Forecasting Ontario Electricity Prices using ARMA

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Abstract

Electricity is an essential for most markets, making accurate and timely forecasting crucial for certain investment, and business decisions. The Independent Electricity System Operator (IESO) provides forecasts for Ontario electricity prices; however, improvements are always sought. In this work, we present exploratory data analysis, the theoretical foundation of ARMA models, and the motivations behind their use in this context. We then compare ARMA model forecasts with those of IESO's. The results demonstrate that our ARMA hour-ahead forecasting model achieves a lower mean absolute error than IESO's, while maintaining a quick construction time, and producing residuals that exhibit characteristics of a white noise process.

Keywords— ARMA models, IESO, electricity

Introduction

Electricity is fundamental to most markets, making accurate price forecasting a key component of decision intelligence. Achieving better predictive power remains a recurring objective in this domain. A paper from 2007 demonstrated the use of ARIMA models for forecasting electricity prices in the Spanish and Californian markets [1]. Inspired by this approach, we aim to apply similar methodologies to the Ontario market to enhance the official forecasts currently provided by the Independent Electricity System Operator (IESO).

ARMA Model

The ARMA model consists of an Auto-Regressive(AR), and a Moving Average(MA) component. The AR models the dependency between previous observations and the current. The MA models the relationship between the current observation and past shocks.

Formally, for a prediction y_t:

- AR(p): $y_t = \sum_{i=1}^{p} \phi_i y_{t-i} + e_t$, where e_t is a White Noise error term
- MA(q): $y_t = \sum_{i=1}^{q} \theta_i e_{t-i} + e_t$
- ARMA(p, q): $y_t = \sum_{i=1}^{p} \phi_i y_{t-p} + \sum_{i=1}^{p} \theta_i e_{t-p} + e_t$

The model assumes stationarity in the time series; uncorrelated residuals, and linearity in the relationship between current and past values, as well as past errors. As the ARIMA model yielded promising results in the Spanish and Californian markets, we suspected the assumptions to be met for the Ontario market. In the Exploratory Data Analysis, we find a particular set of p, and q most applicable to the data.

Exploratory Data Analysis

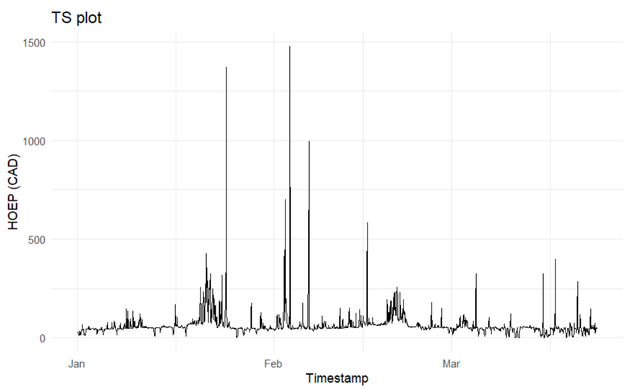
Data

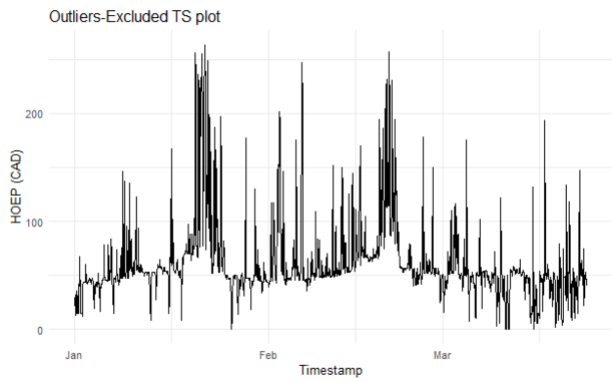
All data is sourced from Independent Electricity System Operator(IESO)[2]. The data consists of the Ontario electricity prices within Jan 1 - Mar 24 of 2025 in MegaWatts/CAD (hourly), as well as IESO's forecasts from 1 to 3 hours ahead.

Filtering & Observations

Graphically, we observe extremely large outliers that are potentially corrupting the first four moments. We use this as justification to remove outliers. We define to be points 3 standard deviations away from the mean which amounted to 23 out of 1968 points(roughly 1% of the data).

