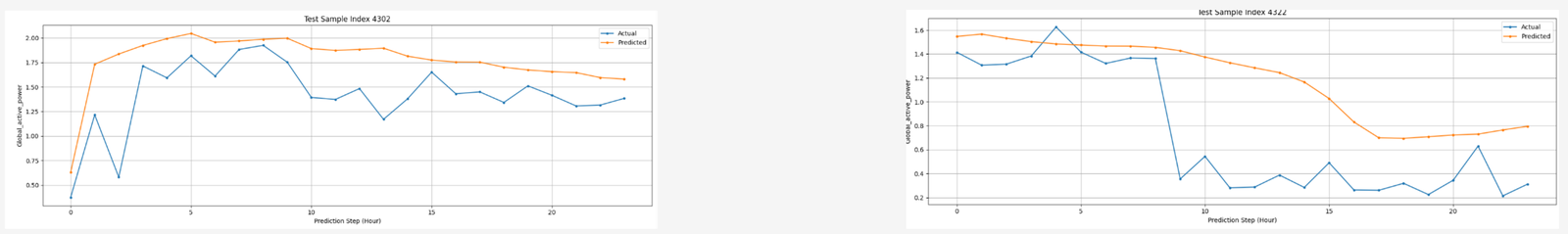

Figure 2: Actual vs. Predicted energy demand for two sample periods (Transformer model).

Full Series Comparison

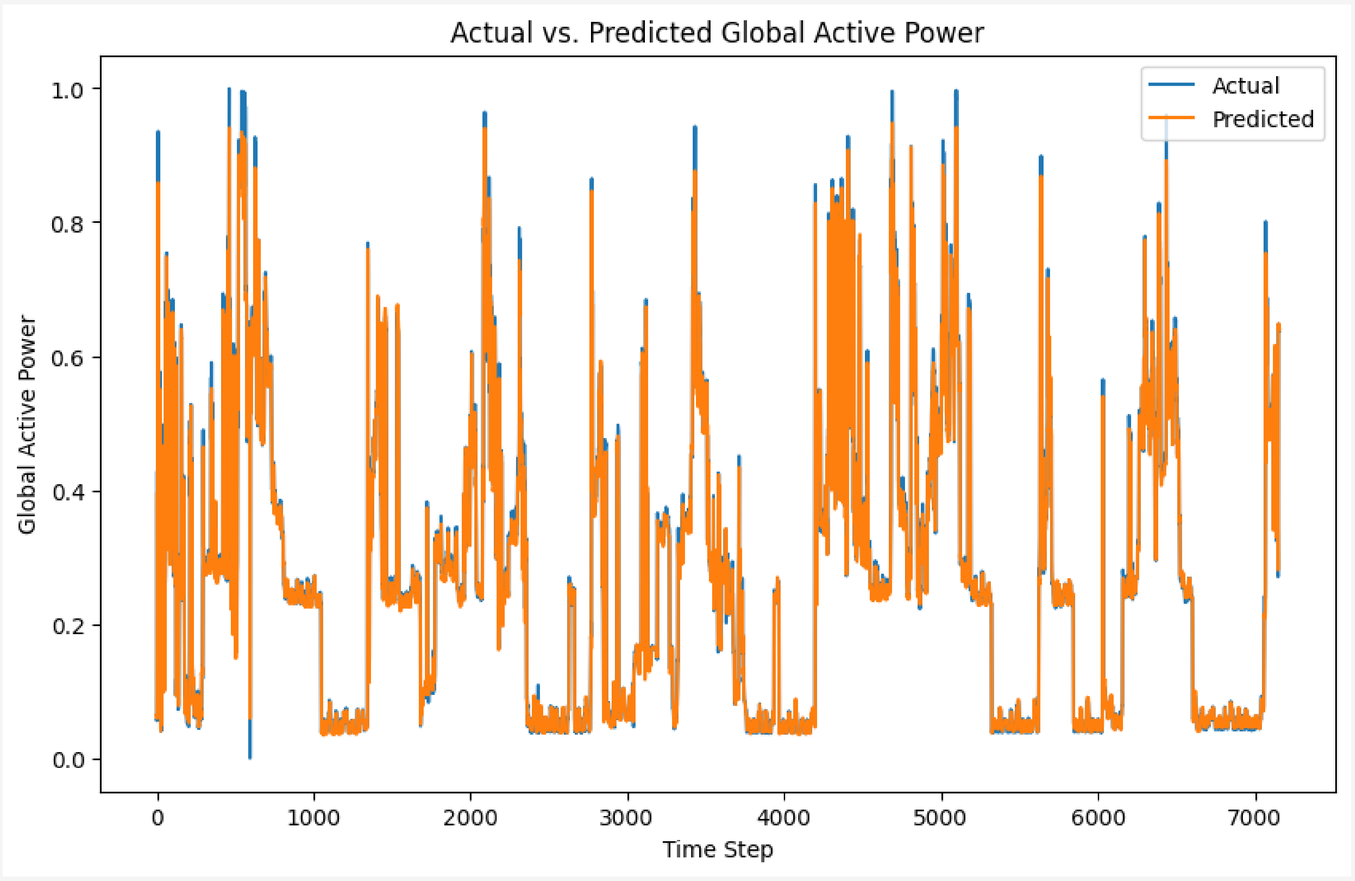

Figure 3: Hybrid model prediction across the entire test period.