Accuracy of Wind and Load Forecasts

April 2021–March 2022

Information paper

17 October 2022

Version control

Version	Date amended	Comments
1	12 July 2022	First draft
2	22 July 2022	Peer reviewed
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4	19 September 2022	Included SO feedback

Executive summary

A factor contributing to the 9 August 2021 grid emergency was the inaccuracy and unreliability of wind generation and demand forecasts. This increases risk for the operators of slow-start thermal generation plant (such as the Huntly Rankine units, and the Huntly and Stratford combined cycle units), who must assess the likelihood of being dispatched at a sufficient level, duration and price to recover their costs, and hence justify making their plant available to run.

Since it can take these plants 6 to 12 hours to start up from cold and reach full load, they must make these decisions based on forecast schedules well ahead of real-time.

This review investigates the accuracy of wind generation and demand forecasts and bids leading up to real time over the 12-month period from April 2021 through to March 2022.

We find that both wind and demand forecasts (and bids) have significant uncertainty more than a few hours ahead of real-time, significantly increasing risk for slow-start thermal operators, and consequently the power system as a whole. If slow-start thermal operators anticipate their plant is not required, and the forecast generation/demand balance subsequently deteriorates, it may be too late for them to start up, leaving the system short of capacity. This is essentially what happened on 9 August 2021. More accurate wind and demand forecasts out to around 12 hours ahead of real-time would likely have helped.

The increasing penetration of wind and solar generation that is already underway as New Zealand seeks to decrease reliance on fossil fuels will initially make this problem worse. While we expect this to be offset by the eventual retirement of slow-start thermal generation, forecast accuracy may increase in importance for other technologies such as demand response.

Our analysis suggests that reasonably accurate day-ahead wind generation forecasts are possible using techniques such as machine learning. We understand two NZ windfarm operators are now using proprietary wind generation forecasting software, which appears to show significantly better accuracy than most other windfarms. We understand the system operator also trialled this software recently; they found it to be more accurate than a resource persistence model, even within two hours of real-time.

The Authority has initiated a project to review the current intermittent generation offer provisions, which this analysis will support. Consultation is planned for the second half of the 2022/23 financial year.

The system operator began using a new TESLA load forecasting service for conforming load on 3 March 2022. Based on 5 ½ months experience the new tool has narrowed the spread of forecast error by 35 to 45 percent. While conforming load now has only about half the percentage error as non-conforming load, it still contributes more of the overall load forecast error. The Authority will continue to monitor the accuracy of the new load forecasting service.

For purchasers at several non-conforming GXPs there may be room for improvement in complying with rebidding requirements. The Authority's compliance team and the system operator have been working with purchasers to improve compliance, and this has resulted in significant improvement in recent months.

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1.2 We investigated the accuracy of wind generation forecasts leading up to real-time over the 12-month period from April 2021 to March 2022. We chose a 12-month period in order to cover any seasonal variations.

1.3 We investigated demand forecast accuracy over a longer period in order to assess the impact of the new TESLA load forecast tool, which the system operator began using on 3 March 2022.

1.4 We looked at windfarm accuracy both individually and in aggregate.

1.5 We looked at demand accuracy in the following groupings:

(a) in aggregate

(b) conforming and non-conforming subtotals

(c) non-conforming load at individual GXPs

2 We compared quantities from the non-responsive schedules with quantities from final pricing schedules

2.1 For each trading period, we compared load and generation quantities from the non-response schedule long (NRSL) and non-response schedule short (NRSS) with the corresponding quantities from the final pricing (FP) schedule.

2.2 Working directly with the generation offers and load bids has several disadvantages:

(a) Bids and offers can occur at any time, and typically occur at different times for different participants and possibly also locations, making aggregation less straightforward.

(b) Load bids can have more than one price tranche and (in the EA data system) tranches are not necessarily populated at each submission time (ie. apply until another submission for that tranche), so need to be rolled forward to fill any gaps.

(c) Furthermore, deemed offers and nominated bids need to be accounted for. The Code provides that until such time as initial offers and nominated bids have been submitted for a trading period, they are deemed to be rolled forward from the corresponding trading period two days earlier.[1]

2.3 Using load and generation from the forecast schedules automatically accounts for these complications.

[1] This is a simplified description. Refer to clause 13.8 and 13.8A of the Code for the precise wording.

2.4 The NRSL and NRSS use the sum of the nominated bid quantities for non-conforming GXPs and the system operator's load forecast for conforming GXPs.

2.5 NRSL results are 2-hourly, while NRSS results are half-hourly but only cover the last four hours before real time. So we interpolated forecast results to half-hour intervals to facilitate aggregation and analysis.

2.6 Final pricing schedules use exact metered GXP load. However, in final pricing, grid-connected Type B co-generation offers are removed and the metered generation is netted off the load, so we added the reconciled generation back on to the GXP load to be consistent with the forecast schedules.

2.7 Wind offers in the final pricing schedules have the forecast of generation potential (FOGP) set to the metered generation and generally clear at this level.

3 Wind forecasts are inaccurate until the last few hours

3.1 Intermittent generators such as wind generators can submit up to five price tranches like most other types of generators, but must include an extra parameter called 'forecast of generation potential' (FOGP). This is a forecast of the electricity they will generate during each trading period and effectively caps their offers at this level.

3.2 Under the current Code provisions, intermittent generators must submit a revised FOGP at least once per half-hour during the last two hours before the start of the trading period. This must be based on a resource persistence model, unless otherwise agreed with the Authority.[2]

3.3 The Code defines "resource persistence model" as a method based "… on the assumption that the variable resource conditions at the time at which the forecast is prepared will persist throughout the trading period to which the forecast relates."[3]

3.4 Despite the flexibility provided in the Code, it appears most wind generators do base their forecasts in the last few hours on a resource persistence model.

Total wind generation

3.5 Figure 1 shows box and whisker plots of the total New Zealand wind generation forecast error in MW at half-hourly intervals leading up to real-time for the 12-month period from April 2021 to March 2022. We have defined forecast error as forecast minus actual.

3.6 Forecast error in percent is shown in Figure 2.

3.7 Each box and whisker represents 17,520 samples (ie. one for each trading period).

3.8 For most of the forecast period, there is a 90% probability that the forecast error will fall within a range from around -125 MW to +145 MW, while outliers extend as far as +/- 400 MW.

3.9 There is no material improvement in forecast accuracy until the last 3 ½ hours, during which time accuracy steadily improves. This appears to correspond to the time when generators begin submitting resource persistence forecasts.[4]

[2] EIPC clause 13.18A(2)

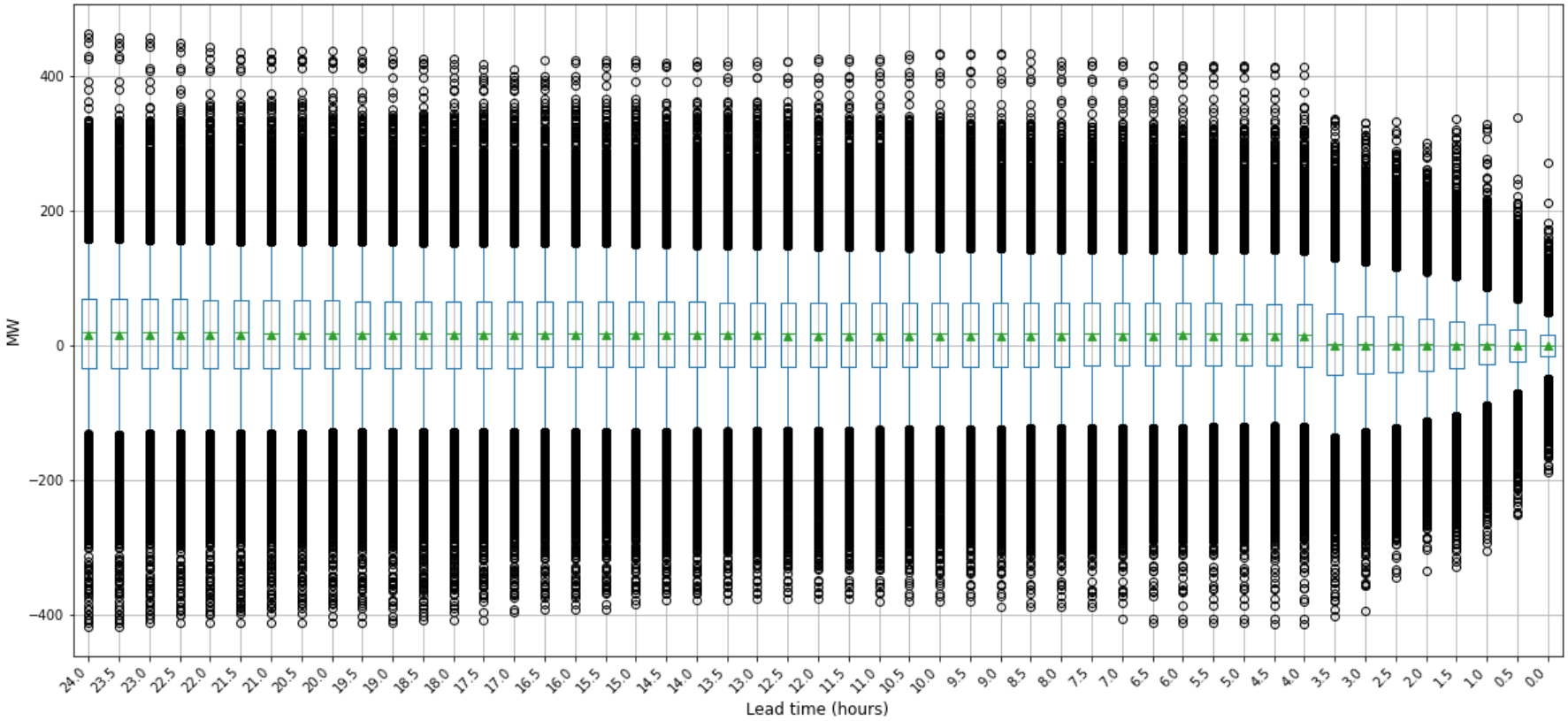
[3] EIPC clause 13.18A(3)

[4] Generators are not required to begin submitting resource persistence forecasts until the last two hours, but analysis implies many begin about fours before real-time.

3.10 While the 90% confidence interval narrows to around +/-50 MW by the start of the trading period, outliers still extend to around +/-200 MW.

3.11 Until the last 3 ½ hours there is a slight positive bias, ie, forecasts tend to exceed actual wind generation on average. This bias will tend to exacerbate security issues (such as occurred on 9 August 2021), as more often than not the wind forecast will be too high. The bias disappears with the persistence forecast.

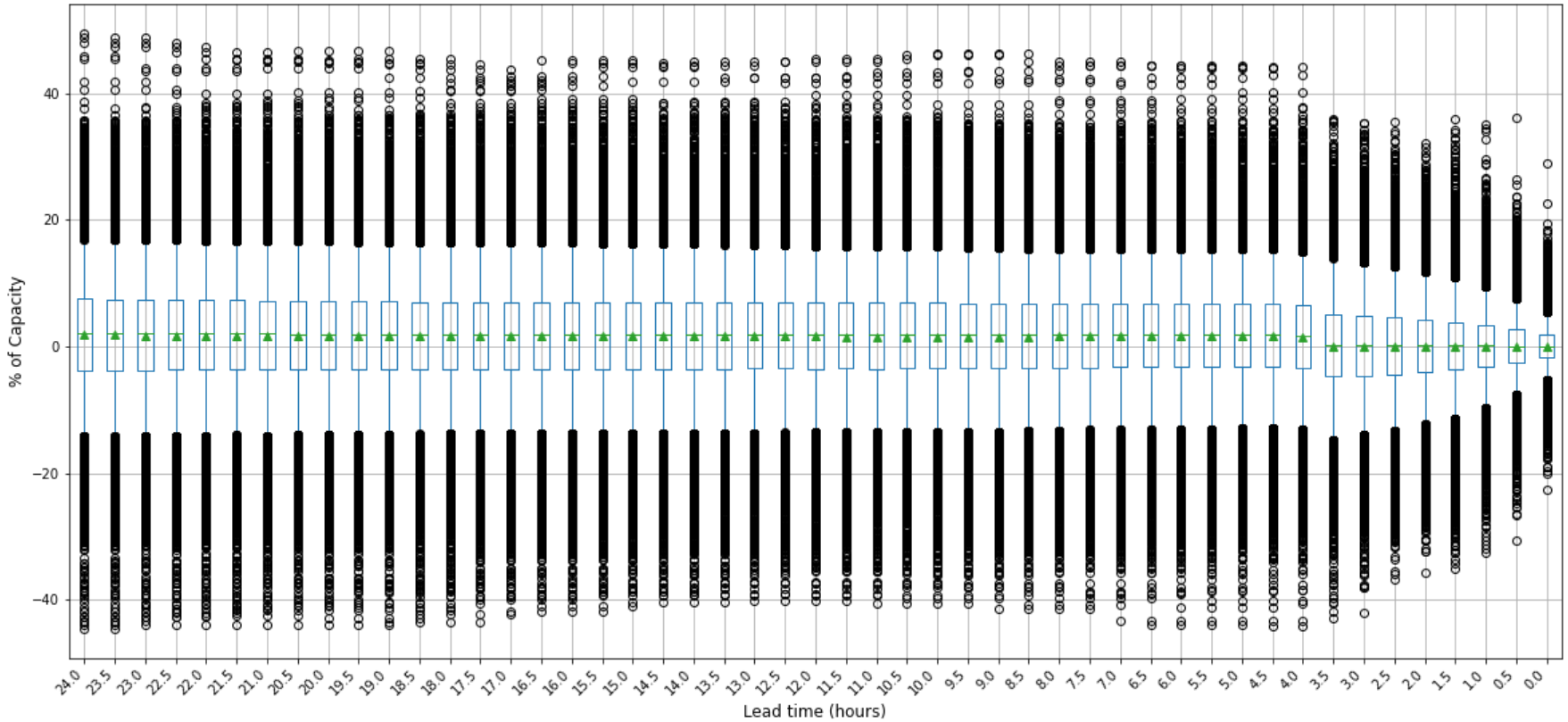
Figure 1: Total wind generation forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

Figure 2: Total wind generation forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

3.12 Slow-start thermal plant requires 6 to 12 hours' notice to start up from cold and reach full load, and this process incurs significant start-up costs. Hence the forecast 6 to12 hours ahead of real-time is the most critical for informing the scheduling of these plants.

3.13 The very wide spread in forecast error remaining at this time frame introduces significant uncertainty into forecast schedule results, and risk for slow-start thermal operators.

Individual Windfarms show differing behaviour

3.14 Box and whisker plots for individual windfarms are shown in Appendix A, grouped by the generating company that offers them into the market.

3.15 Note that the total wind generation percentage error (Figure 2) is significantly less than for individual windfarms due to geographical diversity, ie, not all wind farms are windy or calm at the same time.

Meridian

3.16 Box and whisker plots are shown in Figure 13 through Figure 18.

3.17 Analysis indicates that Meridian begins submitting windfarm offers six or seven days ahead, switching to persistence forecasts about four hours before the beginning of the trading period.

3.18 As with aggregate wind generation, Meridian's forecast accuracy doesn't improve materially until this final four-hour period.

3.19 Forecasts for some windfarms, particularly White Hill, Te Uku and Mill Creek, initially get less accurate with the onset of persistence forecasts, before steadily improving again approaching real-time.[5]

3.20 This indicates that the resource persistence assumption may not provide a sound basis for forecasting more than a couple of hours ahead, and a more sophisticated approach may be preferred.

Manawa-operated windfarms

3.21 Even though Tararua and Mahinerangi are now owned by Mercury, they are operated and offered into the market by Manawa Energy (formerly Trustpower), with whom Mercury has a power purchase agreement.

3.22 Box and whisker plots are shown in Figure 19 through Figure 22.

3.23 Analysis indicates that first offers are submitted about three days ahead, switching to persistence forecasts about two hours before the beginning of the trading period.[6]

3.24 Forecast accuracy doesn't improve materially until this final two-hour period

3.25 There is a range of positive and negative biases, which disappear with the persistence forecast.

Genesis-operated windfarms

3.26 Even though Waipipi is now owned by Mercury, it is operated and offered into the market by Genesis Energy, with whom Mercury has a power purchase agreement.

[5] We haven't investigated why only some windfarm forecasts get worse. It could be that their earlier forecasts were already better, or just a function of the distribution and volatility of wind each the particular site.

[6] This could be because this is when the Code requires persistence forecasts to begin or because Manawa don't think persistence forecasts are accurate more than two hours out.

3.27 Box and whisker plots are shown in Figure 23.

3.28 Analysis indicates the first offer is submitted six or seven days ahead, switching to a persistence forecast about four hours before the beginning of the trading period.

3.29 Forecast accuracy doesn't improve materially until this final four-hour period.

3.30 The slight positive bias disappears with the persistence forecast.

3.31 We understand Genesis started using proprietary wind generation forecasting software from Meteologica, an internationally recognised provider, on 8 June 2022, although it appears they still switch to a persistence forecast for the last three hours or so before the beginning of the trading period.

3.32 Box and whisker plots for the period from 9 June 2022 to 11 September 2022 are shown in Figure 24. Although this covers a relatively small sample, there appears to be a significantly narrower spread in forecast error since the change. For example, at nine hours before real-time, 90 percent of errors fall within a range of -25/+36 percent, compared to -34/+48 percent before the change.

Mercury-operated windfarms

3.33 Turitea is the only windfarm currently operated by Mercury. The windfarms Mercury acquired from Tilt renewables are variously operated by Manawa Energy and Genesis Energy, with whom Mercury has power purchase agreements.

3.34 Box and whisker plots are shown in Figure 25.

3.35 Turitea was only fully commissioned in November 2021, so it has a reduced sample size.

3.36 Analysis indicates that from this time onwards, the first offer was submitted seven days ahead.

3.37 We understand Mercury also uses Meteologica forecasting software, although it appears they also switch to a persistence forecast for the last two hours or so before the beginning of the trading period.

3.38 The Turitea forecast error shows a significantly narrower spread than the other wind farms, consistent with a more sophisticated forecasting approach.

3.39 Forecast accuracy doesn't improve materially until the final two-hour period, at which time the slight negative bias also disappears.

NZ Windfarms

3.40 Box and whisker plots are shown in Figure 26.

3.41 Analysis indicates the first offer is submitted two or three days ahead, followed by a single revision a day or so later and finally commencing frequent persistence forecasts about two hours before the beginning of the trading period.

3.42 Forecast accuracy doesn't improve materially until this final two-hour period. At this point there is a sudden dramatic improvement followed by a further steady improvement up to real-time.

3.43 The sudden improvement may be due to the infrequent offer revisions up to this point.

4 Load forecasts are inaccurate until the last few hours

Total Load

4.1 The system operator began using a new TESLA load forecasting service on 3 March 2022. Since this has significantly improved forecast accuracy, we initially consider only the period since the new forecast was commissioned. Figure 3 shows box and whisker plots of the total New Zealand load forecast error at half-hourly intervals leading up to real-time for the period from 4 March 2022 to 14 August 2022.

4.2 For most of the forecast period, there is a 90% probability that the forecast error will fall within a range from around -200 MW to +100 MW, while outliers extend as far as -600 and +700 MW.

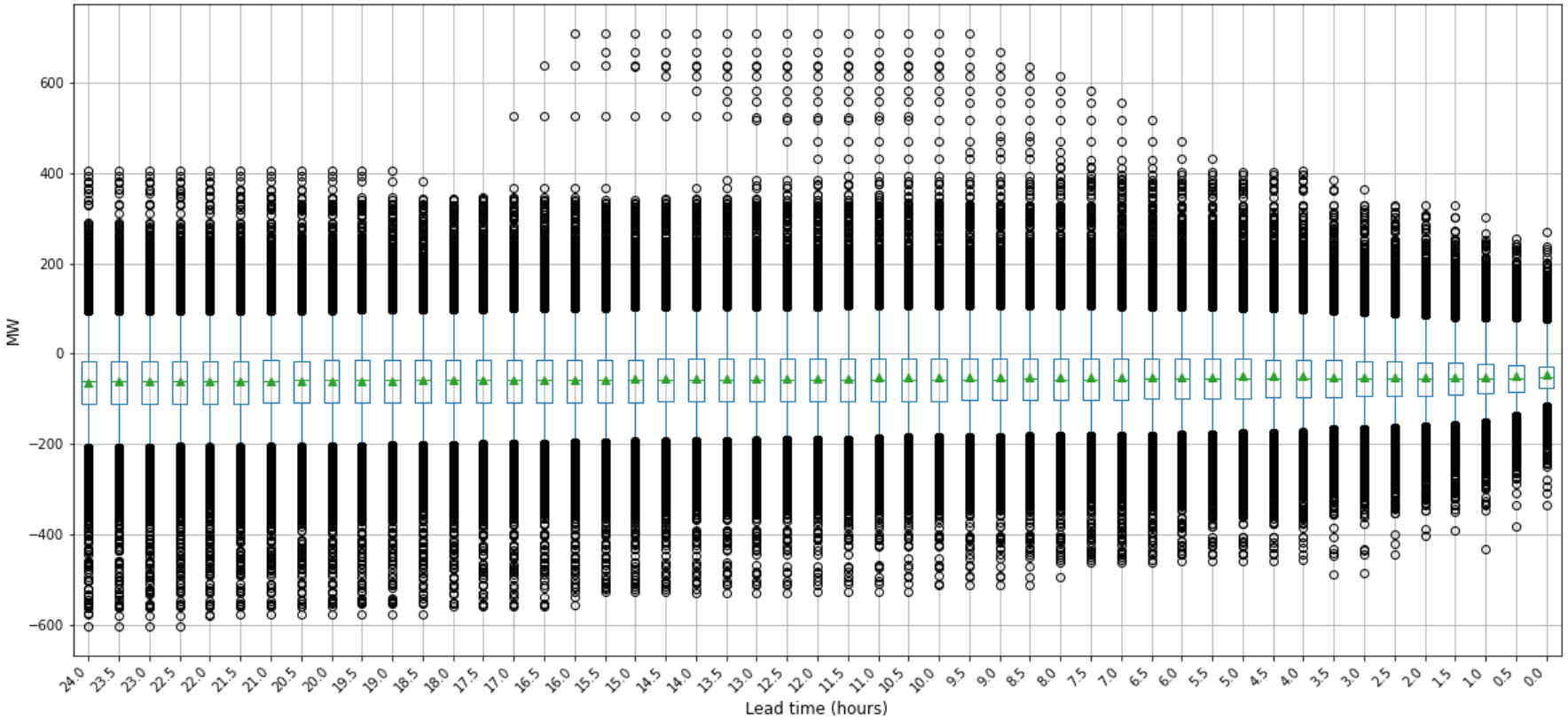
4.3 There is only a gradual improvement in forecast accuracy until about four hours before real-time after which accuracy improves somewhat more quickly.

4.4 While the 90% confidence interval narrows to around -120 to +75 MW by the start of the trading period, outliers still extend to around -340 to +270 MW.

4.5 The results show a persistent negative bias of around 50 to 60 MW, ie, forecasts tend to under-estimate demand on average, which is undesirable from a security perspective. We don’t know what causes this.

4.6 Again, the wide spread in forecast error remaining 6 to 12 hours ahead of real-time introduces significant risk for slow-start thermal operators.

Figure 3: Total load forecast error over 4 March 2022 to 14 August 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

There are two classes of load

4.7 Grid exit points (GXPs) are classified into two types depending on whether or not they exhibit a predictable load pattern:

(a) **Conforming GXPs.** GXPs that have a predictable load pattern are considered to be conforming GXPs. The demand at conforming GXPs is forecast by the System Operator (SO). Purchasers at conforming GXPs do not have to submit nominated bids but may elect to submit difference bids to signal that some load at the GXP may differ depending on the purchaser's real time expectations of price. A difference bid represents the purchaser's reasonable endeavours to predict an increase or decrease in its usual quantity of electricity demanded for a trading period at a relevant price at the GXP.

Over the study period, difference bids were only submitted at one GXP and for less than one percent of trading periods, so these have not been explicitly analysed, although they are implicitly included in the schedule results.

(b) **Non-conforming GXPs.** GXPs that do not follow a predictable daily load pattern are considered to be non-conforming GXPs. Purchasers at non-conforming GXPs are required to prepare their own forecasts of electricity usage at those GXPs for market scheduling purposes in the form of nominated bids. Currently there are 13 non-conforming GXPs. Ten of these serve a single (usually large industrial) customer, while the remaining three serve up to seven different purchasers (retailers).