Moment	Value
Mean	64.21120
Variance	4520.94348
Skewness	11.33327
Kurtosis	59.349203
Filtered Mean	64.21120
Filtered Variance	1214.547370
Filtered Skewness	2.669774
Filtered Kurtosis	9.637853





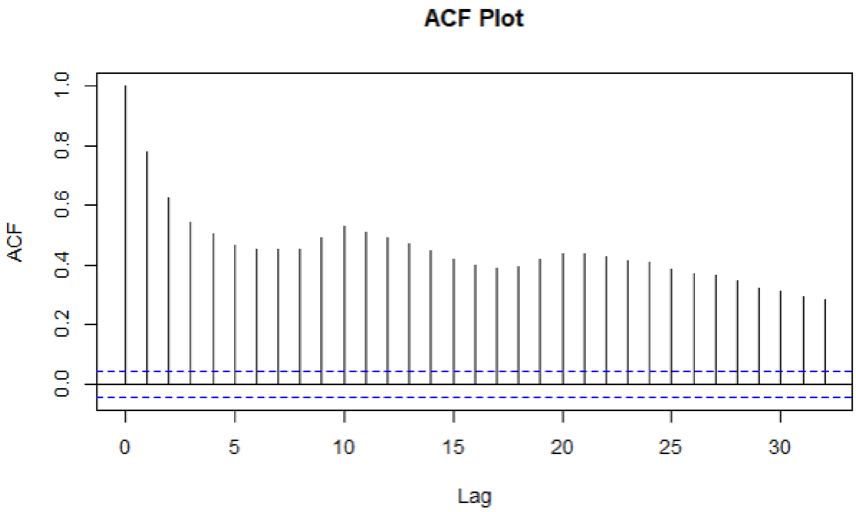
After excluding outliers, we observe a more informative set of moments, and time series plot. We observe that the data is heavily right-skewed; extreme values are likely to occur with a such a large kurtosis of > 9, and a large variance implies very large spikes in the price. Graphically, the time series plot confirms these statistics.

Testing Assumptions

We apply both an Augmented Dickey-Fuller(ADF) test, and plot the autocorrelation function(ACF) for approximately 30 lags to test for stationarity, autocorrelation, and possible persistent shocks. The ADF test yielded a p-value of 0.01, below the conventional 0.05 threshold, allowing us to reject the null hypothesis of non-stationarity and confirm stationarity. The ACF plot suggests a consistent positive autocorrelation above 0.2 across all 30 lags. Moreover, the ACF plot exhibits fluctuations, such as a decrease between lags 1 to 5, followed by an increase from lags 5 to 10. This suggests there may be persistent shocks across the data. These findings provide strong evidence to justify use of an ARMA.

```
        Augmented Dickey-Fuller Test

data:  filtered$HOEP
Dickey-Fuller = -4.9935, Lag order = 12, p-value = 0.01
alternative hypothesis: stationary
```



Fitting ARMA

The decision of p, and q is based on a brute force approach of various p, q values and choosing the best performing set according to the AIC, AICc or BIC value. The function in R we used, `auto.arima`, automates this procedure. The resulting model was an ARMA(3,5) as presented below:

$$y_t = 58.8331 + 0.5081 y_{t-1} - 0.4048 y_{t-2} + 0.8604 y_{t-3} + \epsilon_t + 0.172\epsilon_{t-1} + 0.4486\epsilon_{t-2} - 0.5638\epsilon_{t-3} - 0.3415\epsilon_{t-4} - 0.2054\epsilon_{t-5}.$$

```
Series: ts_filtered
ARIMA(3,0,5) with non-zero mean

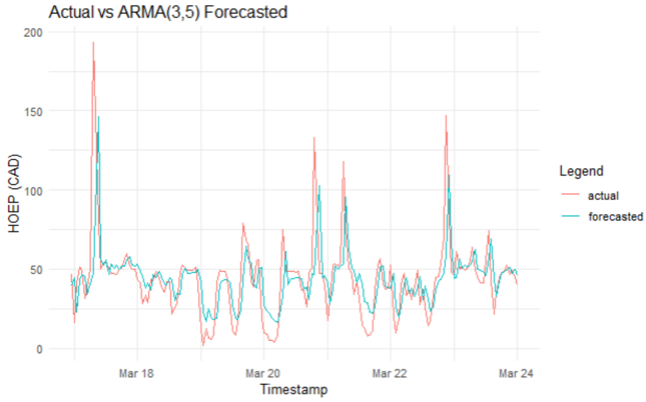
Coefficients:
         ar1      ar2     ar3    ma1     ma2      ma3      ma4      ma5     mean
      0.5081  -0.4048  0.8604  0.172  0.4486  -0.5638  -0.3415  -0.2054  58.8331
s.e.  0.0558   0.0850  0.1047  0.059  0.0936   0.0563   0.0426   0.0226   6.4964

sigma^2 = 441.2:  log likelihood = -8673.72
AIC=17367.45   AICc=17367.56   BIC=17423.17
```

