THE GREAT BRITAIN ELECTRICITY MARKET

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Final Submission Report

Analysis of Intraday Price Trends in the Electricity Market of Great Britain

Problem Statement

The problem focuses on analyzing intraday price trends in the electricity market of Great Britain (GB), which operates under a liberalized and competitive structure.

Data Analysis

- **Key observations include:** Weekends (Saturday and Sunday) have significantly lower prices, with Sunday having the lowest average price (£69). The electricity market experiences two daily price peaks: one in the morning (8-9 AM) and another more pronounced peak in the evening (4-6 PM). (Fun fact- In a strategy where a trade is made between 3am and 5pm, the returns came out to be 18 percent)
- **Price vs Wind Generation Over Time:** Wind generation is highly volatile, while prices remain relatively stable. Price stability is influenced by adequate wind generation. Price and wind generation has negative correlation, meaning that as wind generation goes up price comes down and vice versa.
- **Price vs Solar Generation Over Time:** Solar generation shows sharp, regular peaks, but prices remain stable.
- **Demand-Supply Imbalance Over Time:** Persistent negative imbalance suggests that demand exceeds supply, potentially driving price surges.
- **Price vs Volume:** Prices increase with higher market volumes but show significant outliers.
- **Rolling Price Volatility:** Volatility spikes periodically, indicating market instability linked to renewable energy fluctuations or other market events.
- **Price Spikes Over Time:** Significant price spikes occur, sometimes reaching extreme levels due to sudden supply-demand imbalances or critical events.

Regime Identification

- **Analysis of Hidden Markov Model (HMM):** The Hidden Markov Model (HMM) was used to classify price fluctuations into distinct market regimes. HMM successfully identified multiple regimes where each regime was associated with specific price behaviors. The model clearly separated periods of high volatility (purple regime) and low volatility (yellow regime), providing a meaningful representation of market conditions over time.
- **Testing with K-means:** K-means was initially tested for regime classification, but it performed poorly due to the non-spherical nature of the data. The K-means algorithm struggled with identifying regimes in data with varying densities, leading to suboptimal clustering.
- **Comparison of HMM and GMM:** Both HMM and GMM identified regimes, but HMM was better suited for capturing time-dependent transitions between market states, while GMM lacked the ability to model these transitions effectively.
- **Why HMM is Preferred:** HMM outperforms GMM because it captures the sequential nature of market data, making it more effective for forecasting price behavior over time.

Plots

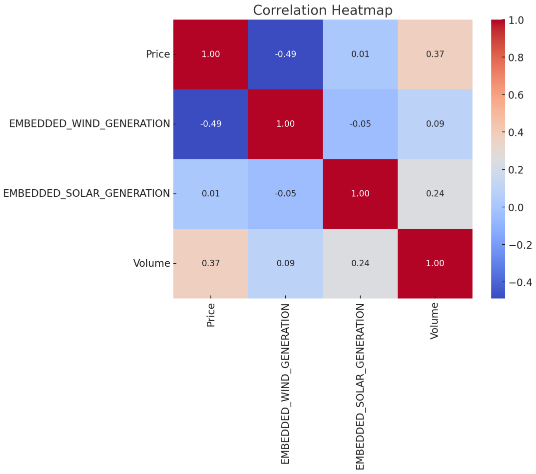

Figure 1: Correlation Heatmap

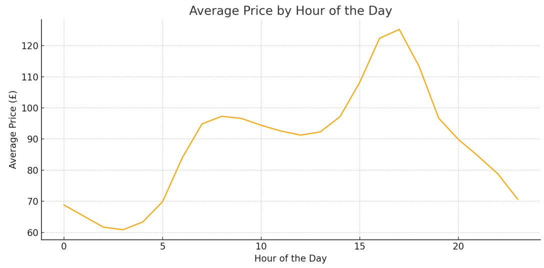

Figure 2: Average Price by Hour of the Day

Trading Strategy Setup and Logic

Initial Setup

- **Initial Capital:** £10,000
- **Position Size:** 2% of current capital, adjusted by the 24-hour Average True Range (ATR_24).
- **Risk Management:** Stop-loss set at 1.5 times ATR_24 and take-profit set at 2 times ATR_24.
- **Indicators Used:**
  - RSI_6 for overbought/oversold conditions.
  - MACD for trend confirmation.
  - Predicted Price from LSTM model for price forecasting.
  - SMA_24 for trend confirmation.