New conforming load forecast is much improved

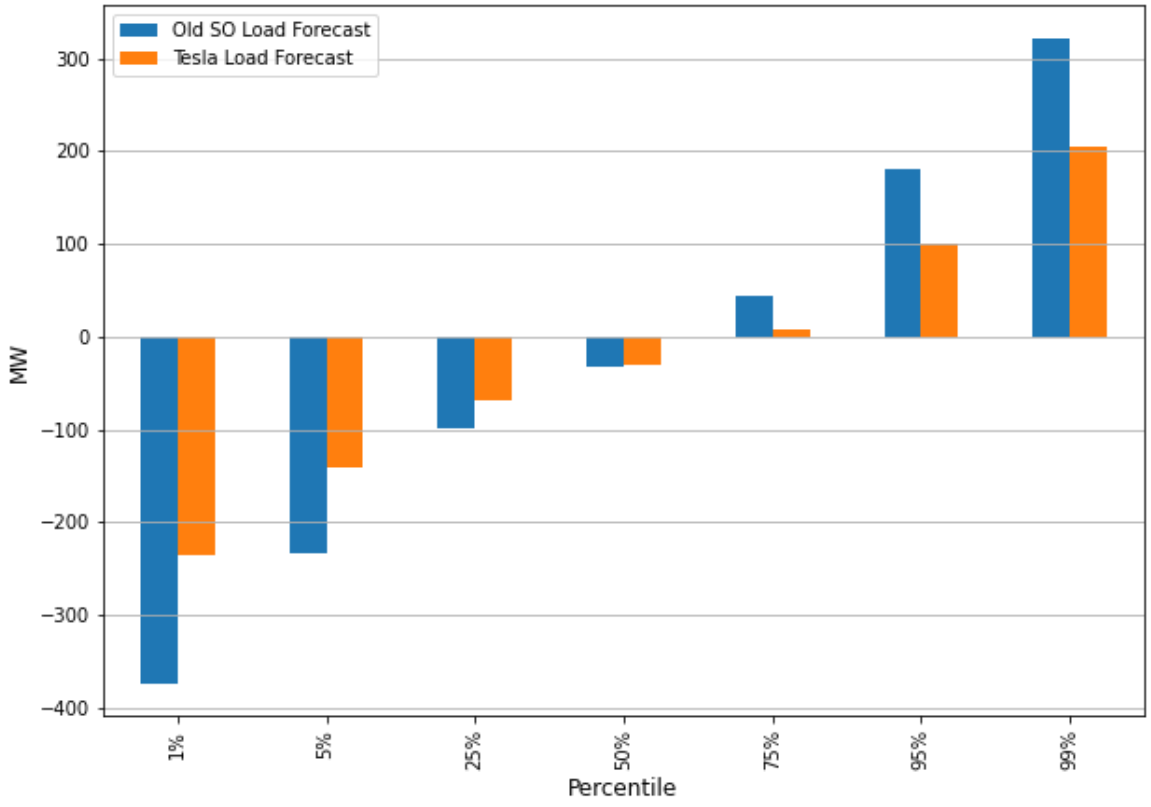
4.8 The system operator began using a new TESLA load forecasting service for conforming load on 3 March 2022. We compared the total conforming load forecast error for the period before and after the new load forecast was commissioned: box and whisker plots of MW error are shown in Figure 5 for the period before the change (1 April 2021 through 2 March 2022) and in Figure 6 for the period after the change (4 March 2022 through 14 August 2022). Figure 7 shows percent error for the period after the change.

4.9 In both cases there is minimal improvement in forecast accuracy up until about four hours before real-time, after which accuracy improves more quickly, particularly for the old forecast. The TESLA forecast shows less improvement over the last four hours partly because it is starting from a more accurate base, as discussed next.

4.10 For the earlier forecasts critical for thermal scheduling, the new forecast tool is significantly more accurate. Figure 4 compares error percentiles for the total conforming load forecast nine hours ahead of real-time, between periods covered by the two load forecasting tools. Based on the 5 ½ months experience to date, the new forecast tool shows a 35 to 45 percent narrower spread.

4.11 However, on average the new forecasting tool still tends to under-estimate demand by around 30 MW, which is undesirable from a security perspective.

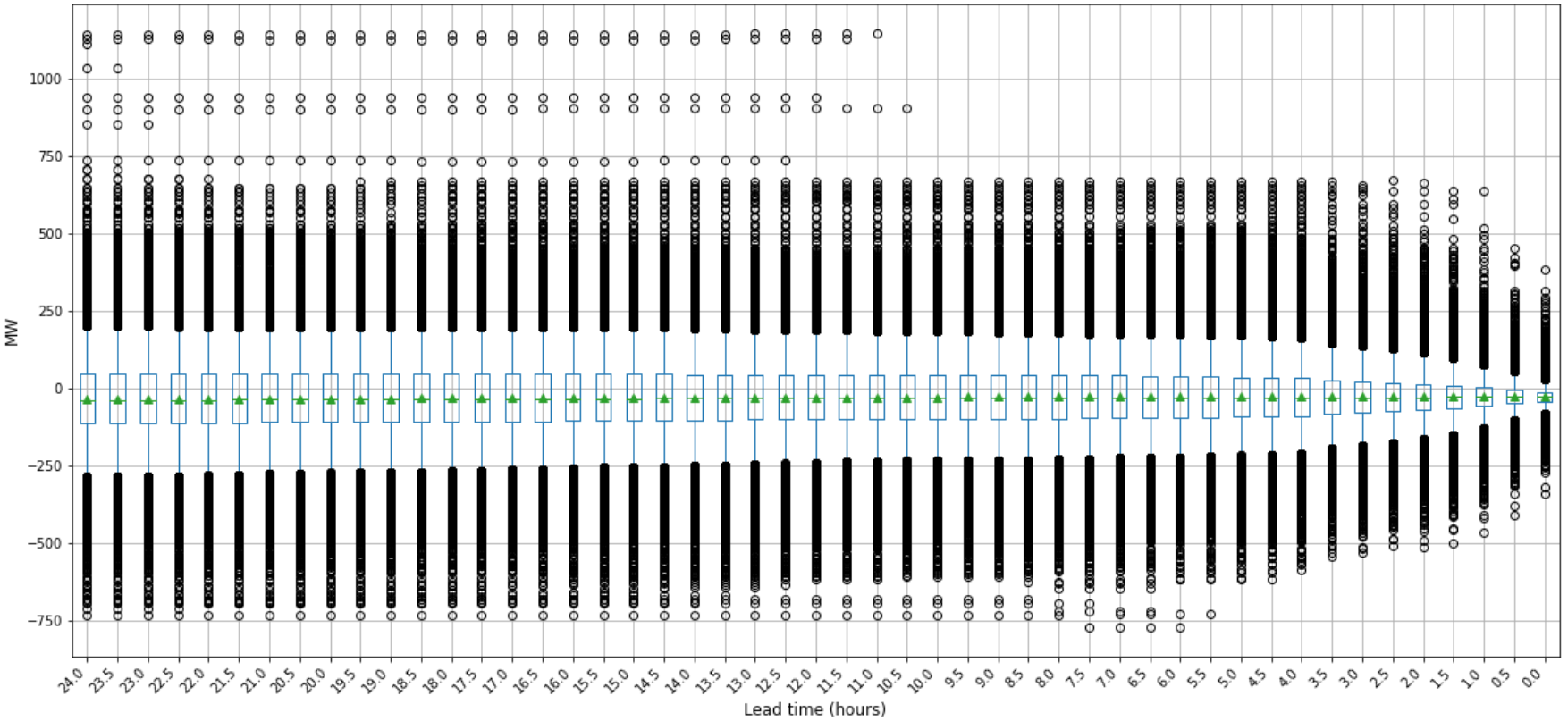
Figure 4: Conforming Load 9-Hour Ahead Forecast Error Percentiles



Source: Electricity Authority

Notes:
1. Blue bars cover period from 1 April 2021 to 2 March 2022
2. Orange bars cover period from 4 March 2022 to 14 August 2022
3. The SO began using the new Tesla load forecast at 12:30 pm on 3 March 2022

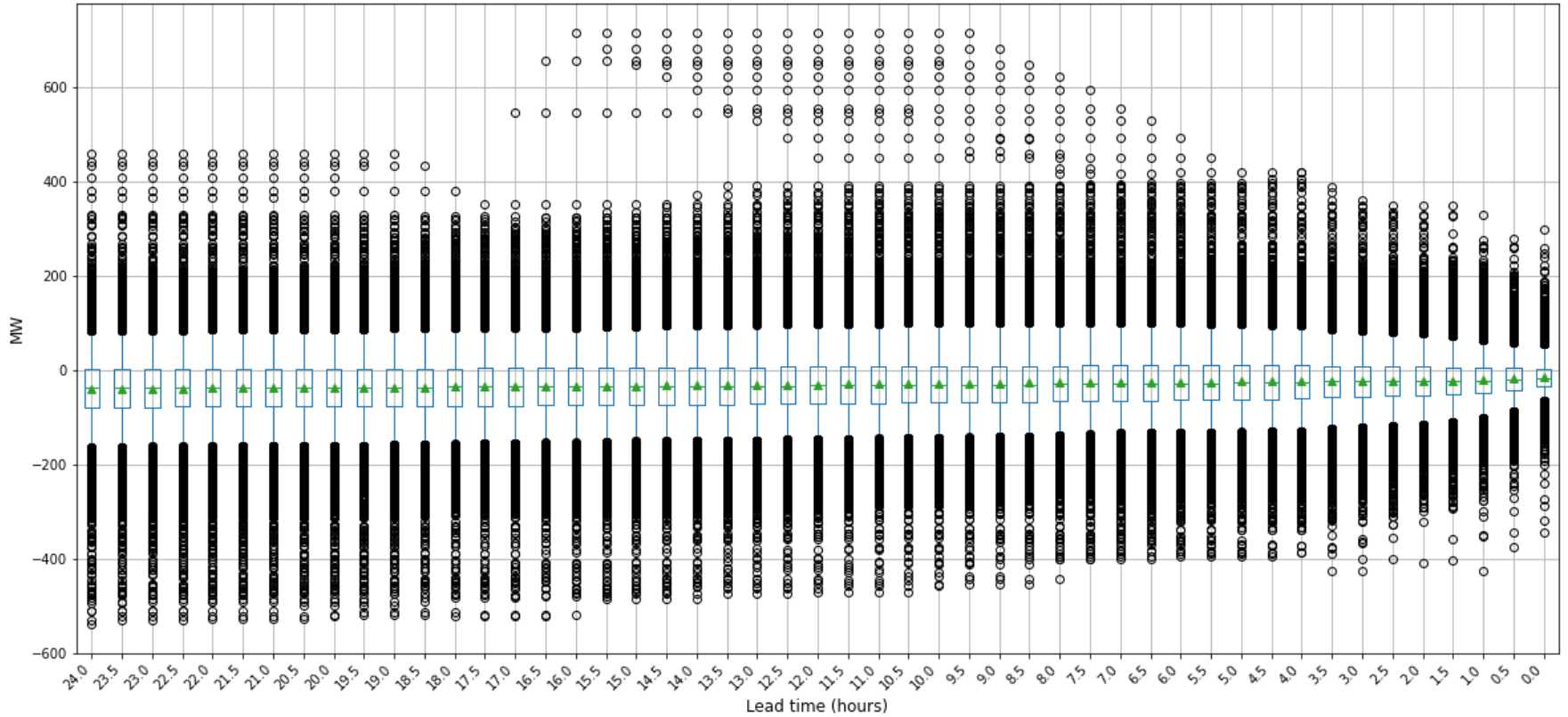
Figure 5: Total conforming load forecast error over 1 April 2021 to 2 March 2022 (old load forecast)



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

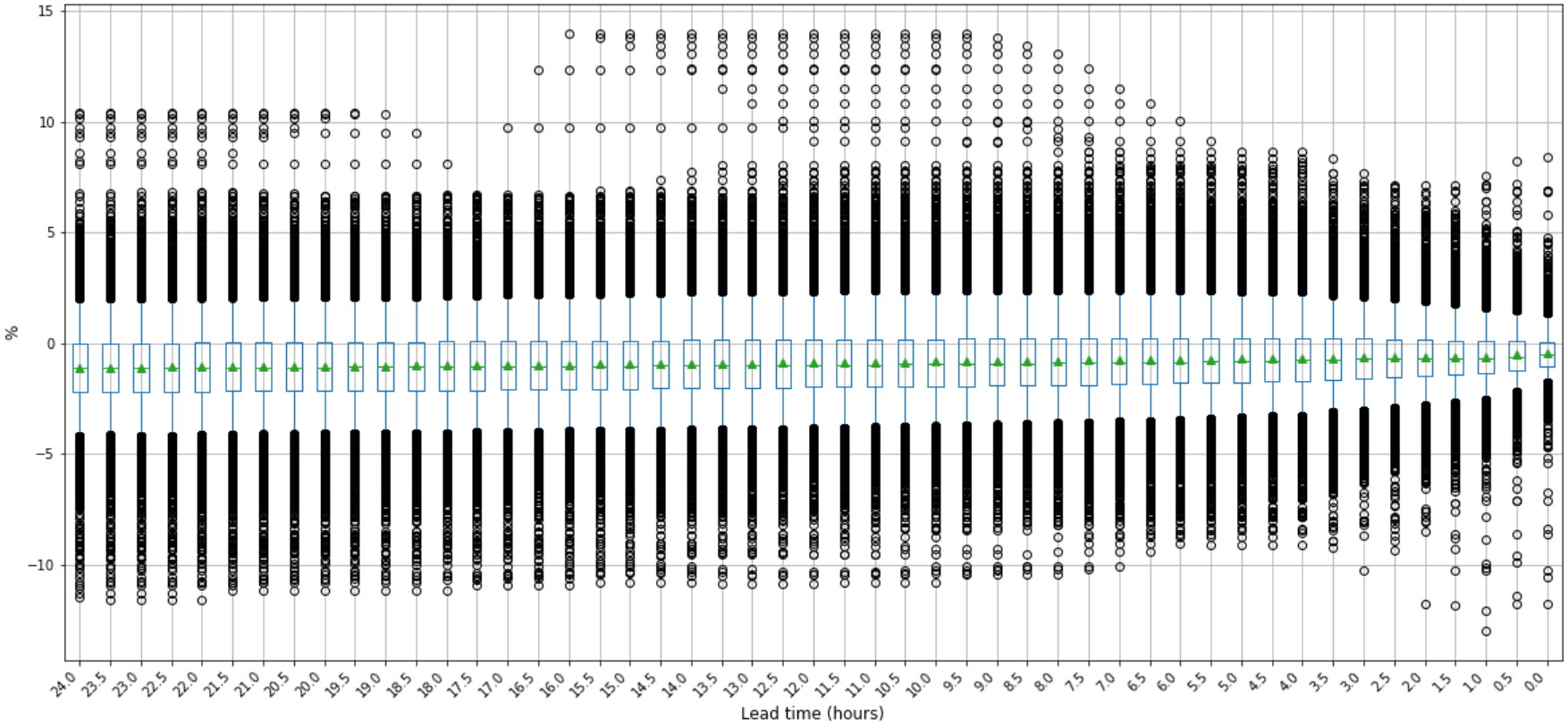
Figure 6: Total conforming load forecast error over 4 March 2022 to 14 August 2022 (new TESLA load forecast)



Source: Electricity Authority

Notes:
6. Blue boxes indicate lower and upper quartile and median
7. Blue whiskers extend to 5th and 95th percentiles
8. Black circles indicate outliers beyond 5th and 95th percentiles
9. Green triangles indicate mean
10. Forecast error ≡ Forecast minus Actual

Figure 7: Total conforming load forecast percent error over 4 March 2022 to 14 August 2022 (new TESLA load forecast)



Source: Electricity Authority

Notes:
11. Blue boxes indicate lower and upper quartile and median
12. Blue whiskers extend to 5th and 95th percentiles
13. Black circles indicate outliers beyond 5th and 95th percentiles
14. Green triangles indicate mean
15. Forecast percent error ≡ 100x(Forecast minus Actual)/max(abs(Forecast), abs(Actual))

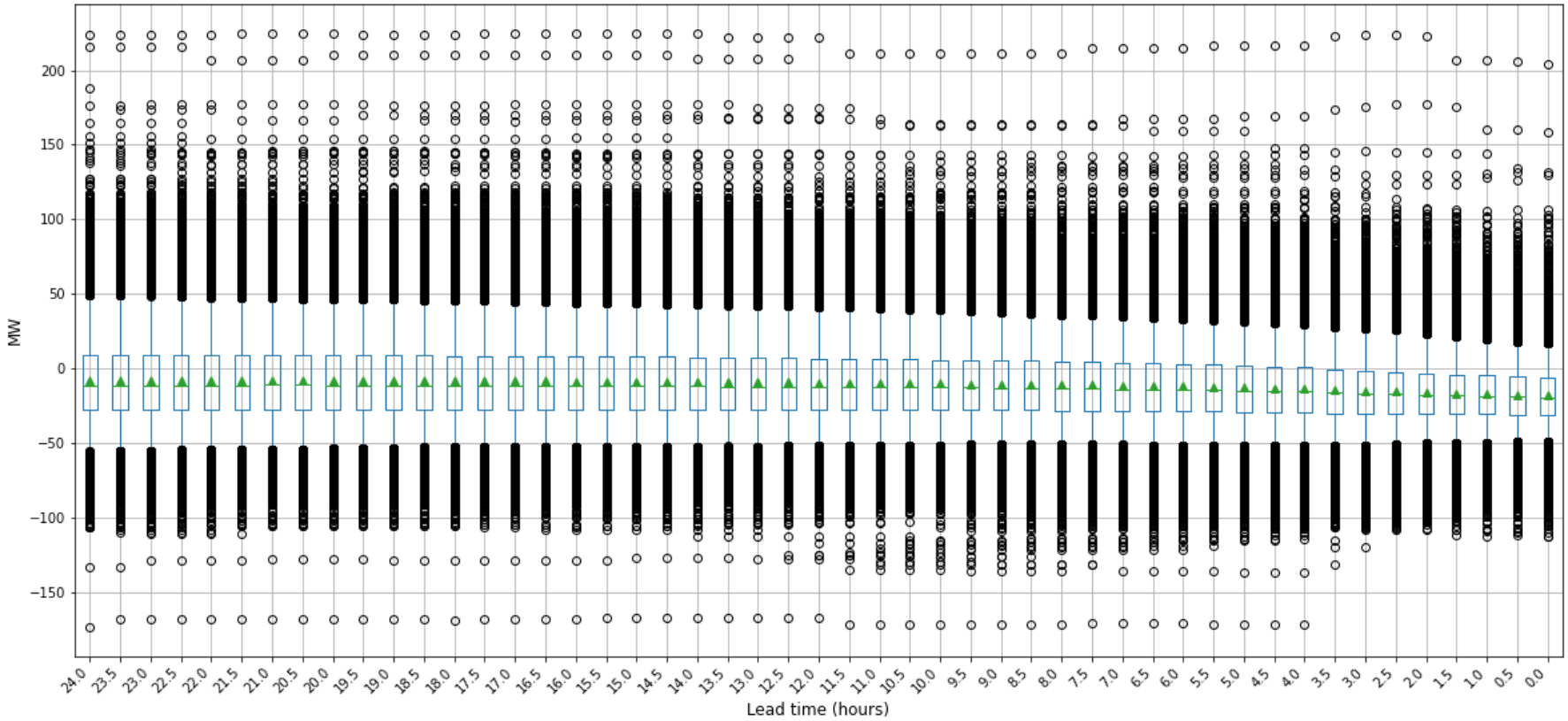
Non-conforming load makes a smaller contribution to total load forecast error

4.12 Box and whisker plots for total non-conforming load are shown in Figure 8 for MW error and in Figure 9 for percent error.

4.13 While the spread gradually gets narrower, particularly in the last few hours before real time, the negative bias actually gets worse.

4.14 While non-conforming load (Figure 9) has about twice the percentage error as conforming load (Figure 7), it contributes a smaller amount to total load forecast error, since it accounts for only about 20 percent of total load on average.

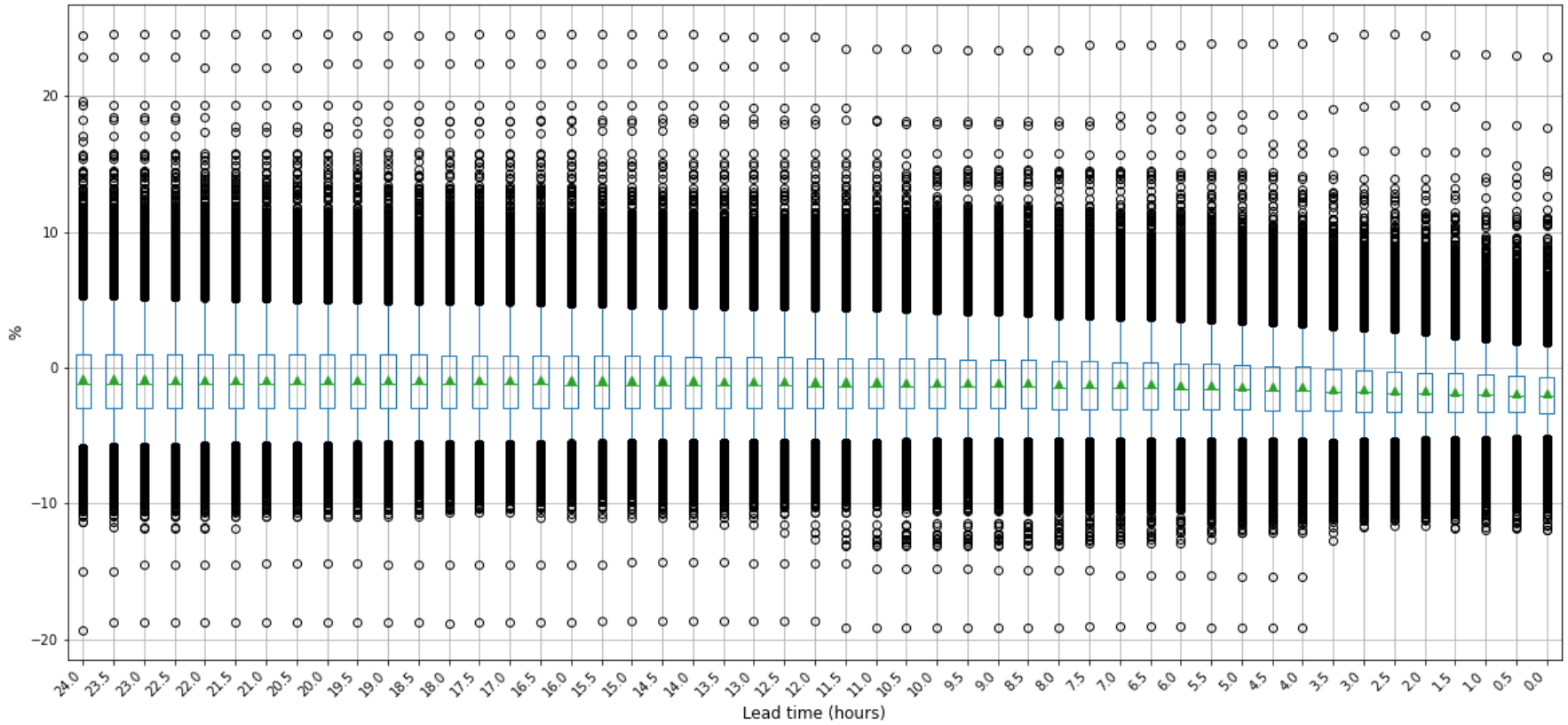
Figure 8: Total non-conforming load forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

Figure 9: Total non-conforming load forecast percent error over April 2021 to March 2022



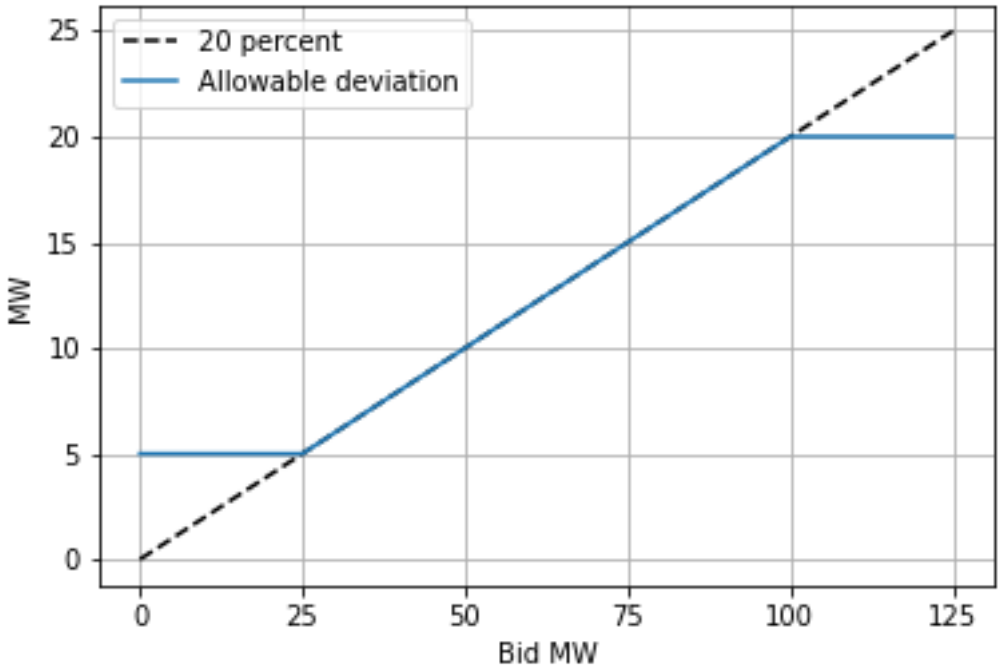
Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/max(abs(Forecast), abs(Actual))

Some non-conforming loads don't appear to comply with rebidding requirements but have improved in recent months

4.15 Under the current Code provisions, purchasers at non-conforming GXPs must revise their nominated bid quantities if they expect their actual consumption to deviate from their bid by more than an allowed limit.[7] The allowable deviation for non-dispatch bids as a function of bid quantity is depicted in Figure 10.[8]

Figure 10: Allowable deviation for non-dispatch bids



Source: Electricity Authority

Notes: 1.