ARMA vs IESO

We use the Mean Absolute Error(MAE), and Root Mean Squared Error(RMSE) statistics to compare the ARMA model with the IESO 1-hour ahead forecasts for all electricity prices within Mar . We use a sliding window technique for training, and testing: i.e fitting the ARMA on the first $1945 - i$ data points, and forecasting the $(1945 - i + 1)^{th}$ value for $i = 1, .., 7 \cdot 24$.

Graphically, we observe a fairly strong structural fit in the ARMA, but occasional overestimations done by IESO 3-step. Furthermore, the ARMA achieves a slightly lower MAE than all of IESO's forecasts. The ARMA does have a greater RMSE than the IESO 3-step.



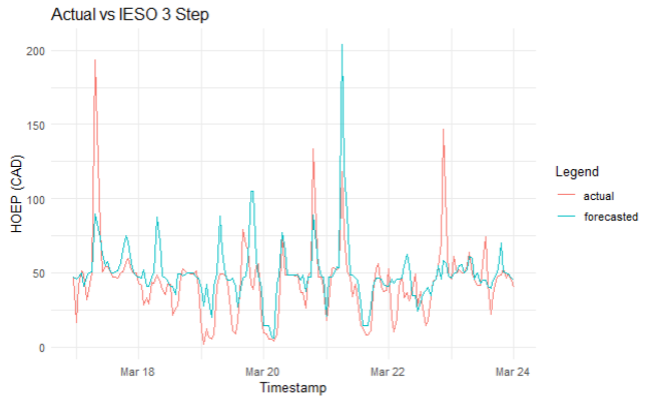


Table 1: IESO Predictions vs ARMA(3,5)

Model	MAE	RMSE
IESO 1	16.47065	33.26514
IESO 2	14.75583	25.67910
IESO 3	12.53815	20.55756
ARMA	12.19296	20.87337

White Noise Characteristics in Residuals

We perform a Box-Ljung test to evaluate whether autocorrelation remains in the ARMA residuals. The resulting p-value exceeds 0.05, indicating no significant autocorrelation. Furthermore, the ADF test produces a p-value of 0.01, confirming that the residuals are stationary. Based on these results, we conclude that the residuals exhibit characteristics of white noise, suggesting the ARMA model provides a strong fit.

```
        Box-Ljung test

data:  results$Residuals
X-squared = 22.426, df = 25, p-value = 0.611
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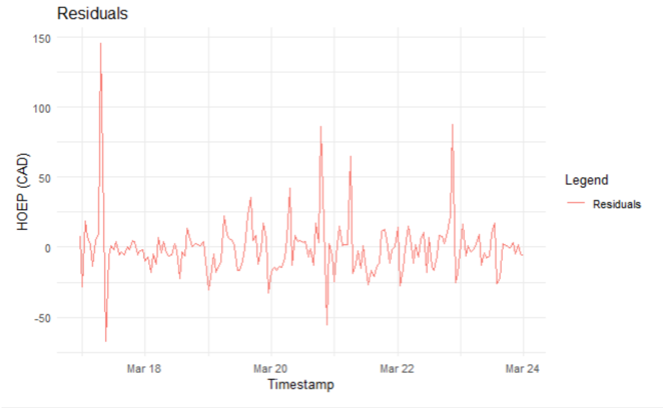

Conclusion

The findings of this paper demonstrate that ARMA models perform well in forecasting electricity prices in Ontario. The specific model, ARMA(3,5), was observed to achieve a slightly lower Mean Absolute Error (MAE) compared to the official forecasts provided by IESO. Furthermore, the residuals were found to exhibit characteristics of white noise, supporting the validity of the model. Future work could focus on analyzing the removed outliers and investigating potential external variables that may have influenced them.

References

[1] Li, G., Liu, C., Mattson, C., Lawarree, J. (2007). *Day-ahead electricity price forecasting in a grid environment.* IEEE Transactions on Power Systems, 22(1), 266-274.

[2] Independent Electricity System Operator. (2025). *Yearly Hourly HOEP OR Predispatch Reports.* Retrieved April 6, 2025, from reports-public.ieso.ca/public/PriceHOEPPredispOR/