LSTM Model

In our project, Long Short-Term Memory (LSTM) is used to predict intraday electricity prices based on historical price data and various influencing factors such as wind and solar energy production. LSTM is a specialized form of Recurrent Neural Network (RNN) designed to capture long-term dependencies in sequential data, making it ideal for time-series forecasting like electricity price prediction.

LSTM consists of memory cells that maintain and update the cell state over time. The key features of an LSTM cell include:

- Forget Gate: Decides which information from the previous time step should be discarded.
- Input Gate: Determines which new information should be added to the memory.
- Output Gate: Controls the output based on the updated memory.

The formulas for the LSTM gates are as follows:

$$f_t = \sigma(W_f \cdot [h_{t-1}, x_t] + b_f)$$
$$i_t = \sigma(W_i \cdot [h_{t-1}, x_t] + b_i)$$
$$\hat{C}_t = \tanh(W_C \cdot [h_{t-1}, x_t] + b_C)$$

$$C_t = f_t * C_{t-1} + i_t * \hat{C}_t$$
$$o_t = \sigma(W_o \cdot [h_{t-1}, x_t] + b_o)$$
$$h_t = o_t * \tanh(C_t)$$

Where: - f_t is the forget gate, - i_t is the input gate, - $\hat{C}_t$ is the candidate cell state, - C_t is the cell state, - o_t is the output gate, - h_t is the output of the LSTM unit.

These gates allow the model to learn dependencies over time and make predictions based on past market behaviors. LSTM is well-suited for time-series data such as electricity prices, where future prices depend on complex patterns in past data.

Below is the visual representation of the LSTM model's price prediction.

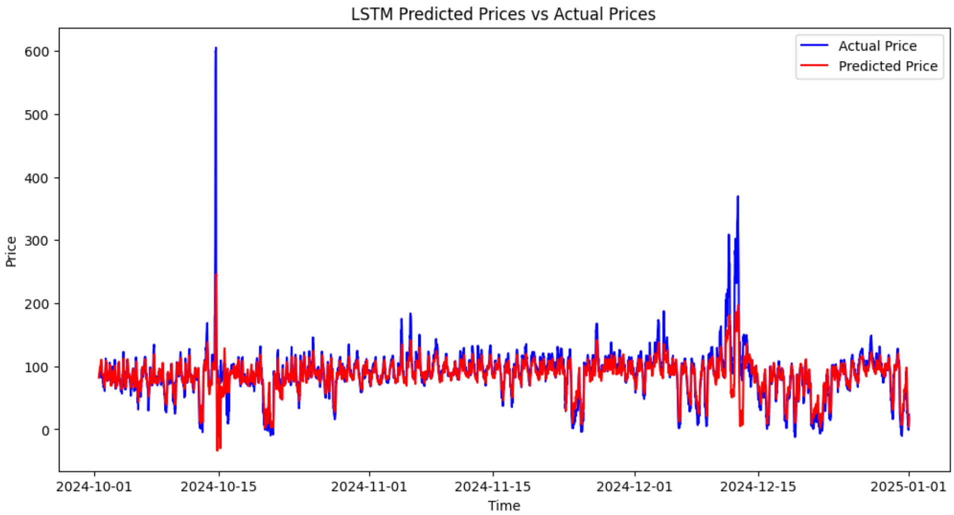

Figure 3: LSTM Model for Price Prediction

By leveraging the LSTM model, the strategy predicts intraday price trends and informs optimal trading decisions, improving the profitability of renewable energy trading strategies.

Strategy Logic

Buy Signal: Generated when:

- Predicted Price exceeds the SMA_24.
- RSI_6 is below the buy threshold (30), signaling oversold conditions.
- MACD is greater than the Signal Line, confirming upward momentum.

Sell Signal: Generated when:

- Predicted Price is below the SMA_24.
- RSI_6 is above the sell threshold (70), signaling overbought conditions.
- MACD is below the Signal Line, confirming downward momentum.

Stop-Loss and Take-Profit

- Stop-loss is set at 1.5 times ATR_24 below (for long) or above (for short) the entry price.
- Take-profit is set at 2 times ATR_24 above (for long) or below (for short) the entry price.

Position Management

- Trades are executed when a valid signal is generated based on LSTM predictions and technical indicators.
- Positions are closed when either stop-loss or take-profit levels are reached, or at the end of the trading day.

Conclusion

The strategy effectively leverages the LSTM model in combination with SMA, RSI, MACD, and ATR for risk management. While refinements are needed to handle extreme price fluctuations, the strategy provides a solid foundation for automated trading, showing mixed results depending on market conditions.