4.16 In summary, this means a purchaser at a non-conforming GXP is compliant if their expected deviation from bid is either:

(a) Less than 20 MW and less than 20% of their bid, or

(b) Less than 5 MW.

4.17 Box and whisker plots of forecast error for individual non-conforming GXPs, in terms of both MW and percent, are shown in Appendix B. We can assess compliance with clause 13.19B by examining these plots, ie, to see if the error is trending to within these limits as lead time approaches zero—although strictly this is only valid where there is a single purchaser at the GXP.

4.18 The analysis suggests that for purchasers at several non-conforming GXPs there may be room for improvement in complying with clause 13.19B. The Authority's compliance team and the system operator have been working with purchasers at non-conforming

[7] Simplified wording. Refer to clause 13.19B of the Code for the precise wording.

[8] Currently no participants are submitting dispatch bids.

GXPs to improve compliance with bidding and rebidding requirements. This has resulted in significant improvement in recent months.

ASB0661 (various retailers)

4.19 Refer to Figure 27 and Figure 28. Within +/-20 MW more than 90 percent of the time. Within +/-20 percent about 90 percent of the time. Hence compliant about 90 percent of the time. There are outliers up to about +15/-27 MW.

EDG0331 (various retailers)

4.20 Refer to Figure 29 and Figure 30. Within +/-20 MW more than 90 percent of the time. Within +/-20 percent about 35 percent of the time. Hence compliant about 35 percent of the time. This is partly due to a persistent negative bias, ie, bids tend to be too low on average.

GLN0331 (NZ Steel)

4.21 Refer to Figure 31 and Figure 32. Within +/-20 MW about 90 percent of the time. Within +/-20 percent about 80 percent of the time. Hence compliant about 80 percent of the time. This is partly due to a persistent negative bias, ie, bids tend to be too low on average. There are outliers up to about +60/-75 MW.

KAW0111 (various retailers)

4.22 Refer to Figure 33 and Figure 34. Within +/-5 MW about 93 percent of the time. Hence compliant at least 93 percent of the time. There are outliers up to about +17/-12 MW.

KAW0112 (Norske Skog Tasman)

4.23 Refer to Figure 35 and Figure 36. Within +/-5 MW about 97 percent of the time. Hence compliant at least 97 percent of the time. There are outliers up to about +20/-9 MW.

KAW0113 (Norske Skog Tasman)

4.24 Refer to Figure 37 and Figure 38. Within +/-5 MW about 98 percent of the time. Hence compliant at least 98 percent of the time. There are outliers up to about +/-33 MW.

KIN0111 (Oji Fibre Solutions)

4.25 Refer to Figure 39 and Figure 40. Within +/-5 MW about 90 percent of the time. Hence compliant at least 90 percent of the time. There are outliers up to about +/-14 MW.

KIN0112 (Oji Fibre Solutions)

4.26 Refer to Figure 41 and Figure 42. Within +/-5 MW about 92 percent of the time. Hence compliant at least 92 percent of the time. There are outliers up to about +13/-14 MW.

KIN0113 (Oji Fibre Solutions)

4.27 Refer to Figure 43 and Figure 44. Within +/-20 MW all the time. Within +/-20 percent about 90 percent of the time. Hence compliant about 90 percent of the time. There are outliers up to about +17/-15 MW.

MNG1101 (Trustpower/Manawa)

4.28 Refer to Figure 45 and Figure 46. Within +/-5 MW about 53 percent of the time. Hence compliant about 53 percent of the time. Note because the bid (ie. forecast) is zero for all but two samples, the percent error is mostly undefined (leading to a mostly blank percent error graph), and the 5 MW limit applies. There are outliers up to about -17 MW.

TNG0111 (Winstone Pulp International)

4.29 Refer to Figure 47 and Figure 48. Within +/-20 MW about 99 percent of the time. Within +/-20 percent about 76 percent of the time. Within +/-5 MW about 78 percent of the time. Hence compliant at least 78 percent of the time. There are outliers up to about +/-30 MW.

TWI2201 (NZ Aluminium Smelters)

4.30 Refer to Figure 49 and Figure 50. Within +/-20 MW about 98 percent of the time. Within +/-20 percent about 99 percent of the time. Hence compliant about 98 percent of the time. There are outliers up to about +175/-90 MW.

WHI0111 (Pan Pacific Forest Industries)

4.31 Refer to Figure 51 and Figure 52. Within +/-20 MW about 97 percent of the time Within +/-20 percent about 80 percent of the time. Hence compliant about 80 percent of the time. There are outliers up to about +55/-40 MW.

5 Machine learning shows promise for forecasting wind and demand

5.1 Modelling work recently undertaken by the Authority suggests that forecasting models based on machine learning techniques show promise.

5.2 The work on national demand forecast models was presented in chapter 7 of the Authority's October–December 2021 Quarterly Review.[9]

5.3 The work on wind forecast models is included in Appendix C of this report.

5.4 The models were trained using several years of weather and generation/demand data, and then forecast generation/demand based on weather forecasts one to two days ahead.

5.5 For the national demand forecast model, the weather inputs were apparent temperature data for Auckland and Wellington. Apparent temperature measures what an observer feels. It is a function of wind speed, air temperature, humidity, and solar radiation.

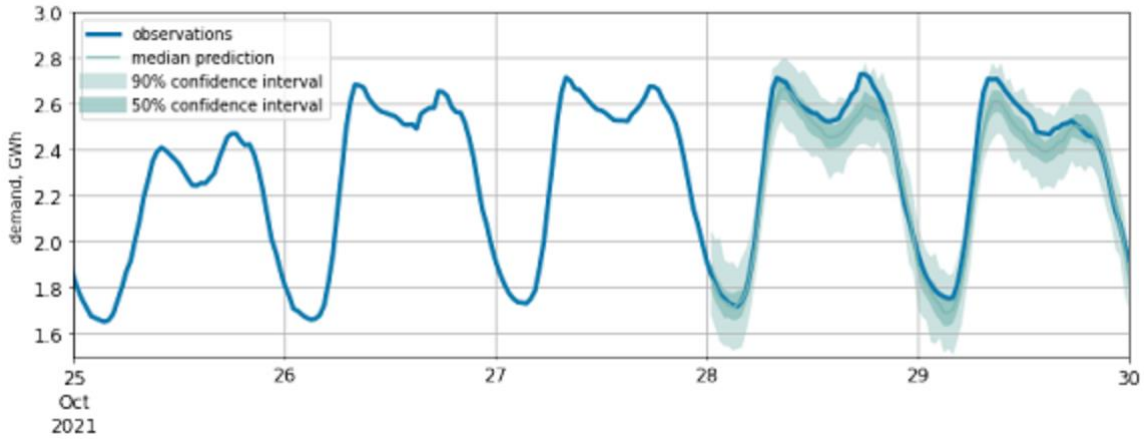
5.6 The wind generation models predicted generation at Meridian's Wellington windfarms (West Wind and Mill Creek) and at Mercury's (formerly Tilt's) Tararua Windfarms. The weather inputs were wind speed and direction and atmospheric pressure measured at Kelburn, Wellington Airport and Aotea Quay (for Westwind and Mill Creek) and at Palmerston North Airport (for Tararua).

5.7 The demand model was able to predict the shape of the daily demand curve fairly accurately. However, the confidence intervals were fairly wide, so there was significant uncertainty in the absolute value of demand (see Figure 11).

5.8 However, it may be possible to improve the model, such as by utilising weather forecasts from more locations.

[9] https://www.ea.govt.nz/monitoring/enquiries-reviews-and-investigations/2021/market/

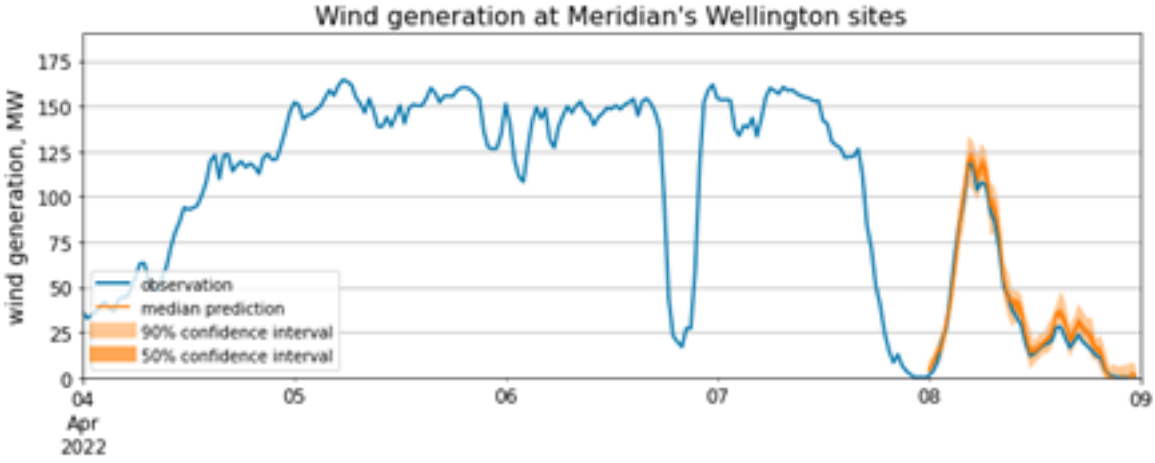
Figure 11: Example of machine learning demand forecast model



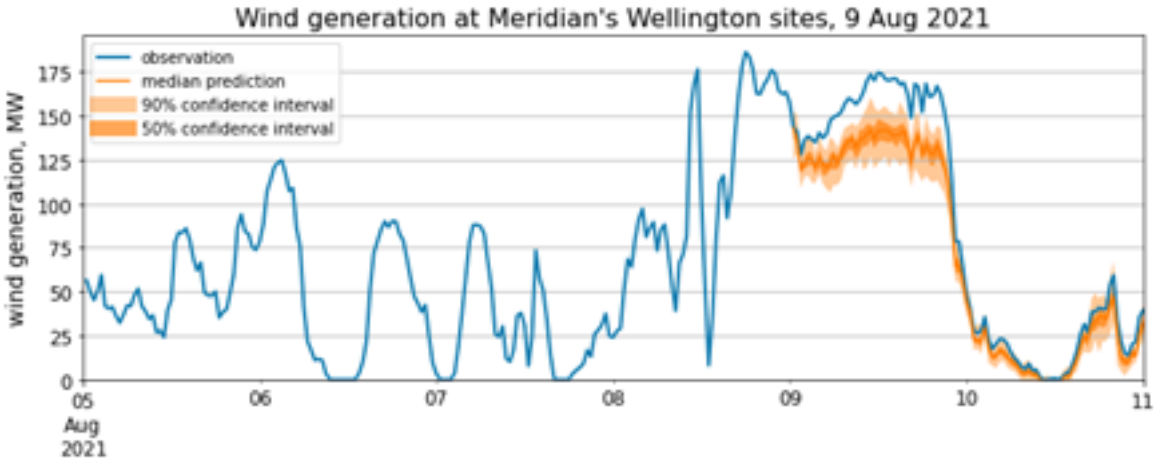
Source: Electricity Authority

Figure 12: Machine learning wind forecast model

Example 1 – generation accurately predicted



Example 2 – generation outside predicted confidence interval



Source: Electricity Authority

5.9 On some days the wind model was able to predict the wind generation very accurately (example 1 in Figure 12), while on other days the generation fell outside the predicted 90 percent confidence interval (example 2 in Figure 12). Even so, the model was able to predict the overall trend very well.

5.10 It is difficult to draw strong conclusions given the small sample size. However, in the case of example 1 in Figure 12, which is for West Wind and Mill Creek on 8 April 2021, the 90 percent confidence interval reached a maximum of only about 25 MW wide (or about 11 percent of the combined capacity of West Wind and Mill Creek. Now, referring to the historical forecast statistics in Figure 16 to Figure 18, the distance between the 5th and 95th percentiles—roughly equivalent to the 90 percent confidence interval—is 50 to 60 percent of capacity up to four hours ahead, depending on the windfarm. This implies that the machine learning model was much more accurate for this small sample size than historical forecasts were on average over the 12-month study period.

5.11 On the other hand, in the case of example 2 in Figure 12, which is for West Wind and Mill Creek on 9 August 2021, the actual generation fell well outside the predicted 90 percent confidence interval. This could be due to overfitting the data, causing the predicted confidence intervals to be too narrow (refer to paragraph 3.5 of Appendix C). So, we will consider the difference between the actual generation and the median prediction, which reached a maximum of about 35 MW, or about 16 percent of the combined capacity. Again comparing with the historical forecast statistics in Figure 16 to Figure 18, a 16 percent error falls well within the 5th and 95th percentiles—roughly equivalent to the 90 percent confidence interval—which is about +/-25 to +/-35 percent up to four hours ahead, depending on the windfarm. So even for this less accurate example, the machine learning model appears to have been somewhat more accurate than historical forecasts.

5.12 Given what we have achieved in a few short months using open-source software and publicly available data, it seems likely that experts in the field could do an even better job and forecast wind generation much more accurately than occurs at present.

5.13 We think the Authority should consider tightening up the Code requirements relating to wind generation offers to achieve greater forecast accuracy—particularly in the timeframe 6-to-12-hours ahead of real-time.

6 Conclusions

6.1 Slow-start thermal generation plant typically requires 6 to 12 hours' notice to start up from cold and reach full load, and this process incurs significant start-up costs.

6.2 When offering their plant into the market, thermal plant operators must assess the likelihood of being dispatched at a sufficient level, duration and price to recover their costs, and hence justify making their plant available to run.

6.3 They must base this decision on information available 6 to 12 hours ahead of real-time. It follows that the accuracy of forecast schedules 6 to 12 hours ahead is critical for informing the scheduling of these plants.

6.4 Unfortunately, both wind and demand forecasts introduce significant uncertainty into forecast schedules more than a few hours ahead of real-time, significantly increasing risk for slow-start thermal operators, and consequently the power system as a whole. If slow-start thermal operators anticipate their plant is not required, and the forecast generation/demand balance subsequently deteriorates, it may be too late for them to

start up, leaving the system short of capacity. This is essentially what happened on 9 August 2021. More accurate wind and demand forecasts out to around 12 hours ahead of real-time would likely have helped.

6.5 The increase in the penetration of wind and solar generation that is already underway as New Zealand seeks to decrease reliance on fossil fuels will initially make this problem worse. However, we expect this to be offset by the eventual retirement of slow-start thermal generation.

6.6 Early studies suggest reasonably accurate day-ahead wind generation forecasts are possible using techniques such as machine learning, and we think the Authority should consider amending the Code to require windfarm operators to put more effort into this—particularly in the 6-to-12-hour timeframe that is critical for scheduling of slow-start thermal plant.

6.7 We understand two NZ windfarm operators are now using proprietary wind generation forecasting software, which appears to show significantly better accuracy than most other windfarms. We understand the system operator also trialled this software recently; they found it to be more accurate than a resource persistence model, even within two hours of real-time.

6.8 The Authority has initiated a project to review the current intermittent generation offer provisions, which this analysis will support. Consultation is planned for the second half of the 2022/23 financial year.

6.9 The system operator began using a new TESLA load forecasting service for conforming load on 3 March 2022. Based on 5 ½ months experience the new tool has narrowed the spread of forecast error by 35 to 45 percent. While conforming load now has only about half the percentage error as non-conforming load, it still contributes more of the overall load forecast error. The Authority will continue to monitor the accuracy of the new load forecasting service.

6.10 For purchasers at several non-conforming GXPs there may be room for improvement in complying with rebidding requirements. The Authority's compliance team and the system operator have been working with purchasers to improve compliance, and this has resulted in significant improvement in recent months.

Appendix A Individual windfarm forecast error plots

A.1 Forecast error box and whisker plots for individual windfarms are shown in this appendix, grouped by the generating company that offers them into the market.

A.2 Meridian windfarms are shown in Figure 13 through Figure 18.

A.3 Manawa-operated windfarms are shown in Figure 19 through Figure 22.

A.4 Genesis-operated windfarms are shown in Figure 23 and Figure 24.

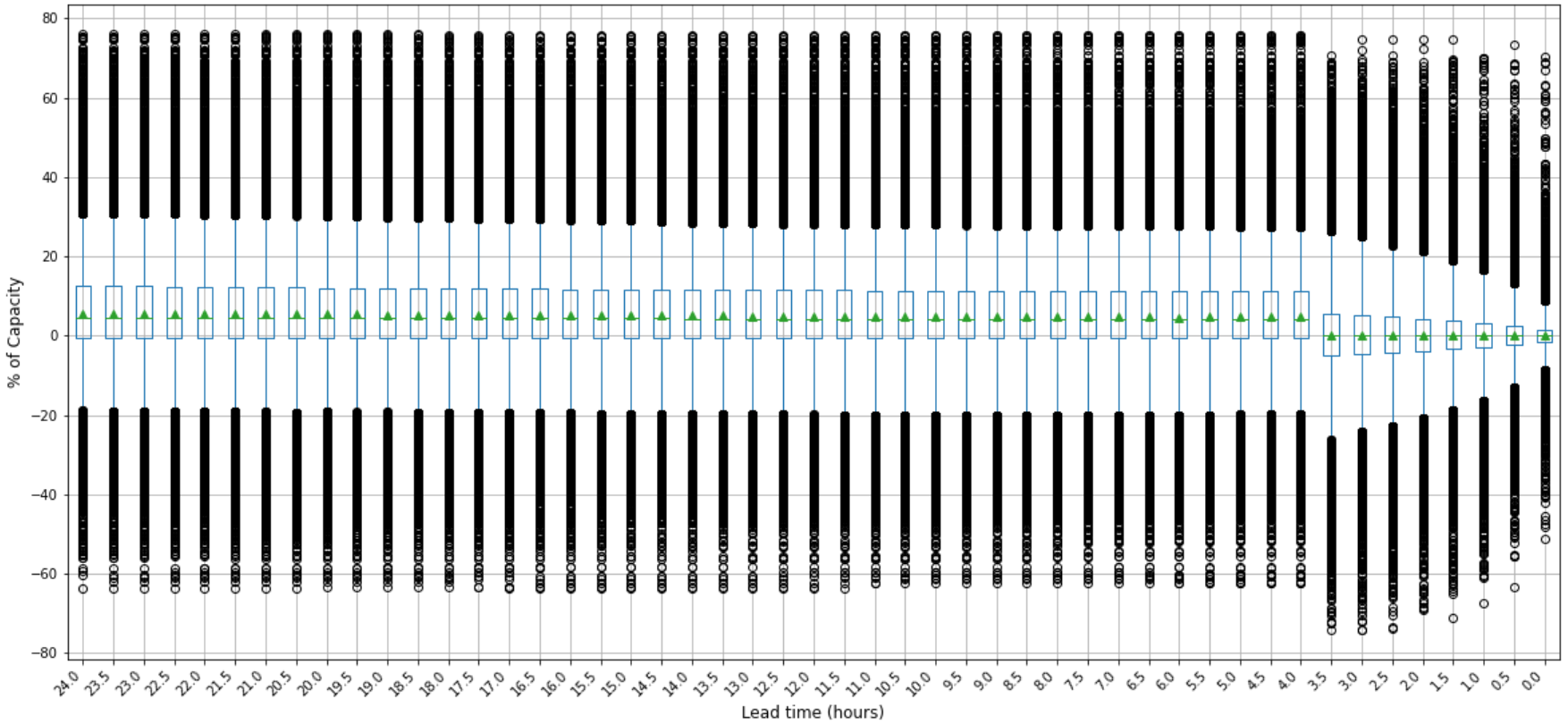
A.5 Mercury-operated windfarms are shown in Figure 25.

A.6 “New Zealand Windfarms” is shown in Figure 26.

A.7 The two Westwind GIPs (WWD1102 WWD0 and WWD1103 WWD0) show different percentage errors. These are each based on a nominal capacity of 80 MW. The difference is thought to be due to Meridian rerouting more power through WWD1103 WWD0 when WWD1102 WWD0 was out of service.

A.8 Further commentary can be found in the body of the report.

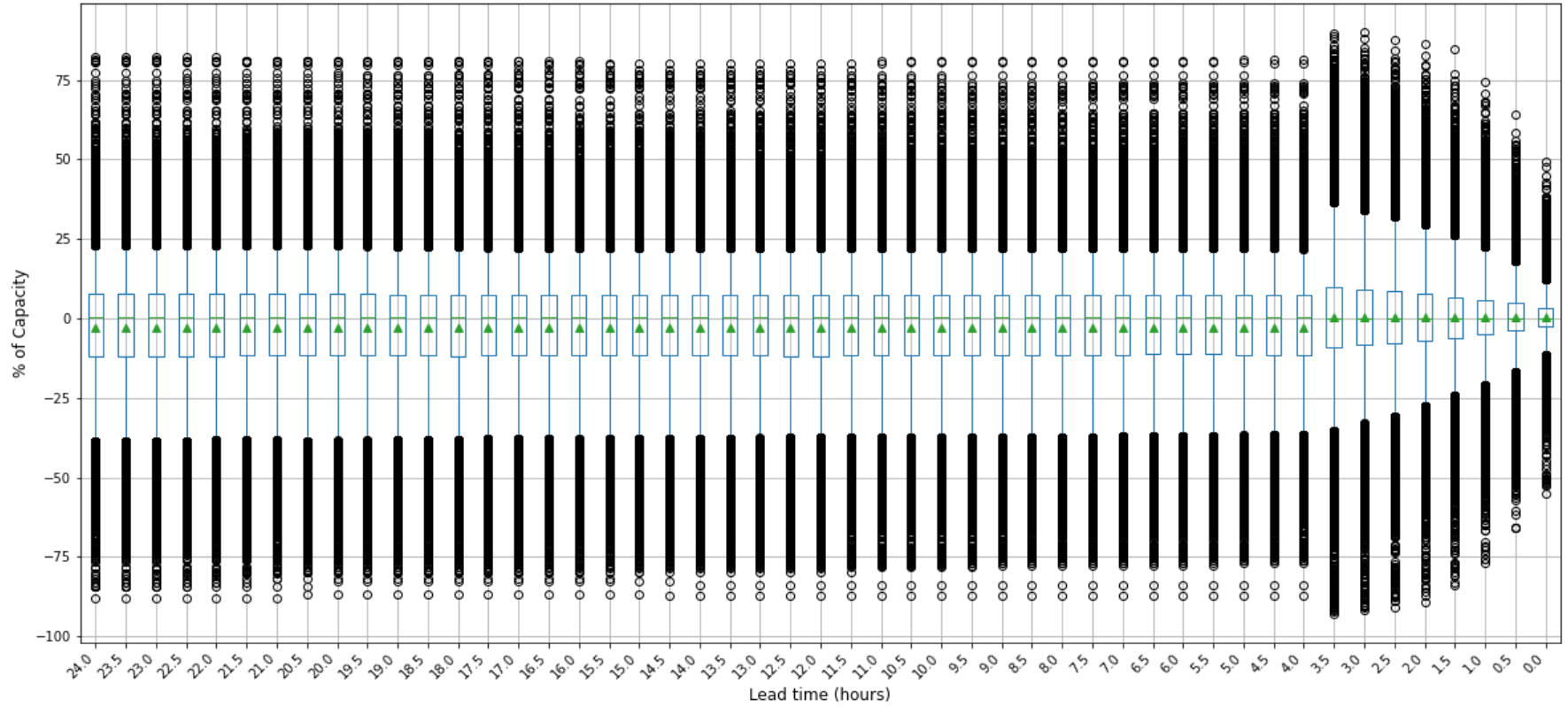
Figure 13: NMA0331 WHL0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

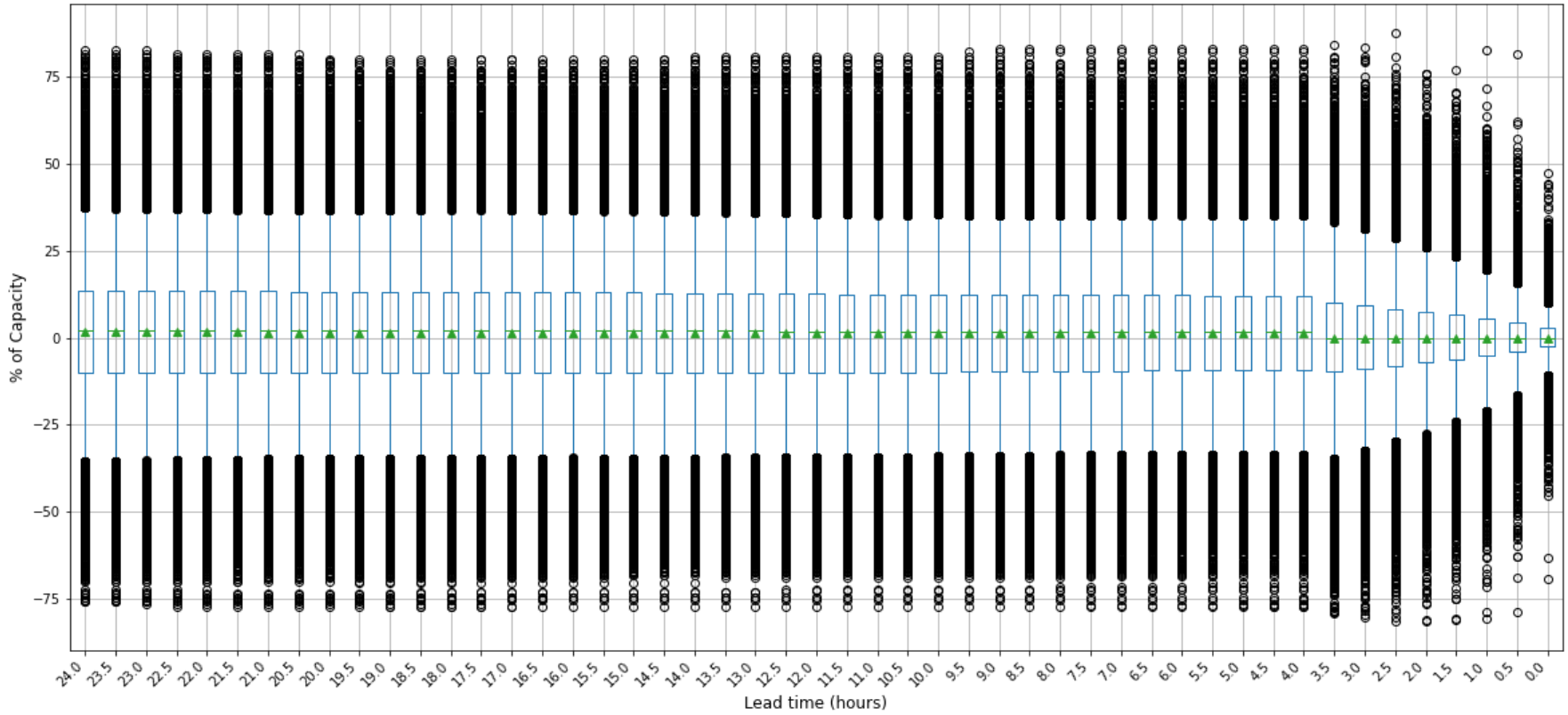
Figure 14: TWH0331 TUK0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

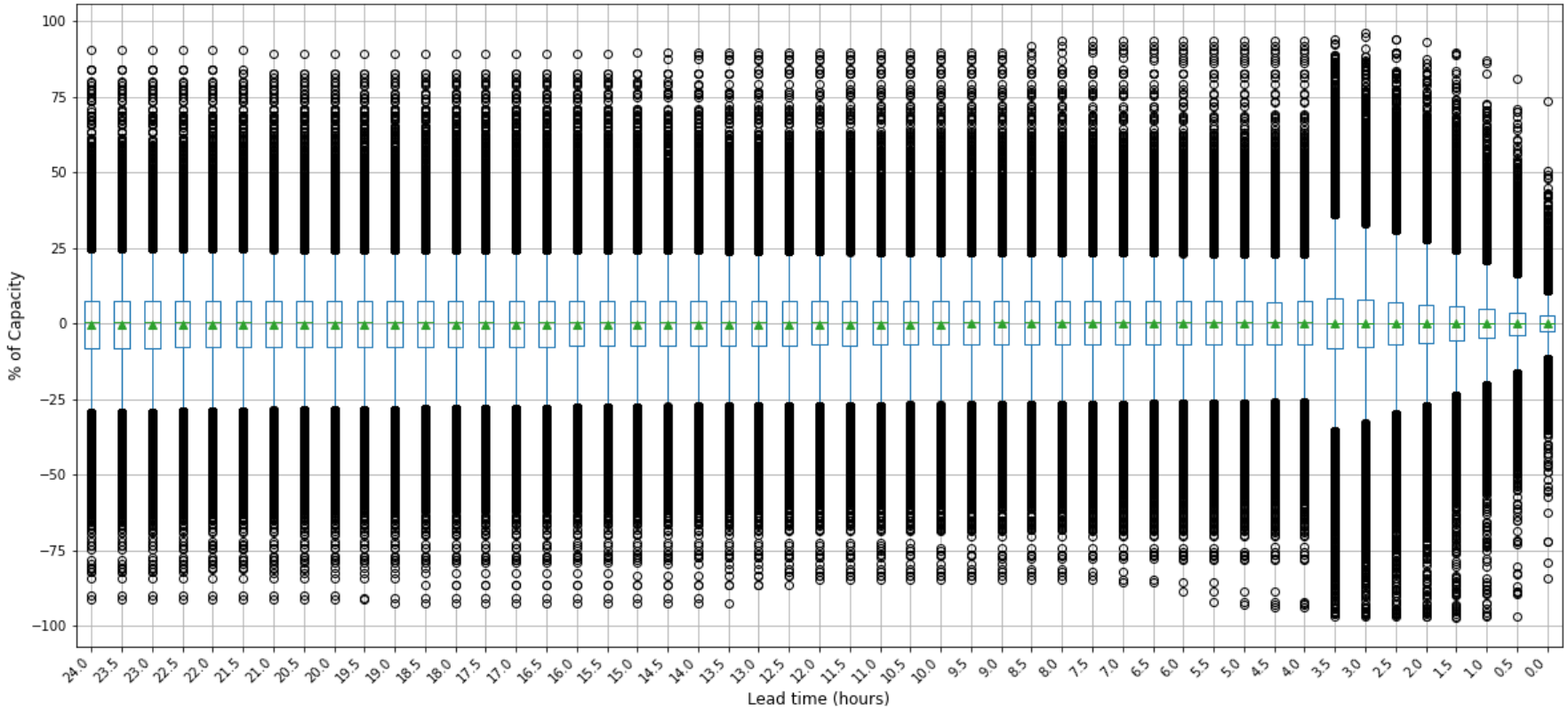
Figure 15: WDV1101 TAP0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

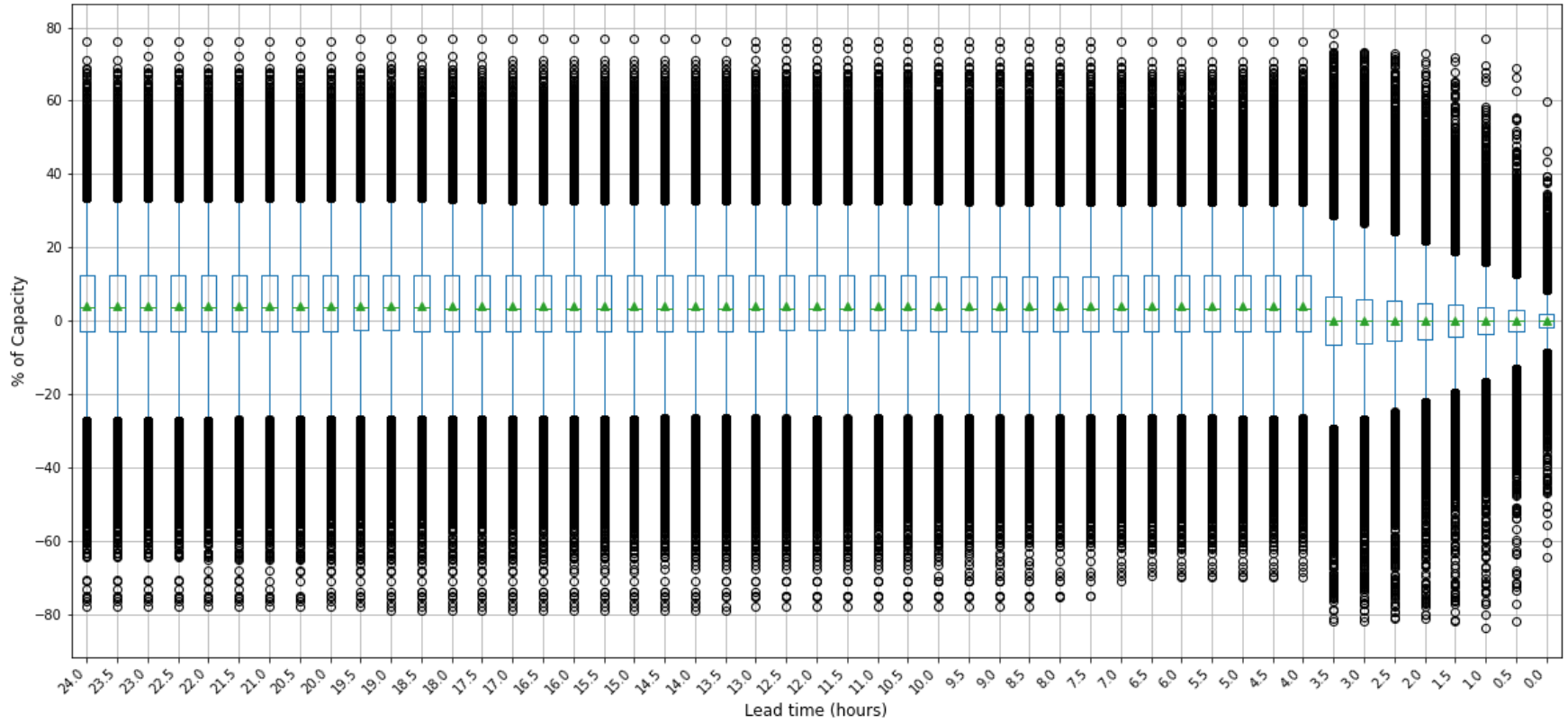
Figure 16: WIL0331 MCK0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

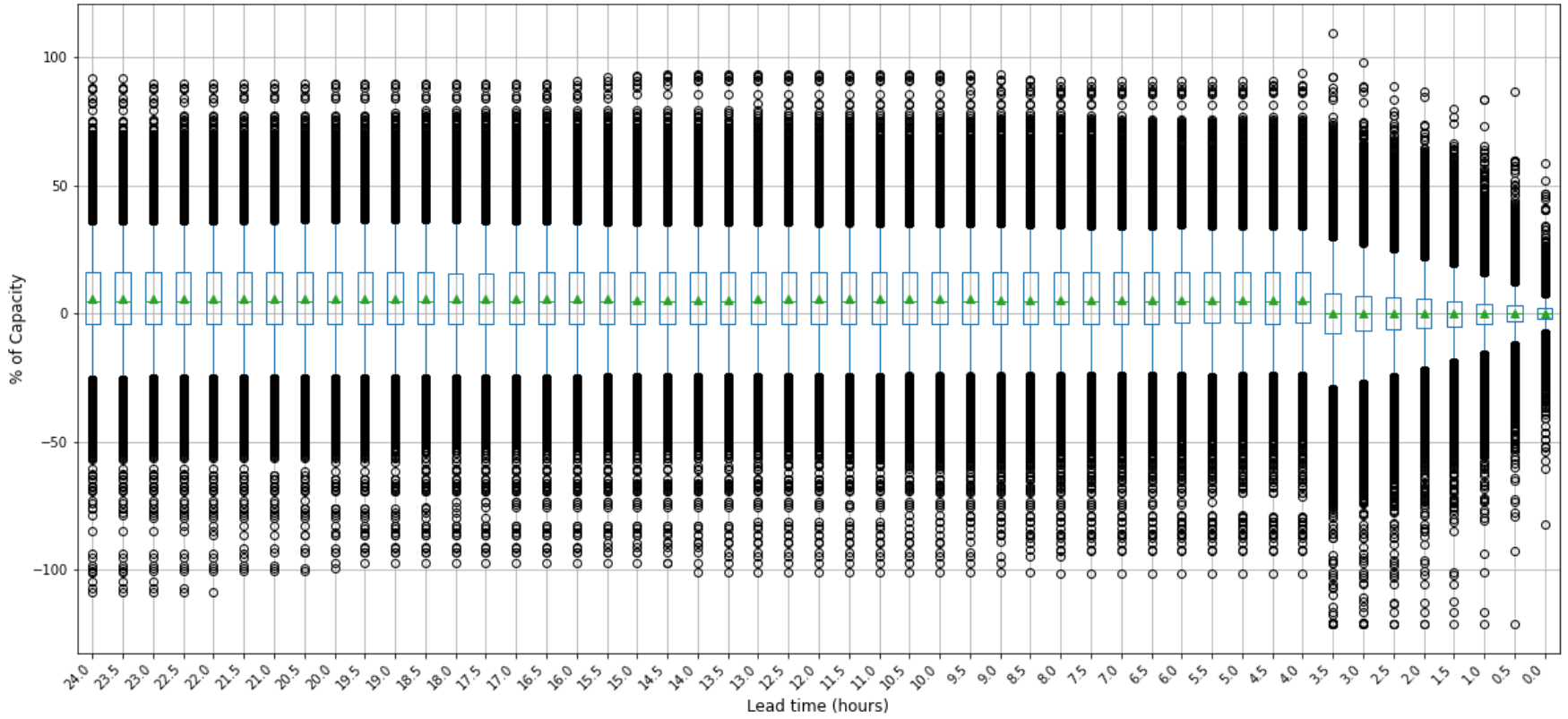
Figure 17: WWD1102 WWD0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

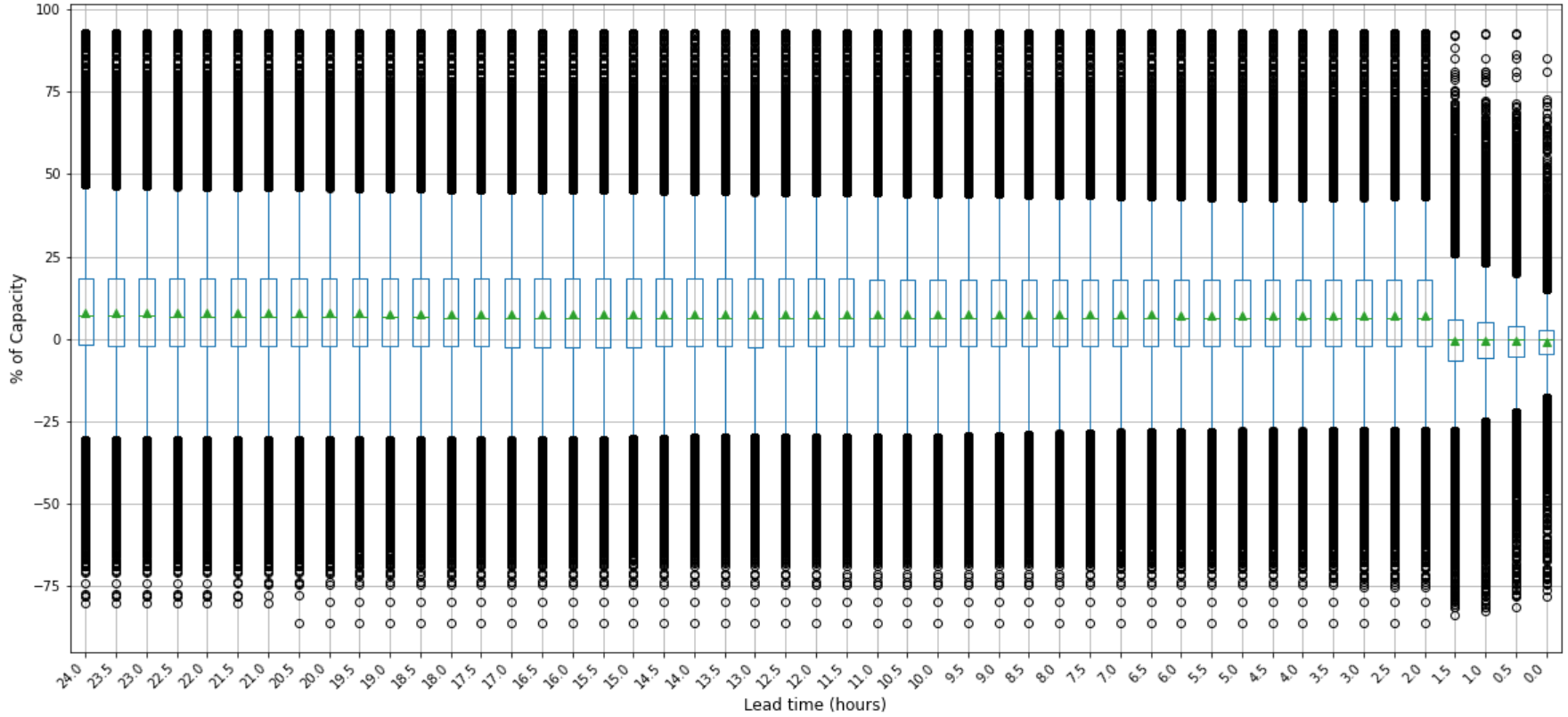
Figure 18: WWD1103 WWD0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

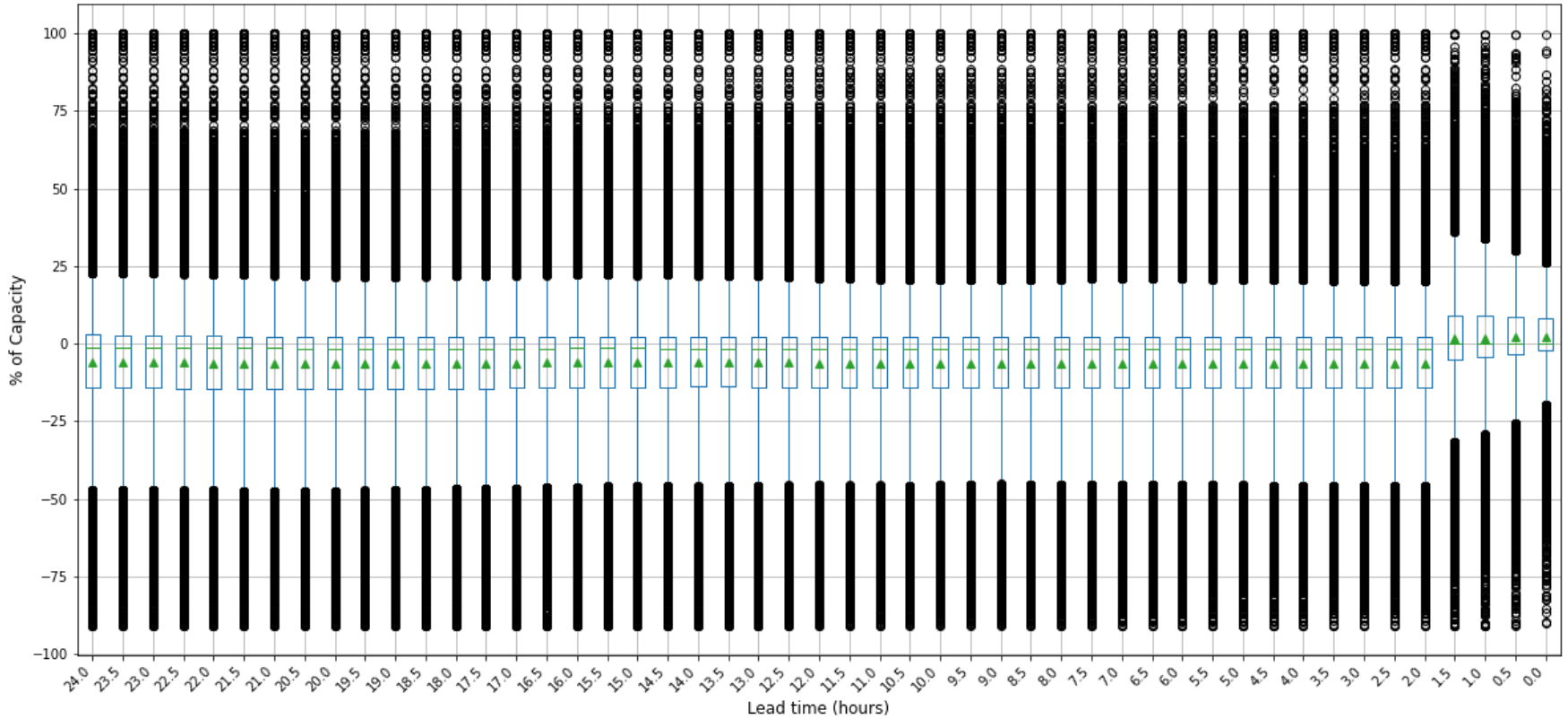
Figure 19: BPE0331 TWF0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

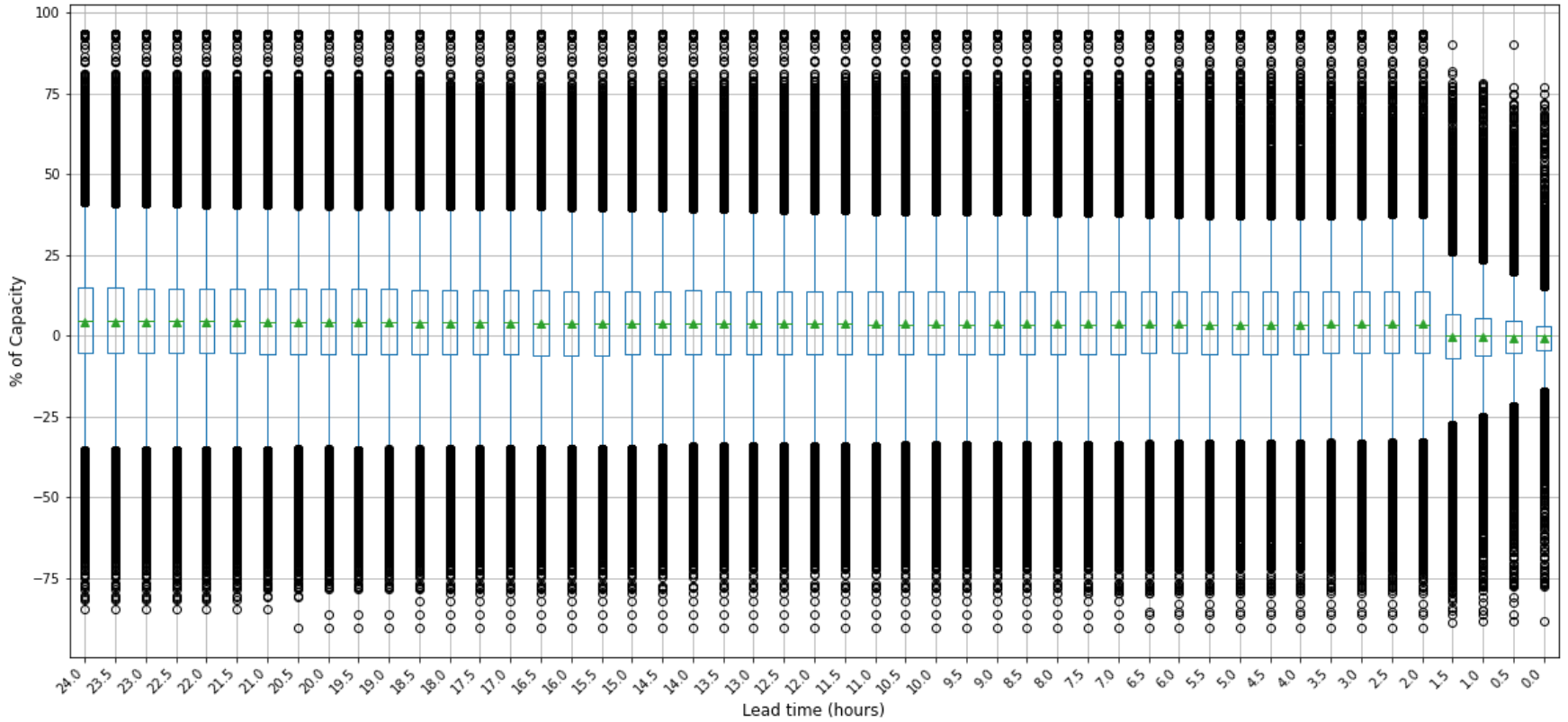
Figure 20: HWB0331 MAH0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