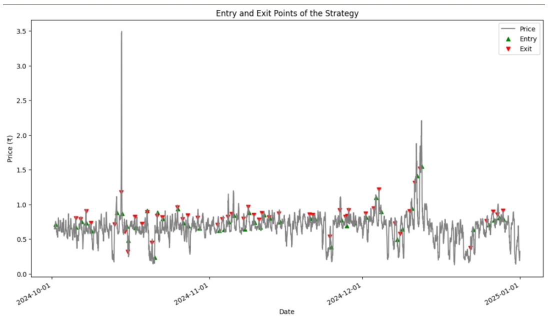

Figure 4: Graph Title

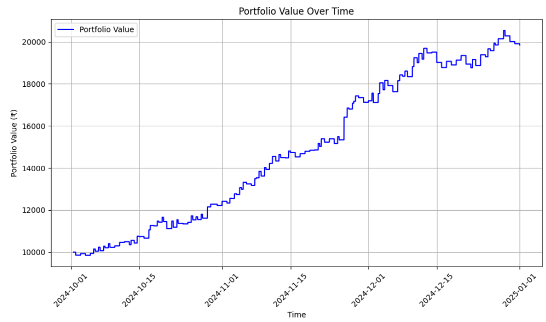

Figure 5: Portfolio Performance

Total Profit/Loss: £ 9849.75 **Final Capital:** £ 19849.75
Strategy Return: 98.50%

Rationale Behind the Combination of Indicators

This strategy integrates multiple trend and volatility indicators to confirm market trends, manage risks, and optimize trade entries and exits in the GB electricity market.

- **PPCMA:** Captures daily price trends by comparing the current price to the previous day's price. It helps identify uptrends or downtrends based on price movement.

$$PPCMA_t = \frac{P_t}{P_{t-1}}$$

- **MAD:** Measures the deviation from PPCMA to assess trend strength. It helps set stop-loss and take-profit levels based on trend strength.

$$MAD_t = \frac{1}{N}\sum_{i=1}^{N} |P_t - PPCMA_t|$$

- **PR:** Oscillates between 0-100 to identify overbought/oversold conditions. It confirms buying or selling opportunities based on price proximity to highs/lows.

$$PR_t = \frac{P_t - \min(P_t)}{\max(P_t) - \min(P_t)} \times 100$$

- **RSI:** Measures momentum to identify overbought/oversold conditions, confirming entry points for buying or selling.

$$RSI_t = 100 - \frac{100}{1 + RS_t}$$

  where $RS_t = \frac{\text{Average Gain}}{\text{Average Loss}}$

- **ADX:** Measures trend strength and confirms if the trend is strong enough to continue.

$$ADX_t = \frac{\sum_{i=1}^{N} |+DI_t - -DI_t|}{N}$$

- **MACD:** Analyzes moving averages to detect trend shifts, identifying buy/sell signals based on momentum changes.

$$MACD_t = \text{EMA}_{12} - \text{EMA}_{26}$$

- **PMOM (Price Momentum):** Compares the current price with the previous trading price to measure market momentum. Positive PMOM indicates upward momentum, while negative PMOM indicates downward momentum.

$$PMOM_t = P_t - P_{t-1}$$

Risk Management Techniques

The strategy implements the following risk management measures:

- **Stop-Loss and Take-Profit:** ATR-Based Exit: Stop-loss is set at 1.5 times ATR and take-profit at 2 times ATR for both long and short positions. This allows the strategy to adapt to market volatility.

- **Position Size:** Risk per Trade: 2% of capital is risked per trade, with position size adjusted based on the 24-hour ATR to account for volatility. This ensures that risk is consistently managed according to market conditions.

Performance Metrics

The following performance metrics provide insight into the strategy's effectiveness and overall performance:

- **Sharpe Ratio:** 0.13
  The Sharpe ratio measures the risk-adjusted return of the strategy. A ratio above 1 typically indicates good risk-adjusted performance.

- **Max Drawdown:** -14.87%
  The maximum peak-to-trough decline in portfolio value during the strategy's trading period, which helps assess the potential risk of large losses.

- **Sortino Ratio:** 0.06
  The Sortino ratio is similar to the Sharpe ratio but only considers downside volatility. It is calculated by dividing the excess return by the downside deviation. A higher Sortino ratio indicates better risk-adjusted returns, focusing on avoiding negative returns.

Sources

The following sources were referenced in the development of this report:

- https://www.neso.energy/data-portal/historic-demand-dataNeso Energy Historic Demand Data

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