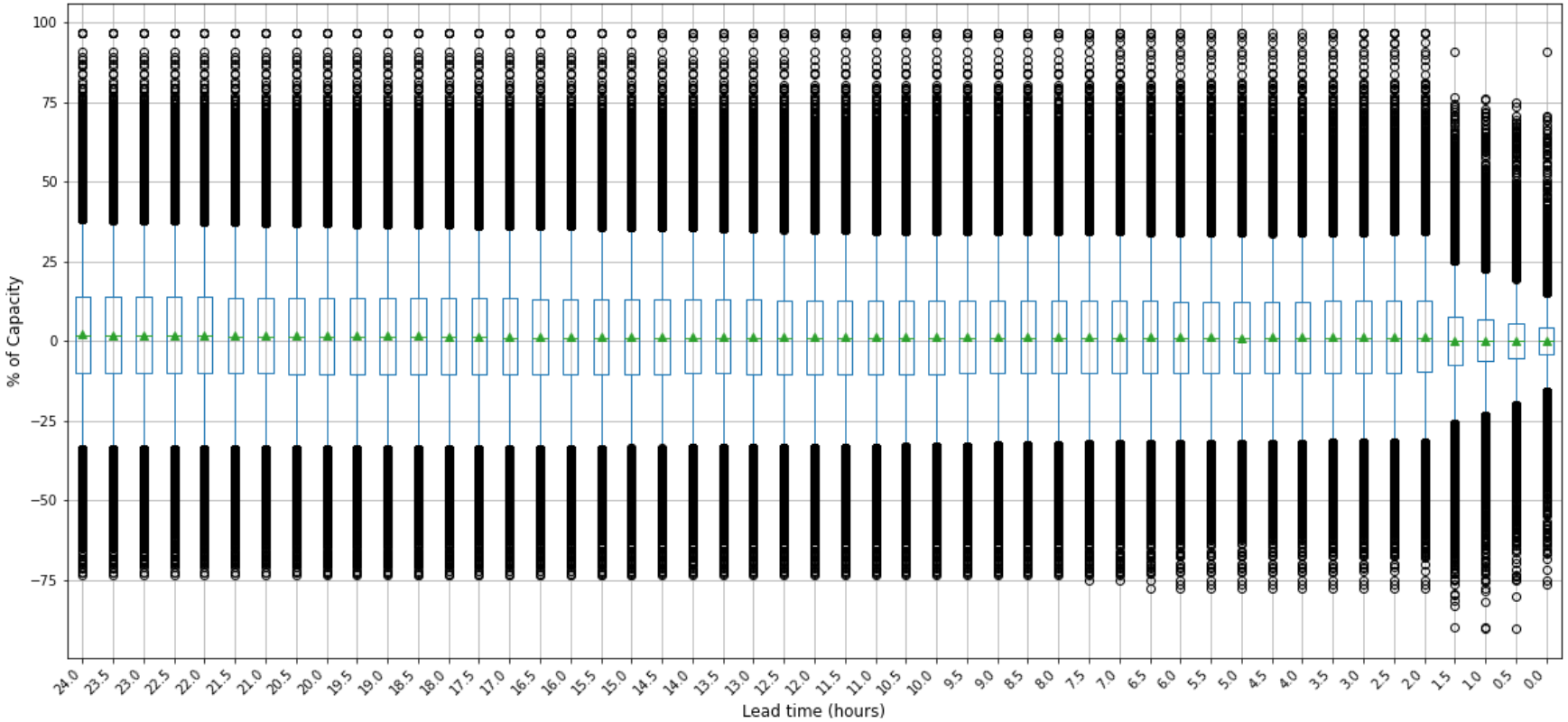
Figure 21: LTN0331 TWF0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

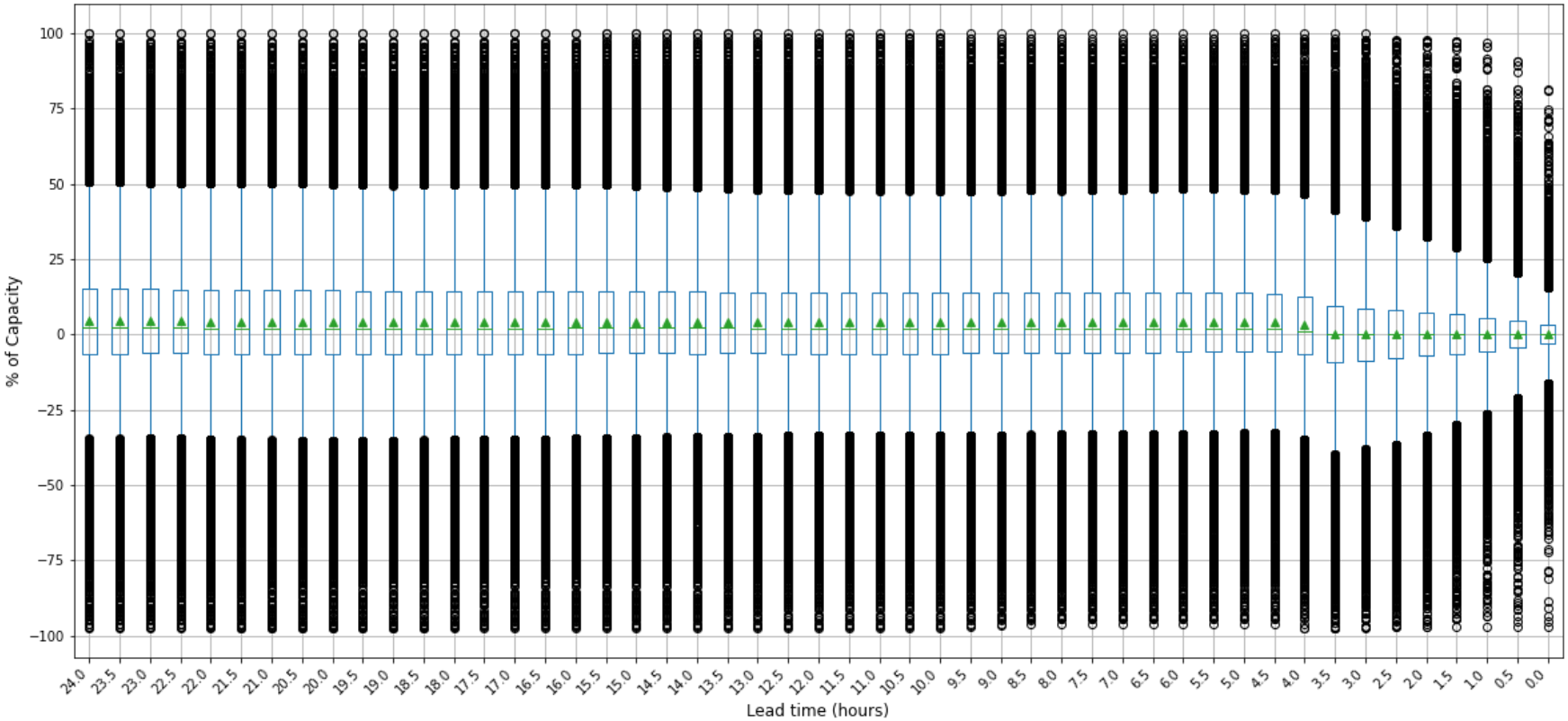
Figure 22: TWC2201 TWF0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

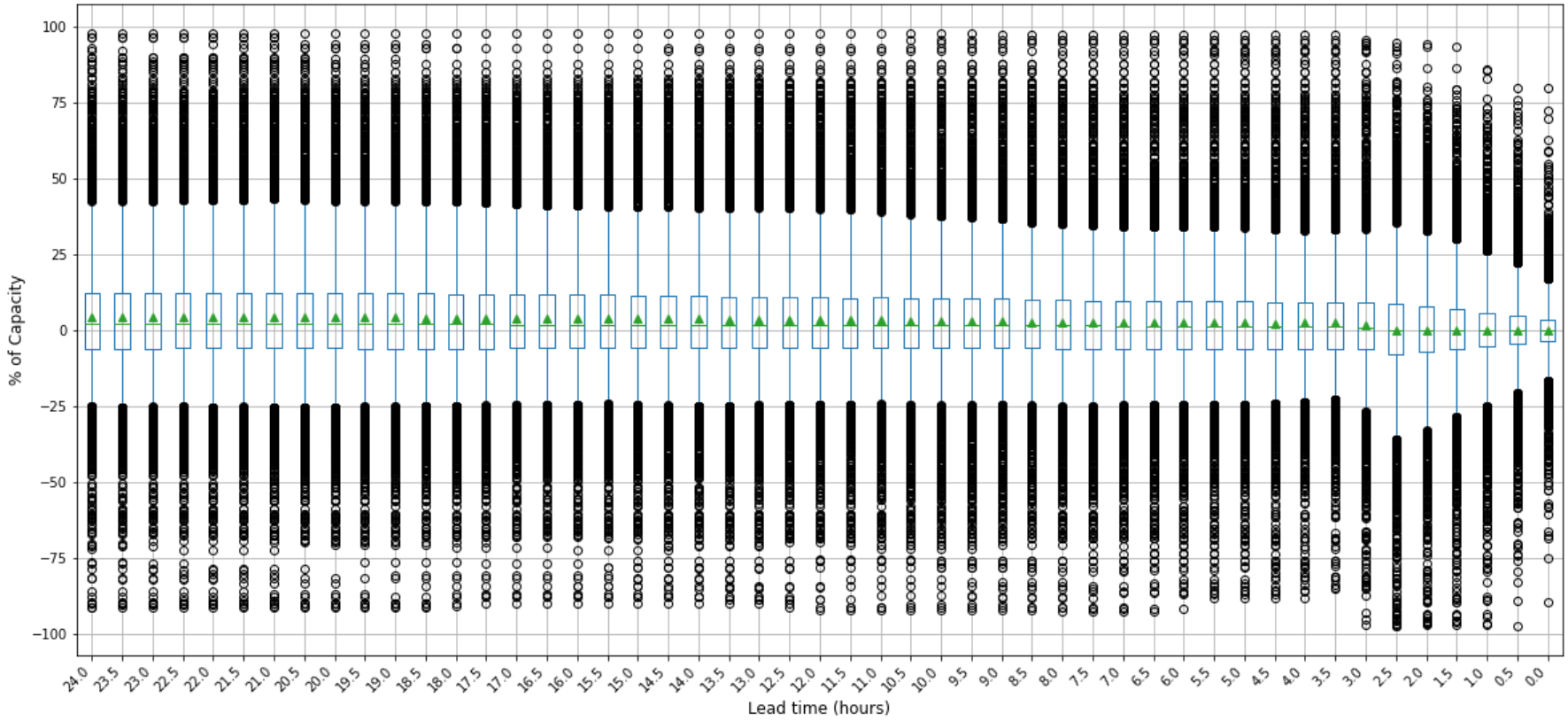
Figure 23: WVY1101 WPP0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
6. Blue boxes indicate lower and upper quartile and median
7. Blue whiskers extend to 5th and 95th percentiles
8. Black circles indicate outliers beyond 5th and 95th percentiles
9. Green triangles indicate mean
10. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

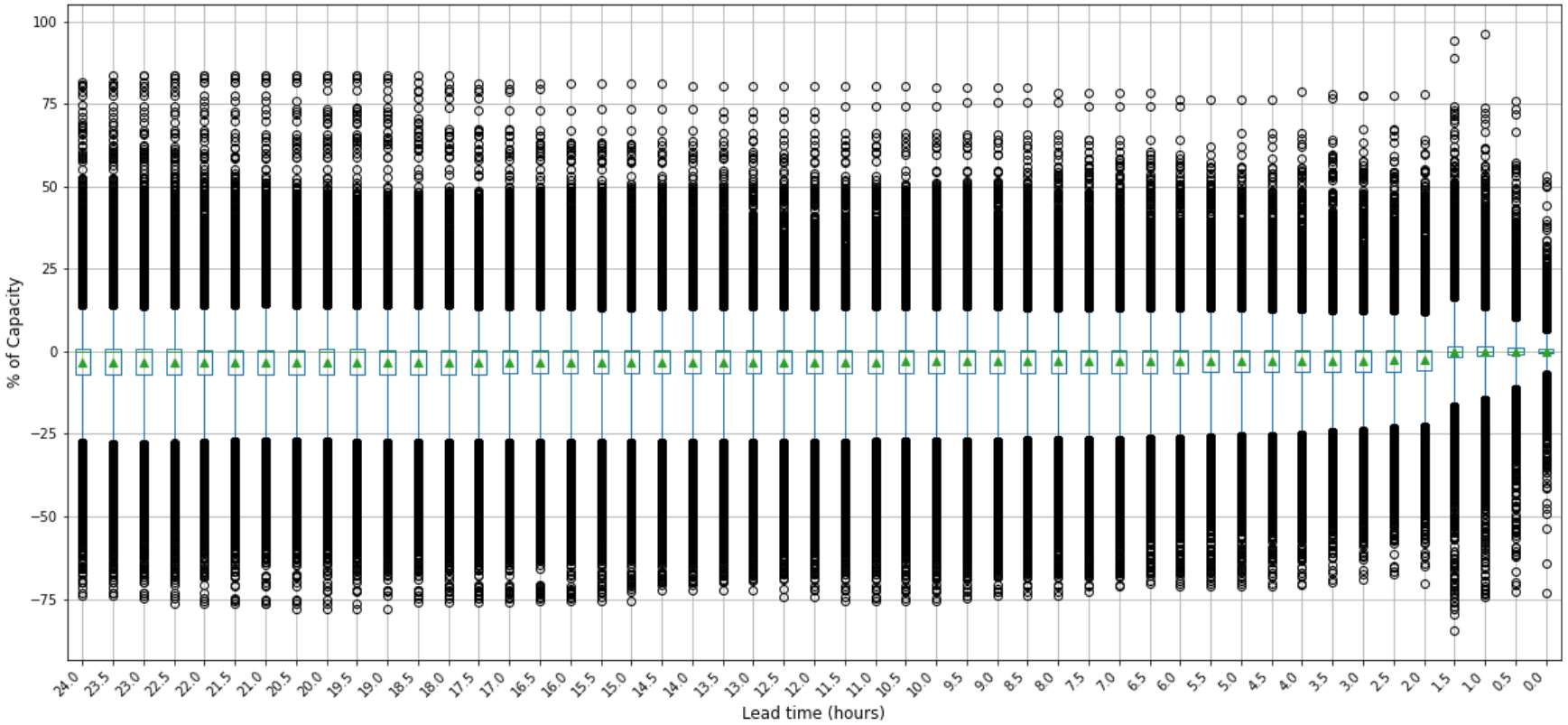
Figure 24: WVY1101 WPP0 forecast error over 9 June 2022 to 11 September 2022 (Meteologica forecast)



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

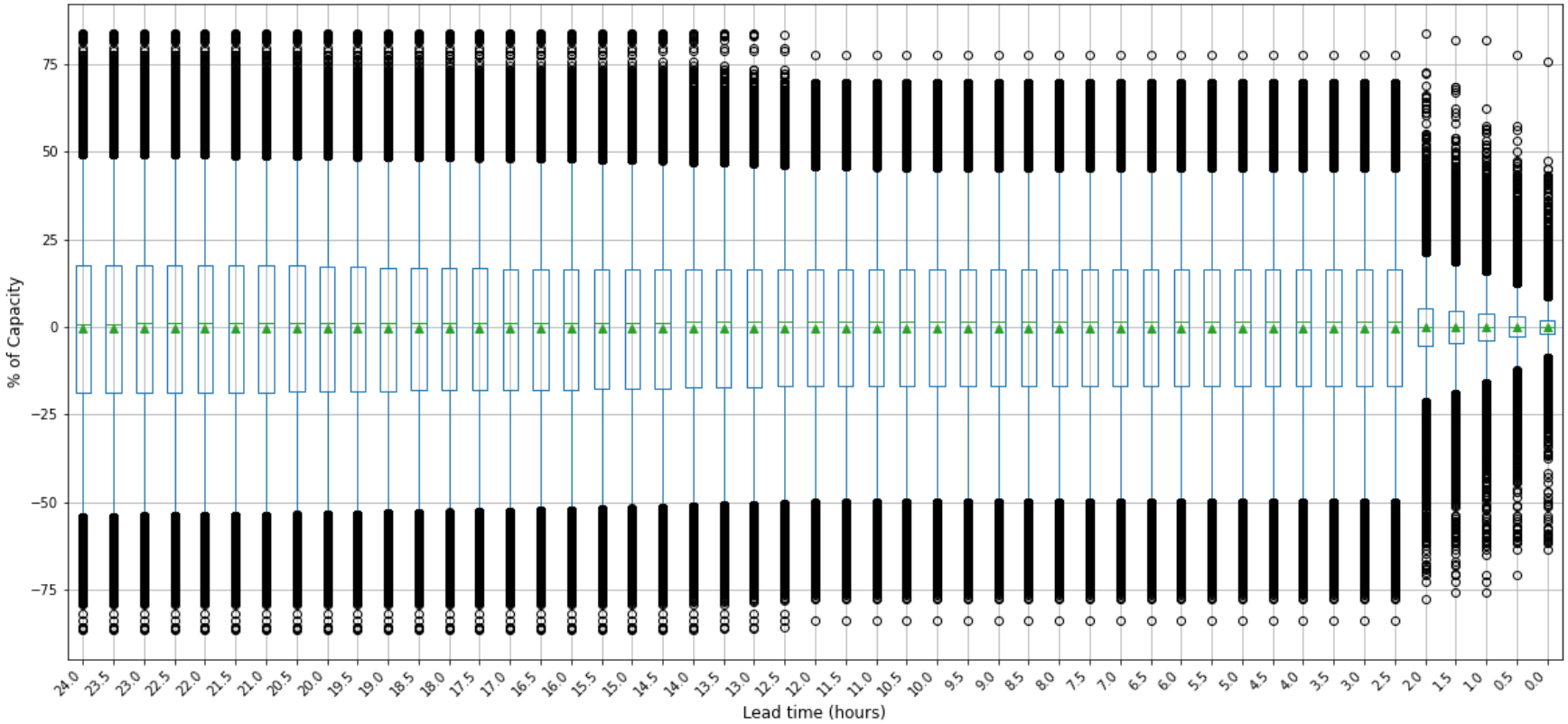
Figure 25: LTN2201 TUR0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

Figure 26: TWC2201 NZW0 forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Capacity

Appendix B Individual non-conforming GXP forecast error plots

B.1 Forecast error box and whisker plots for individual non-conforming GXPs are shown in this appendix, in terms of both MW and percent.

B.2 Further commentary can be found in the body of the report.

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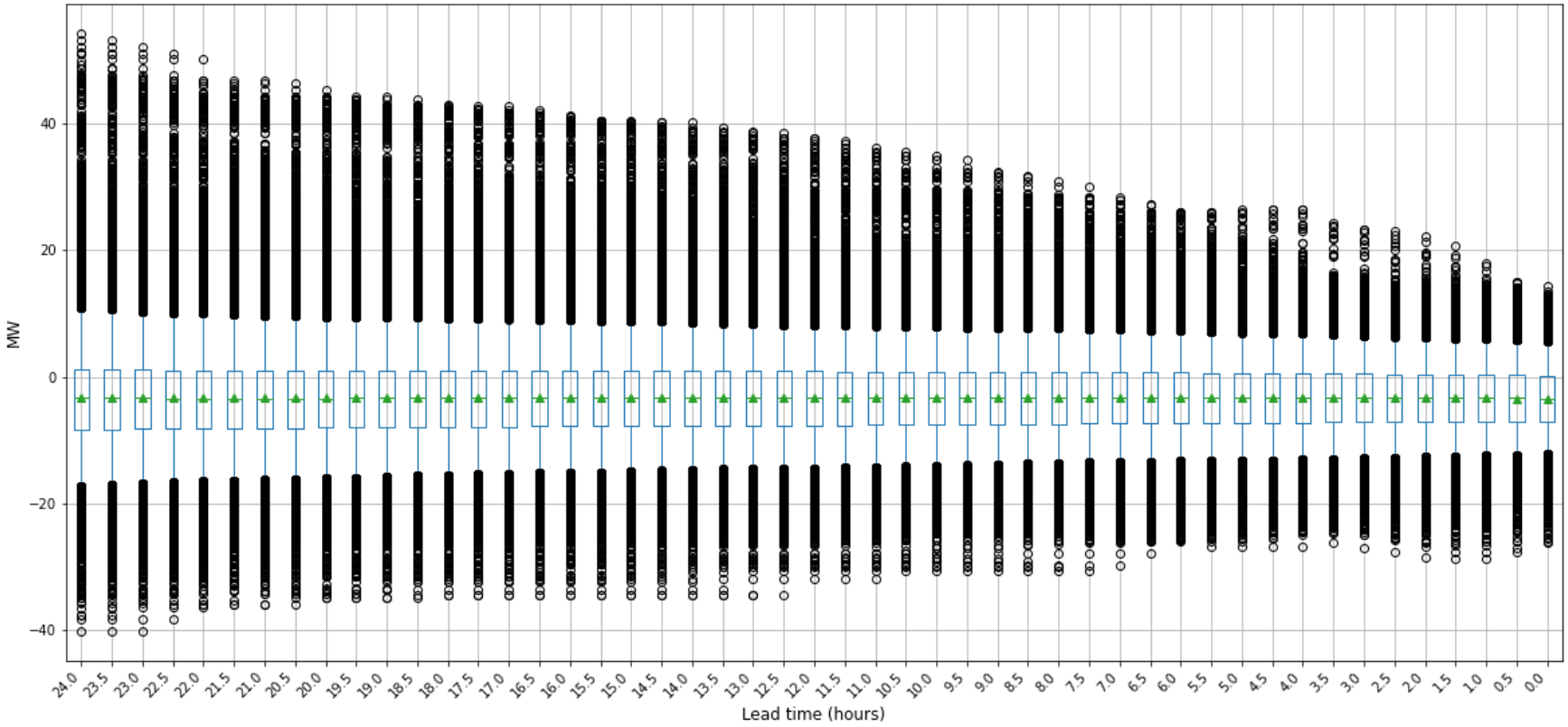
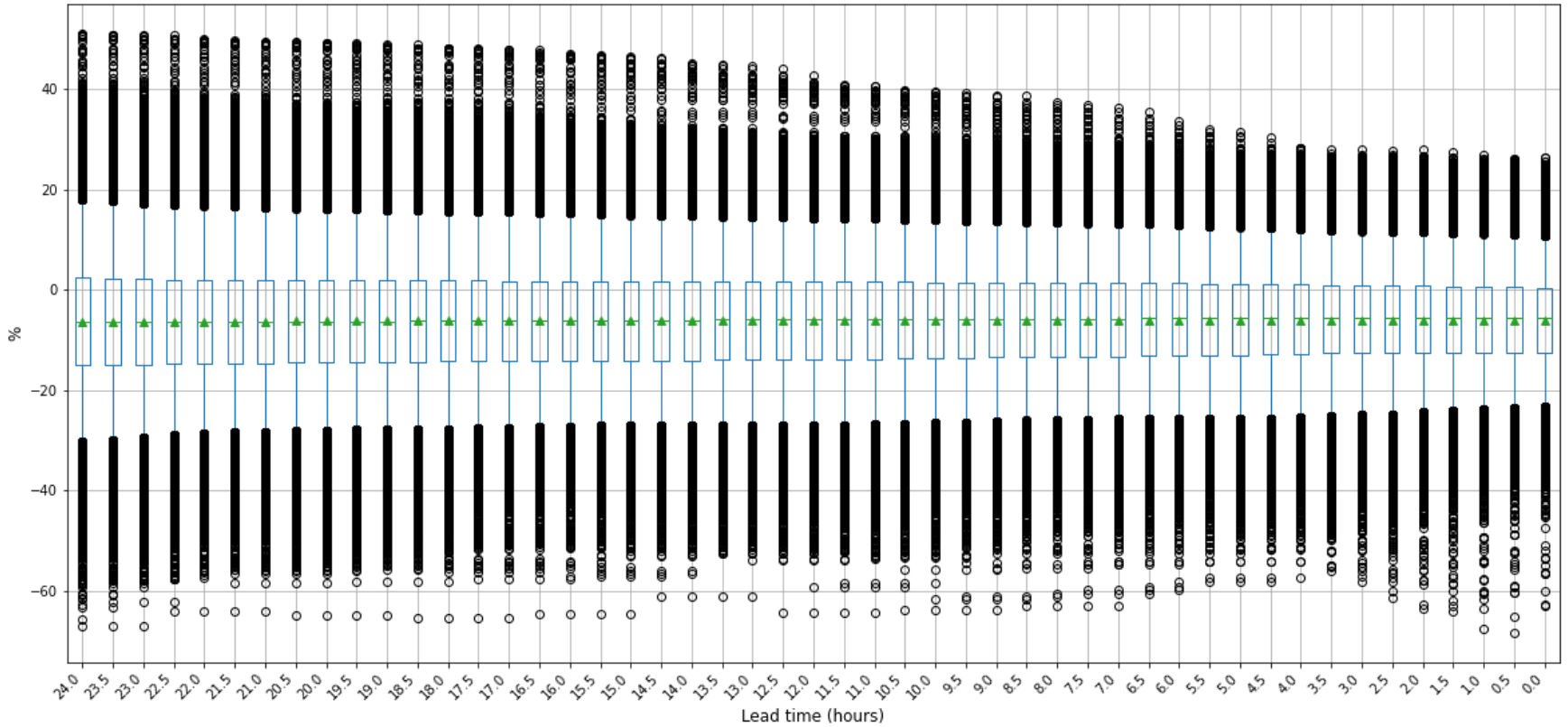
Figure 27: ASB0661 (various retailers) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

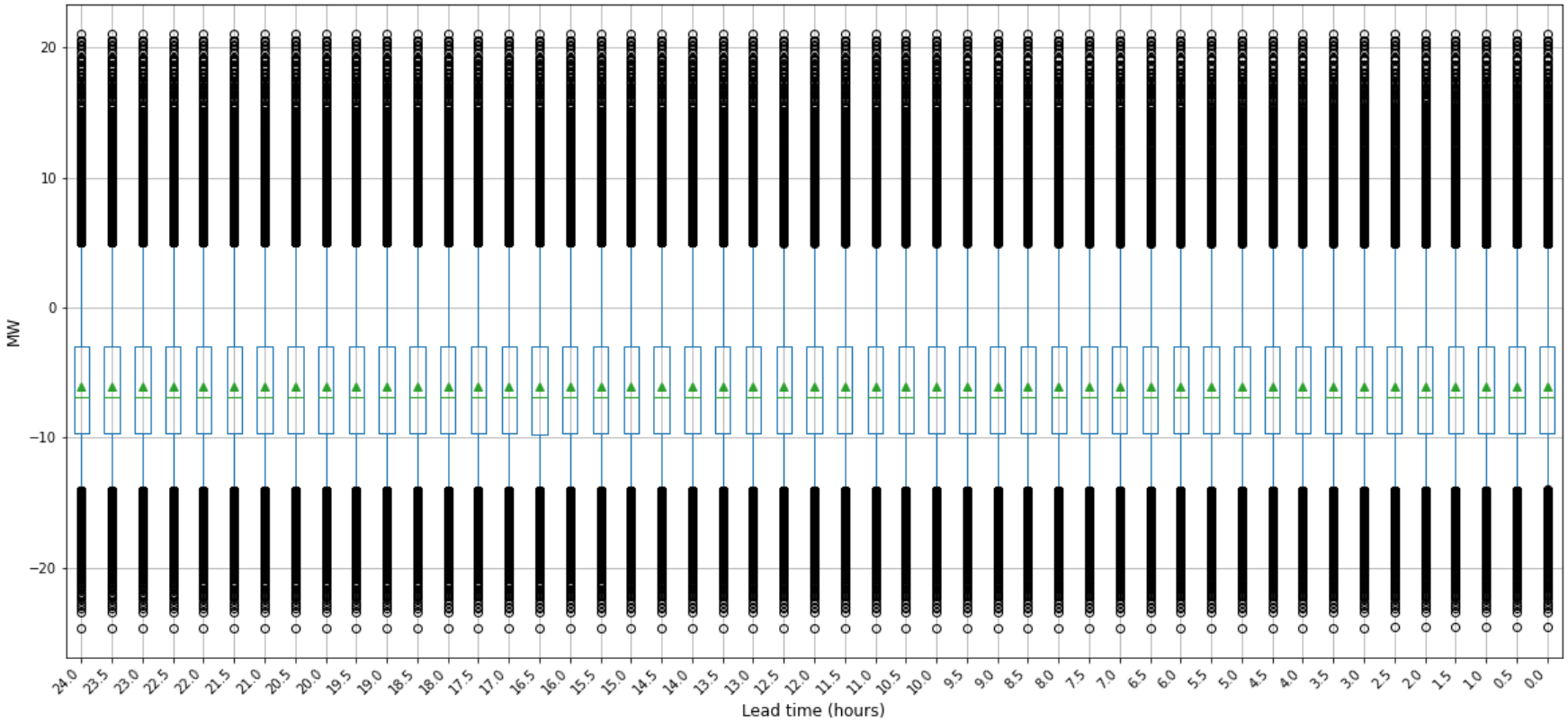
Figure 28: ASB0661 (various retailers) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast

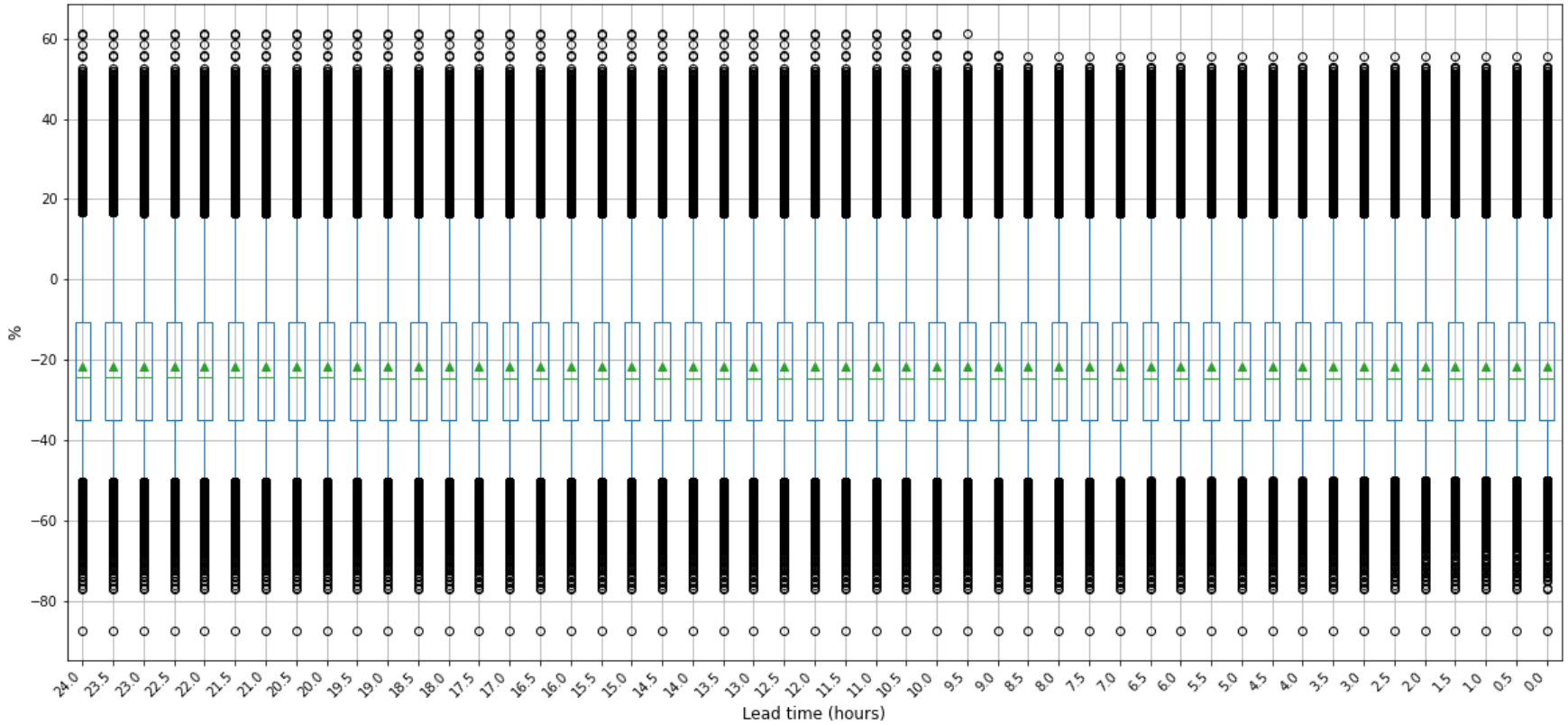
Figure 29: EDG0331 (various retailers) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

Figure 30: EDG0331 (various retailers) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast

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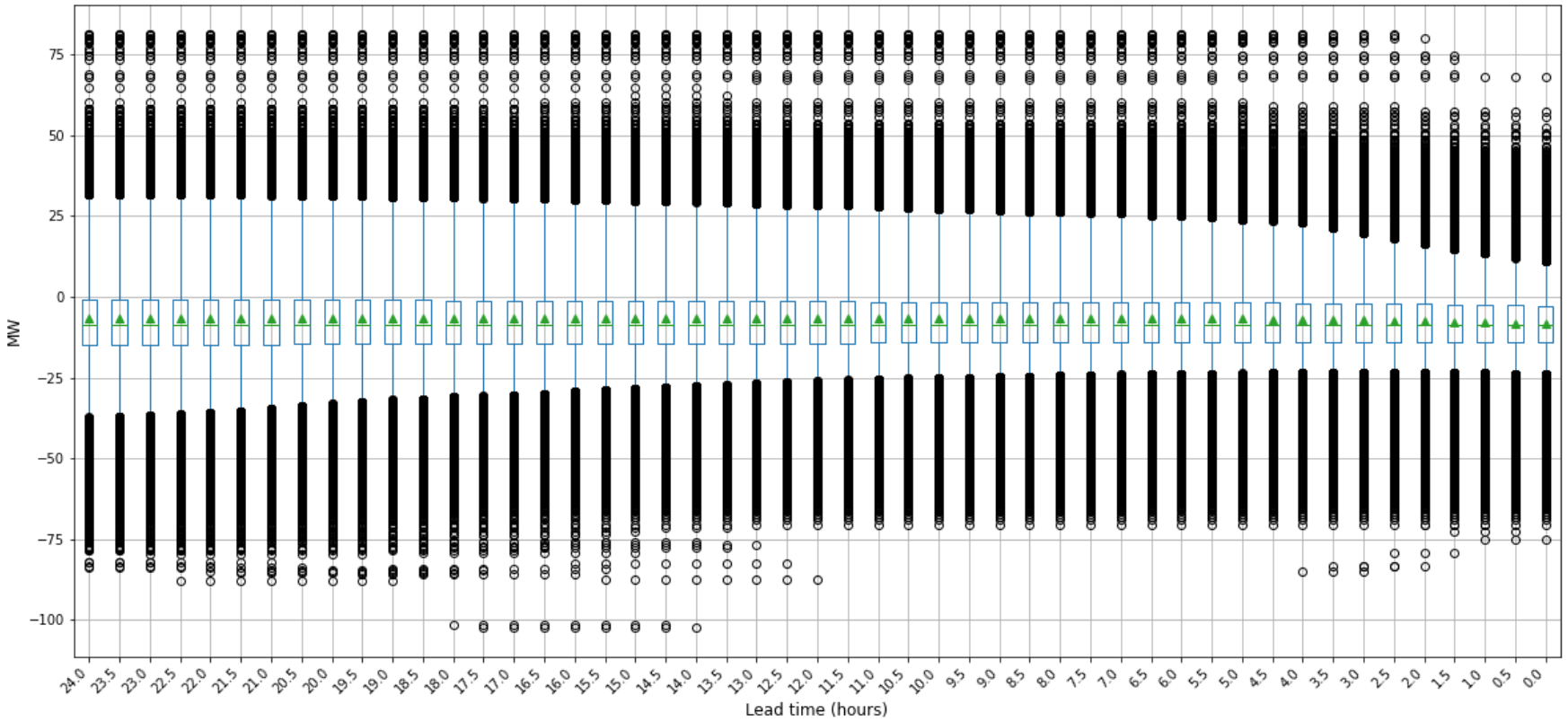
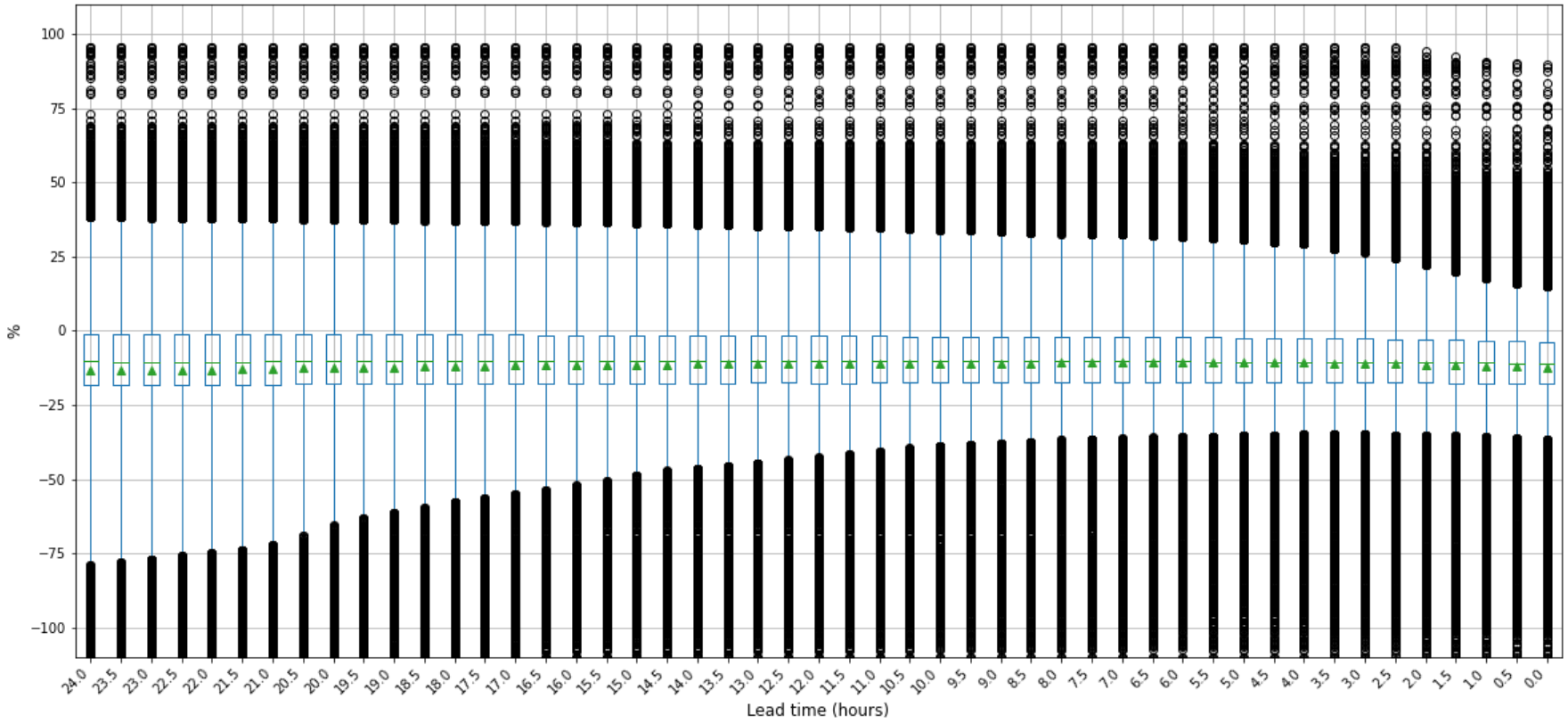
Figure 31: GLN0331 (NZ Steel) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

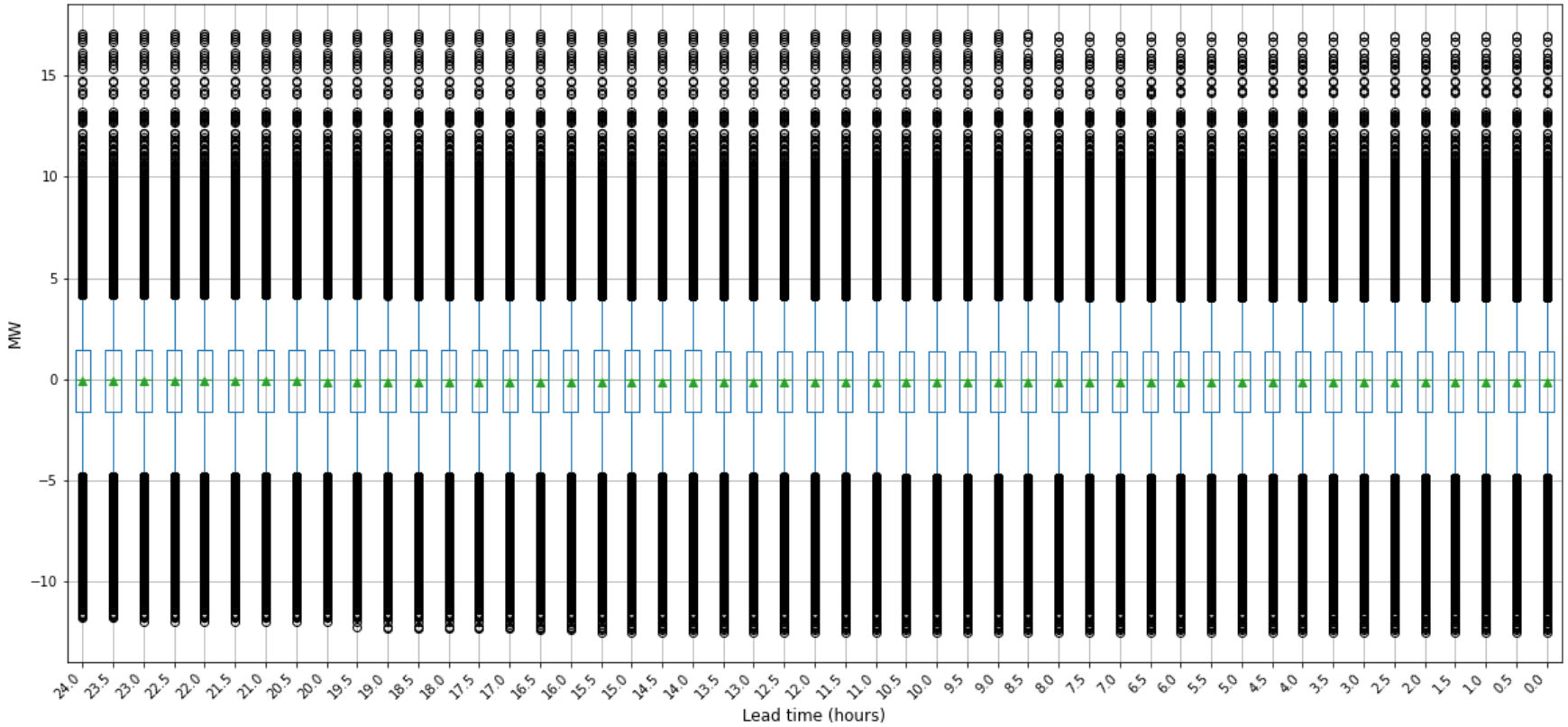
Figure 32: GLN0331 (NZ Steel) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast
6. Truncated at -110%

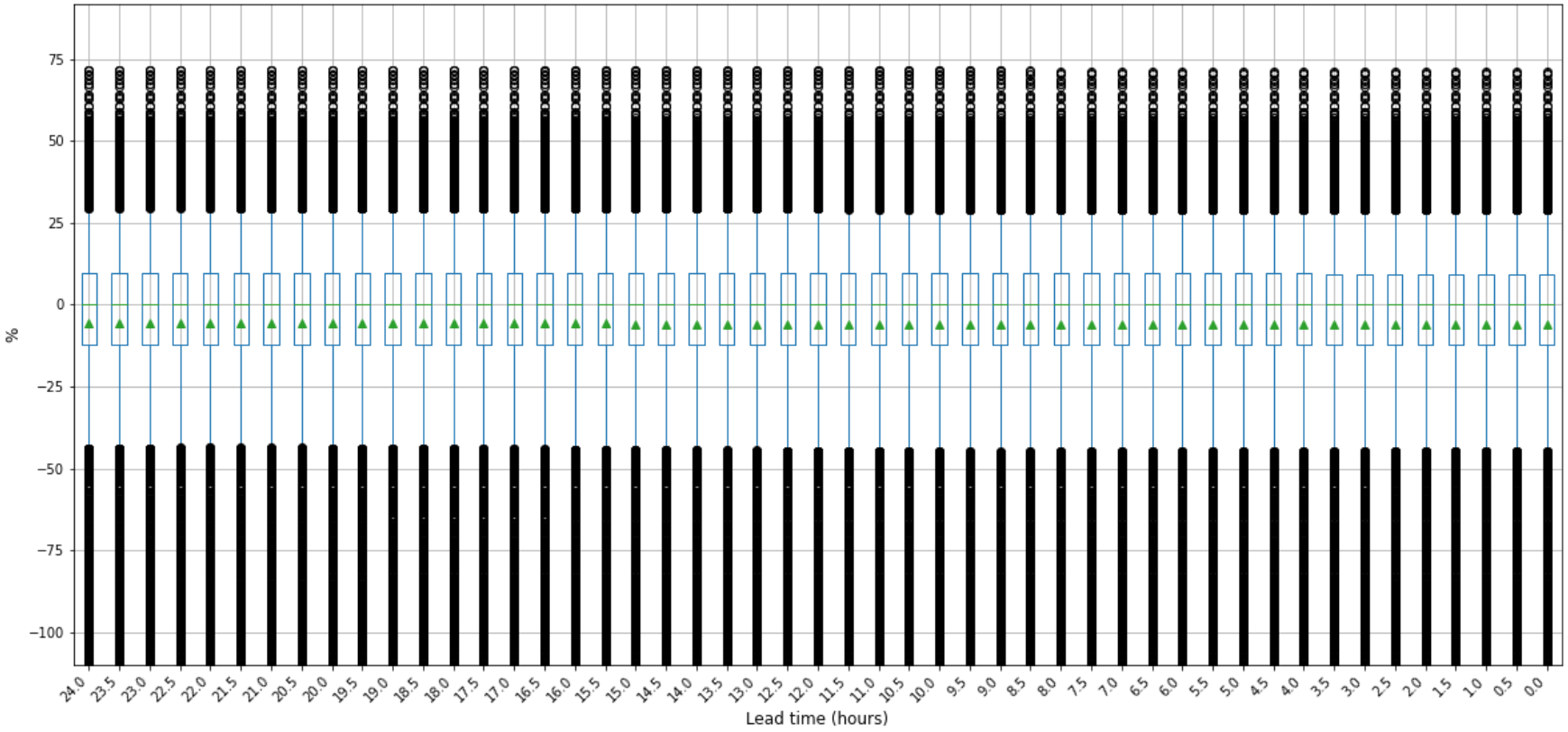
Figure 33: KAW0111 (various retailers) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

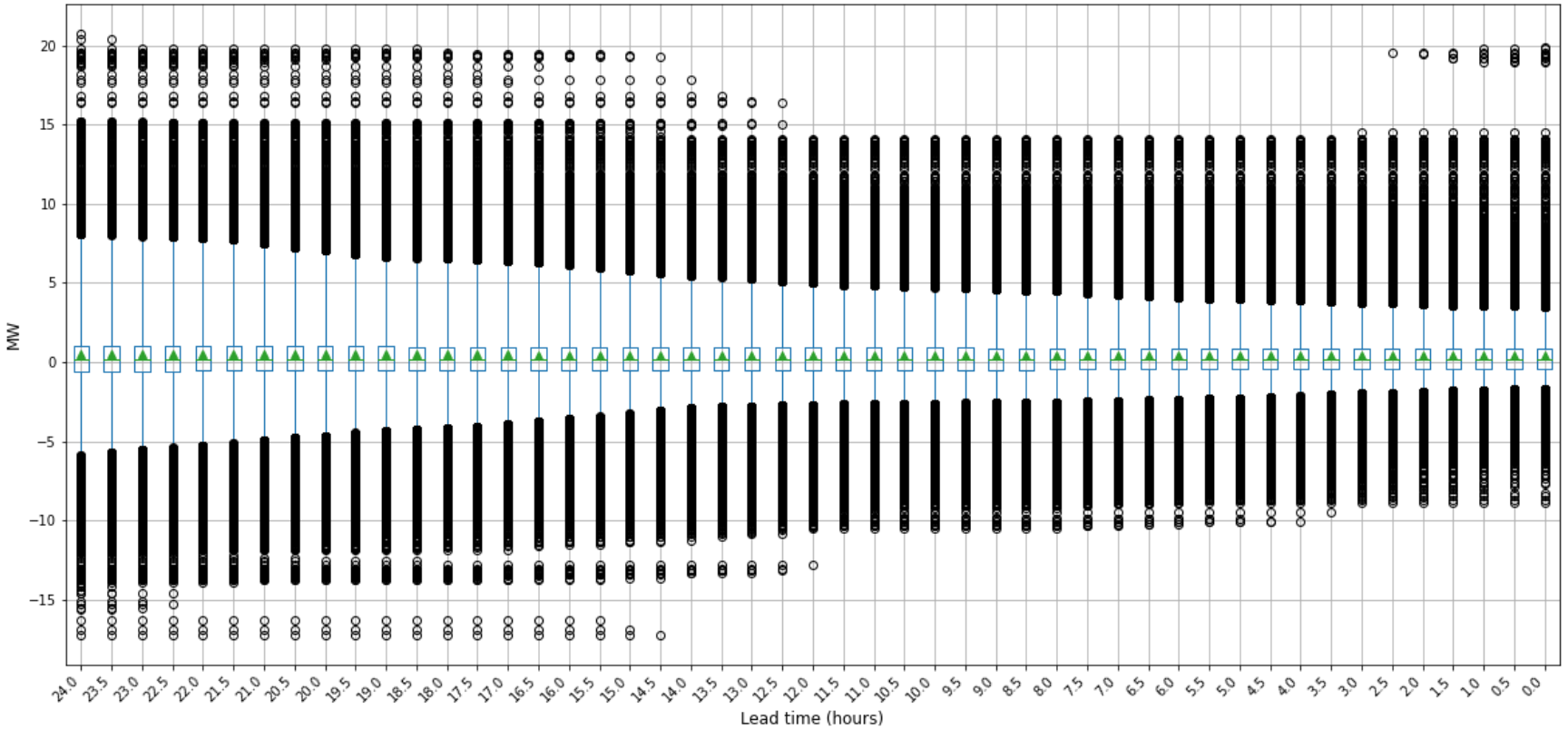
Figure 34: KAW0111 (various retailers) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast
6. Truncated at -110%

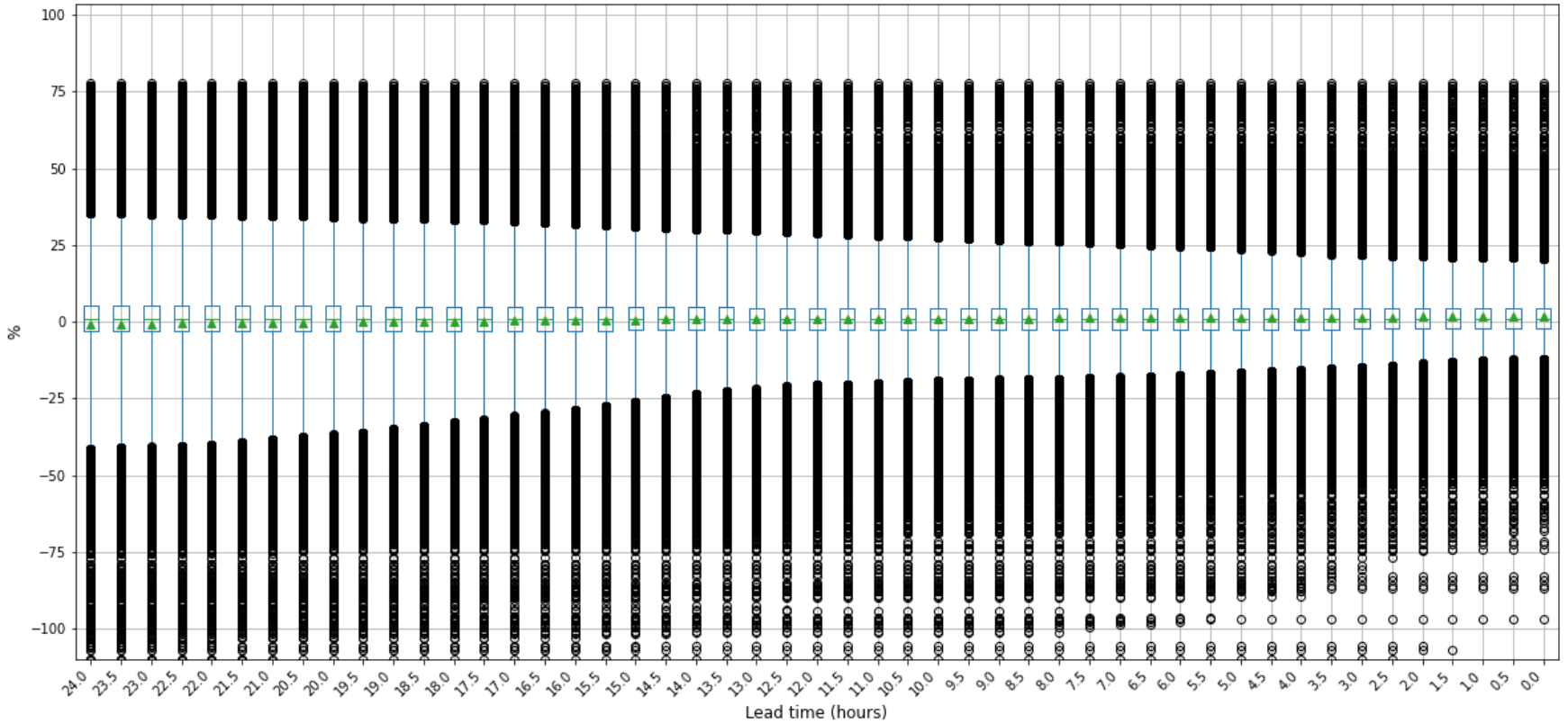
Figure 35: KAW0112 (Norske Skog Tasman) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

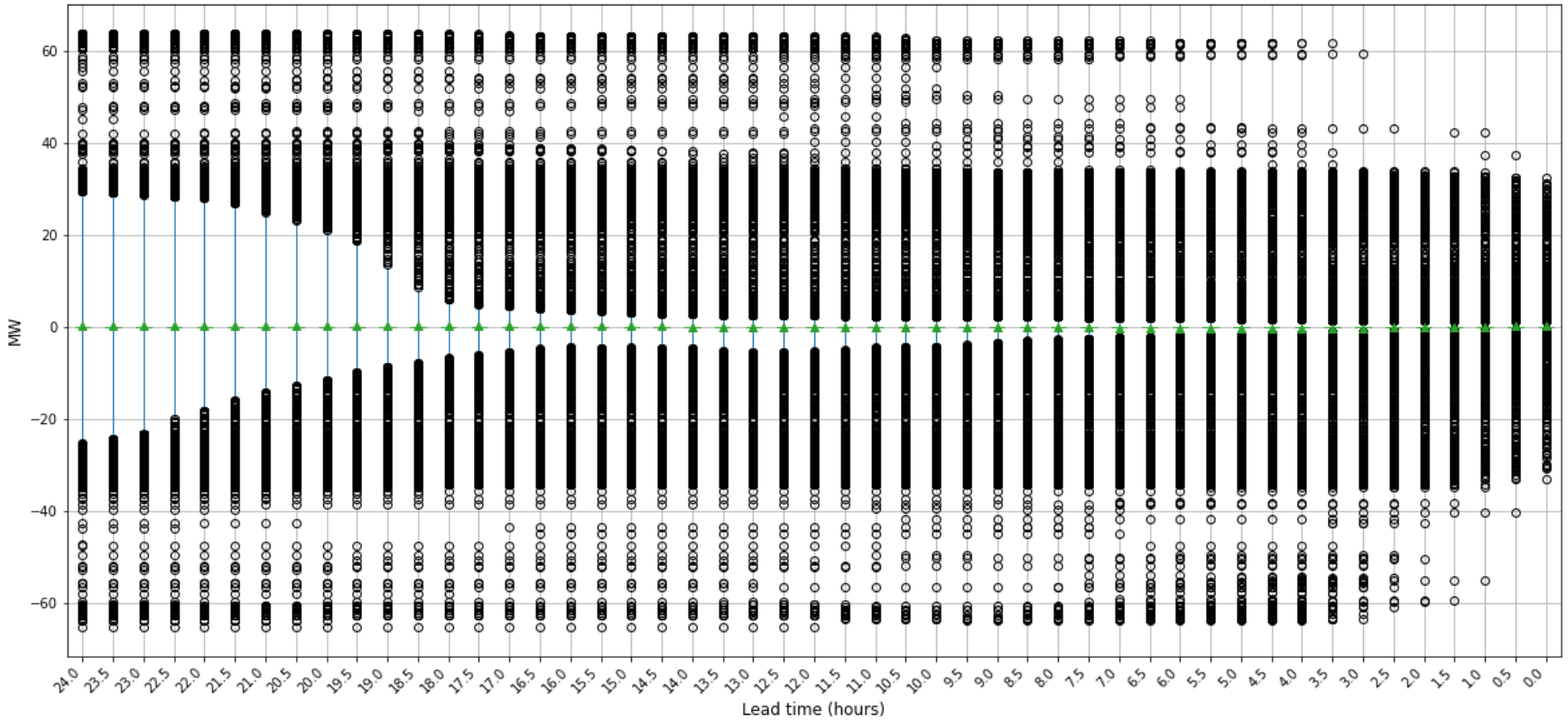
Figure 36: KAW0112 (Norske Skog Tasman) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast
6. Truncated at -110%

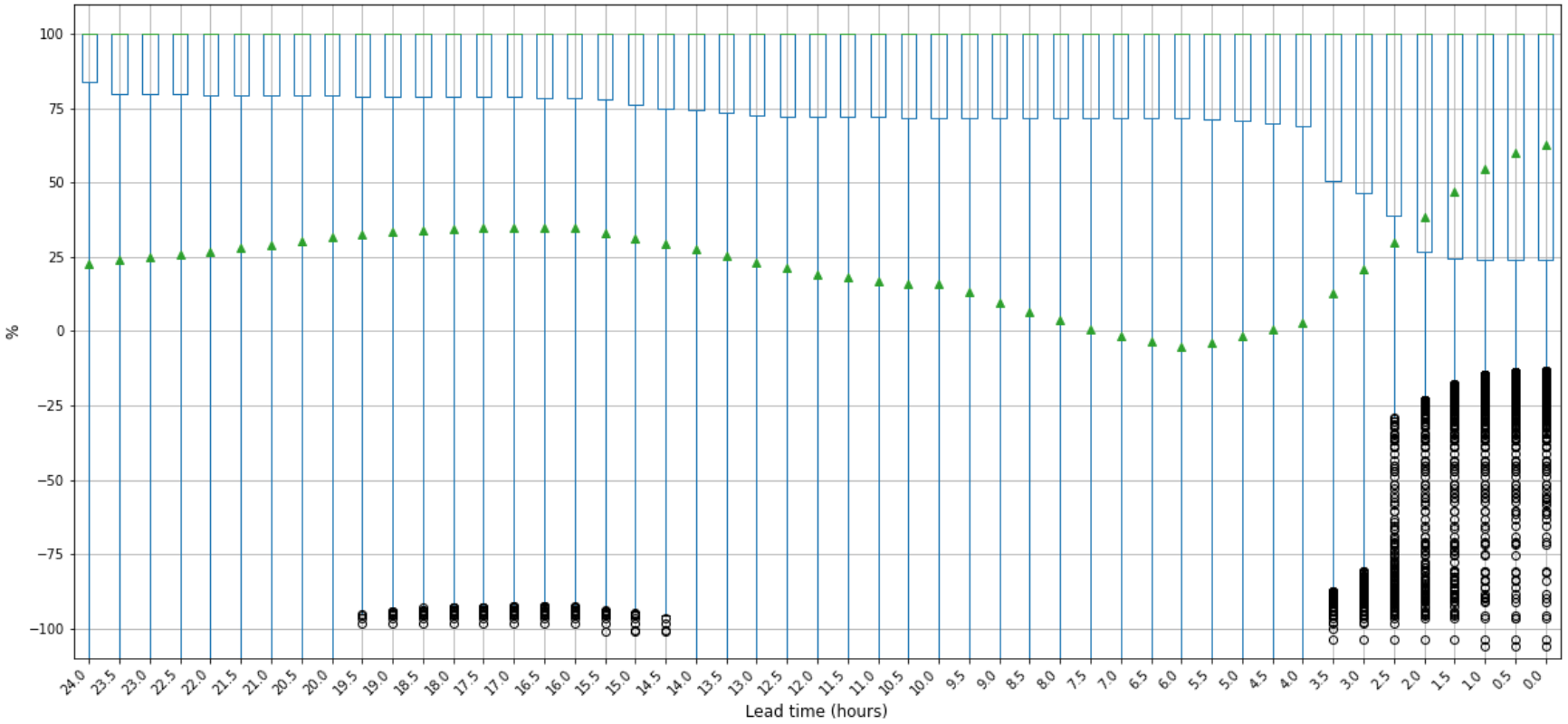
Figure 37: KAW0113 (Norske Skog Tasman) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

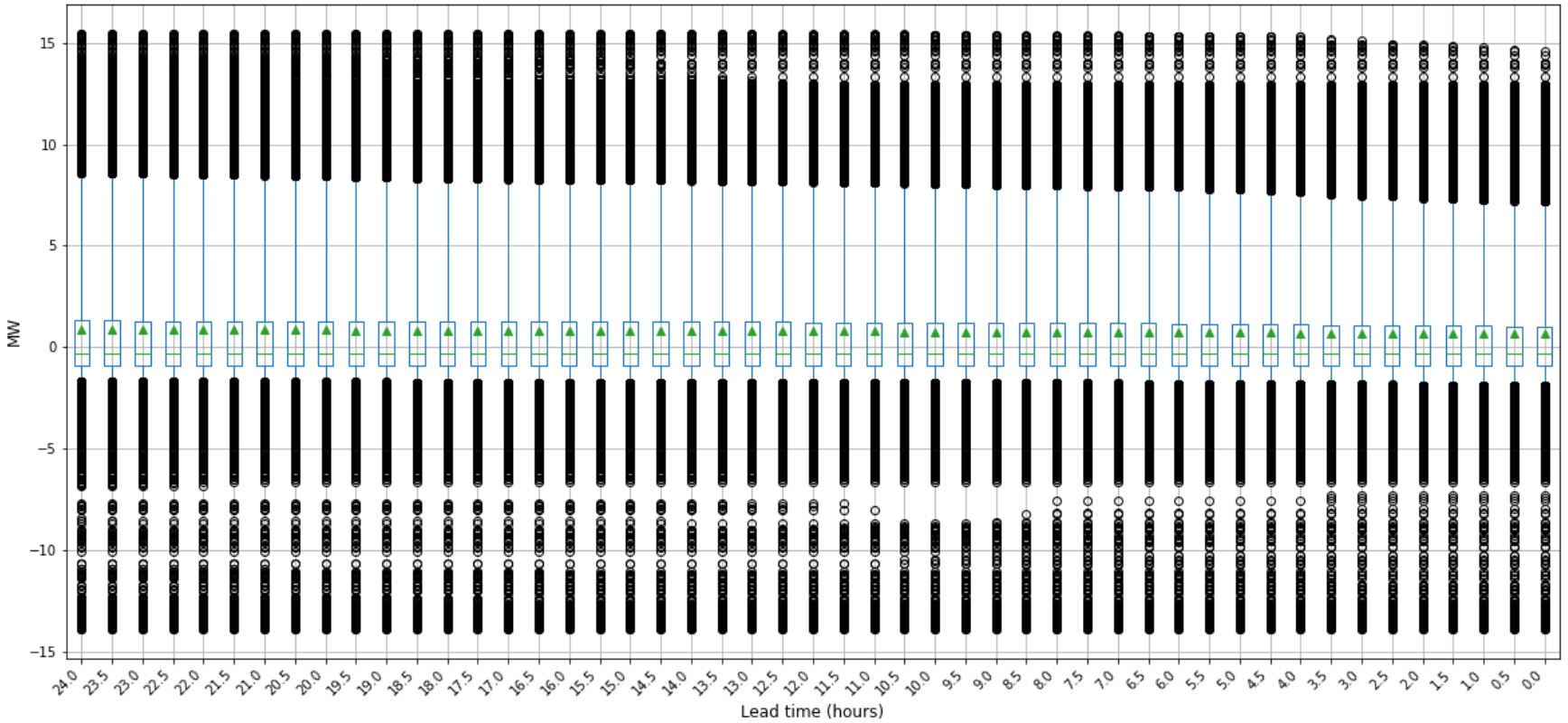
Figure 38: KAW0113 (Norske Skog Tasman) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast
6. Truncated at -110%

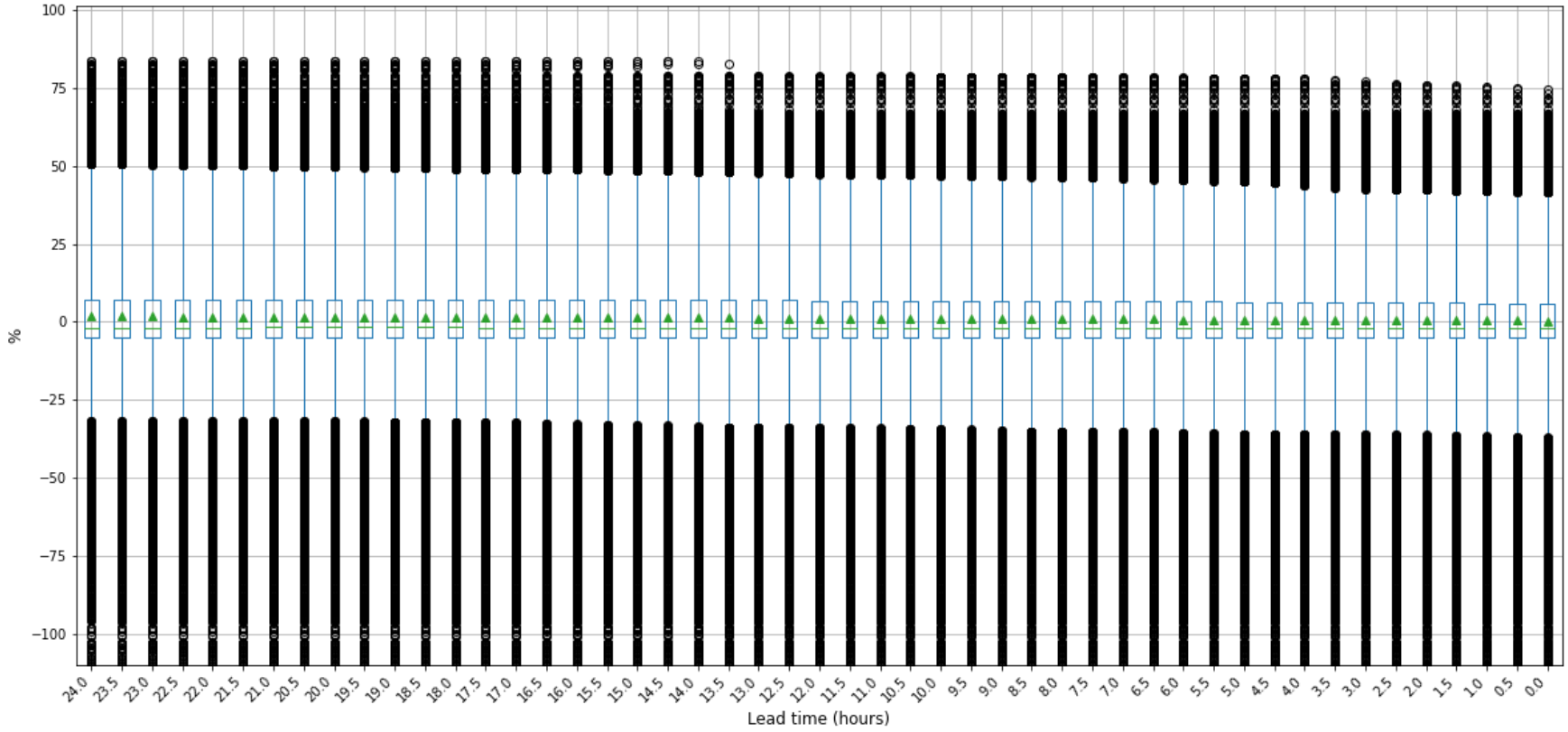
Figure 39: KIN0111 (Oji Fibre Solutions) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

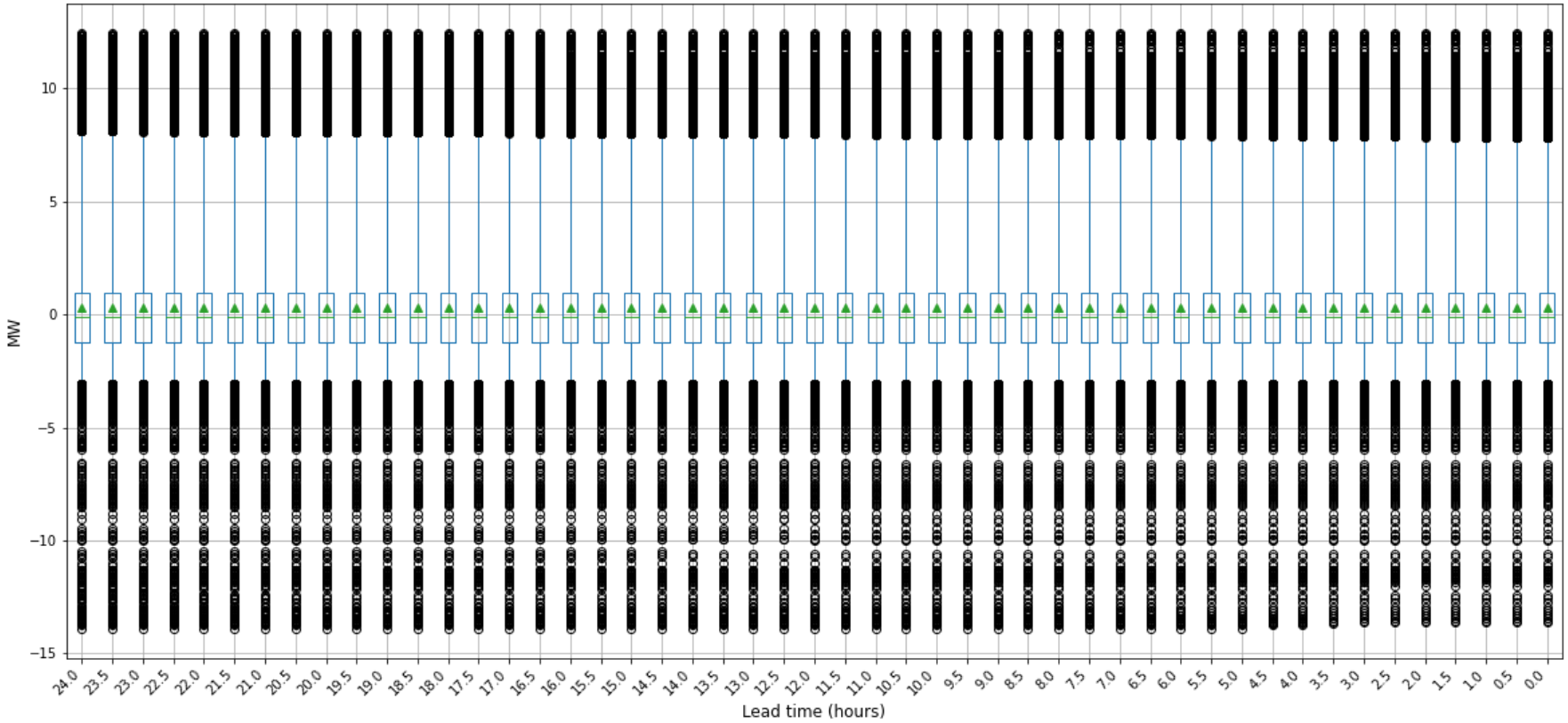
Figure 40: KIN0111 (Oji Fibre Solutions) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast
6. Truncated at -110%

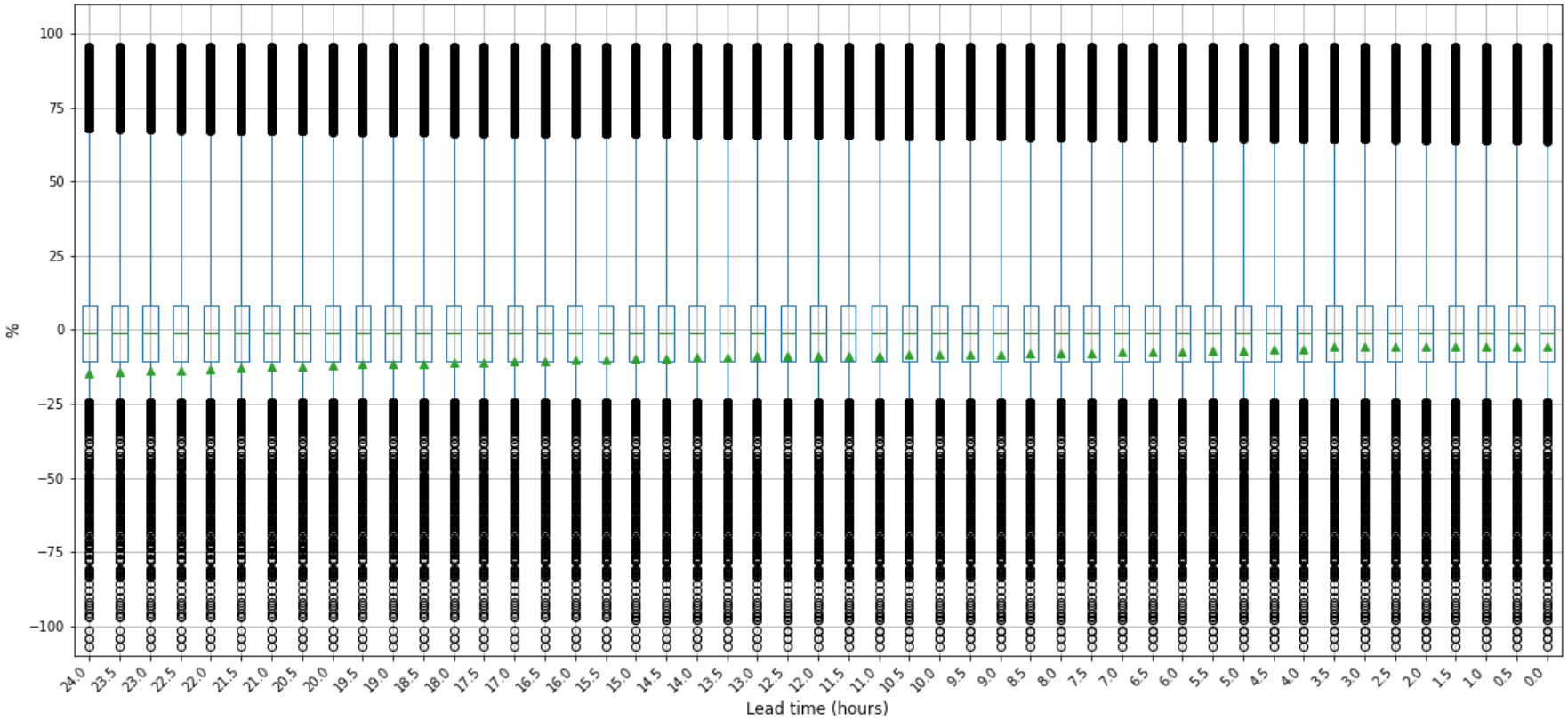
Figure 41: KIN0112 (Oji Fibre Solutions) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

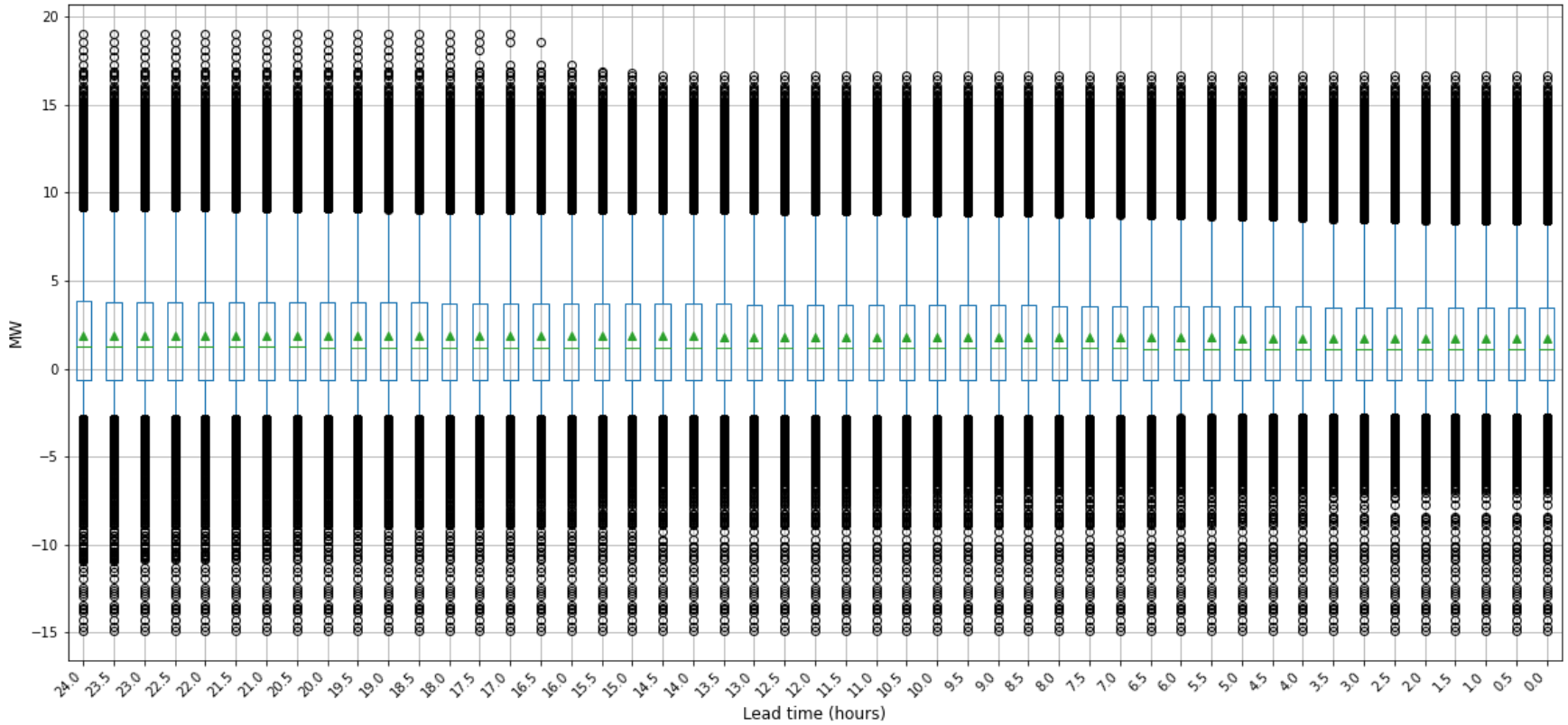
Figure 42: KIN0112 (Oji Fibre Solutions) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast
6. Truncated at -110%

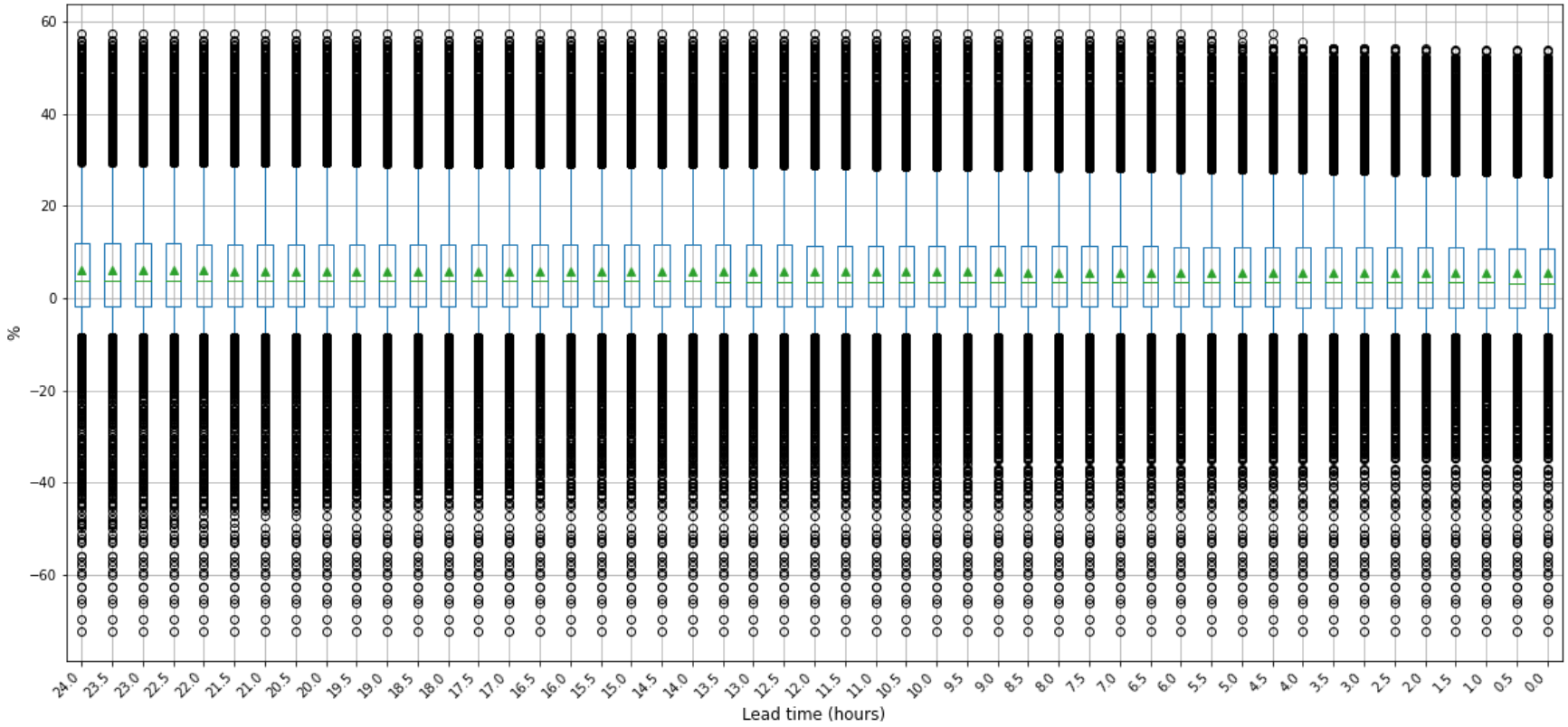
Figure 43: KIN0113 (Oji Fibre Solutions) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

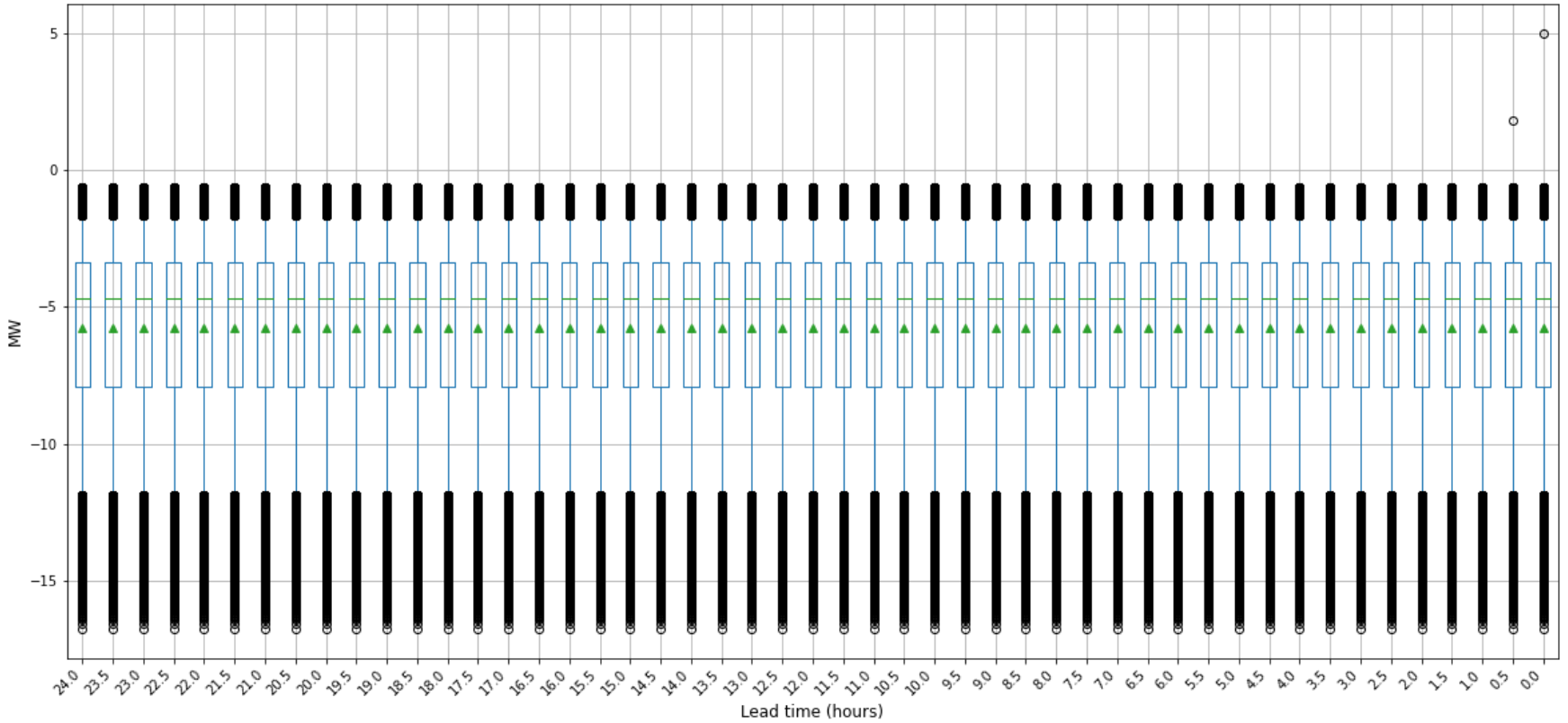
Figure 44: KIN0113 (Oji Fibre Solutions) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast

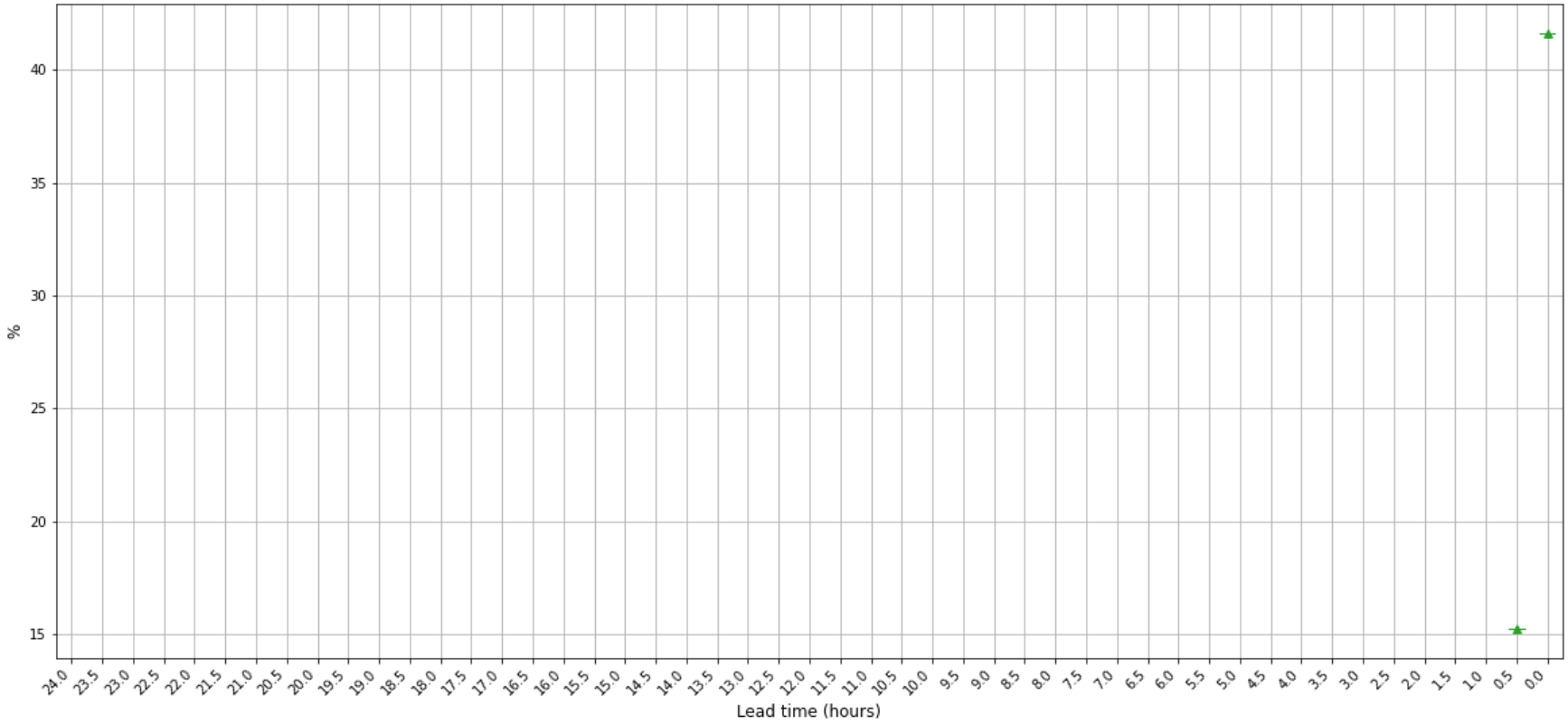
Figure 45: MNG1101 (Trustpower/Manawa) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

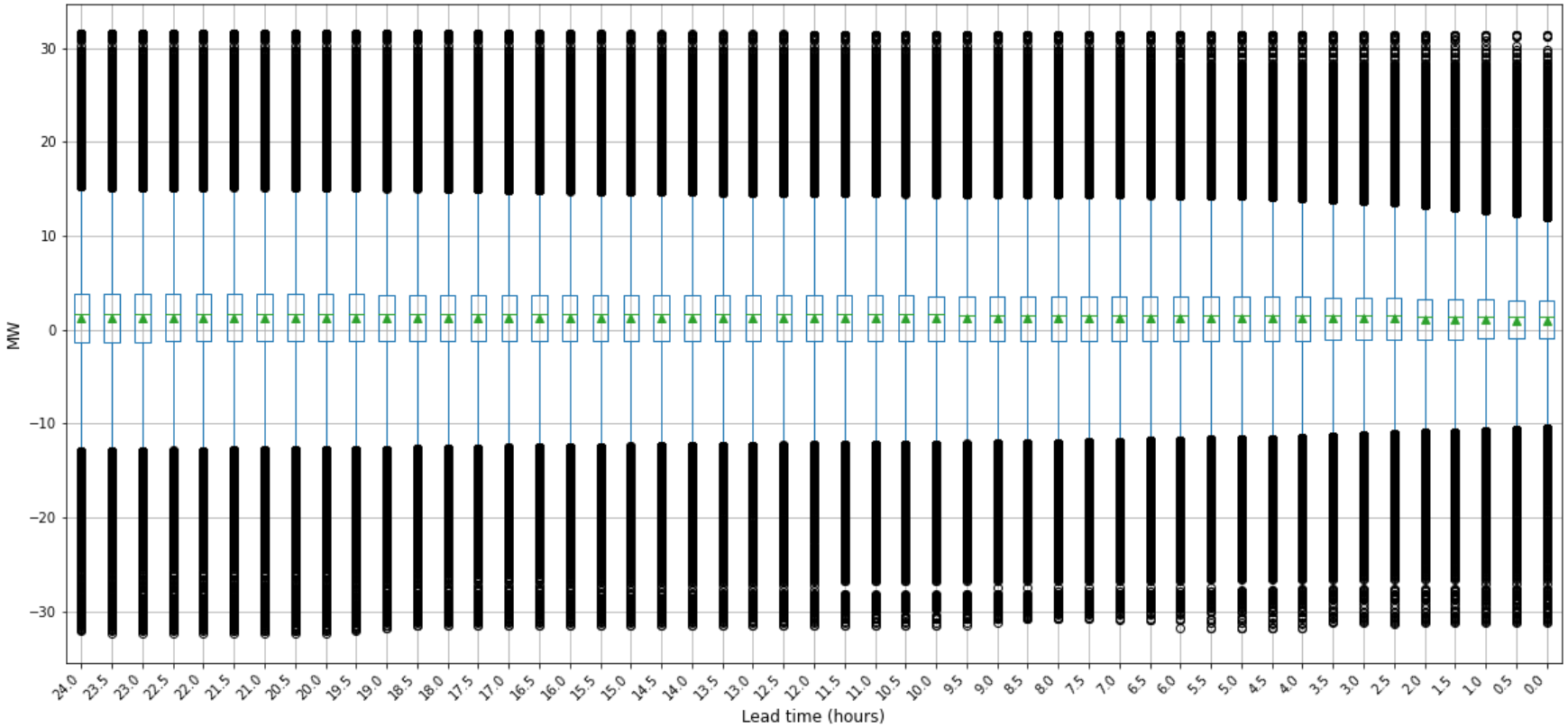
Figure 46: MNG1101 (Trustpower/Manawa) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast

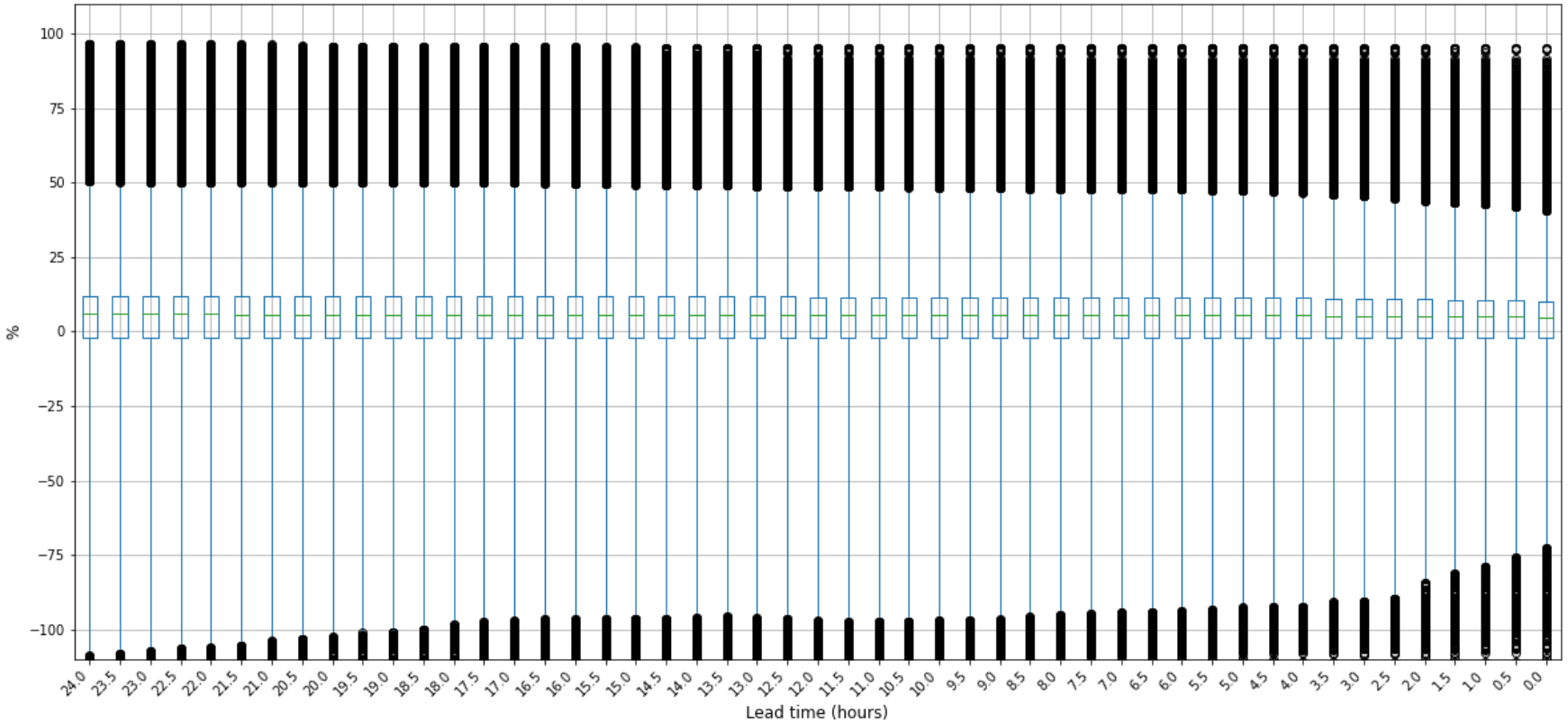
Figure 47: TNG0111 (Winstone Pulp International) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

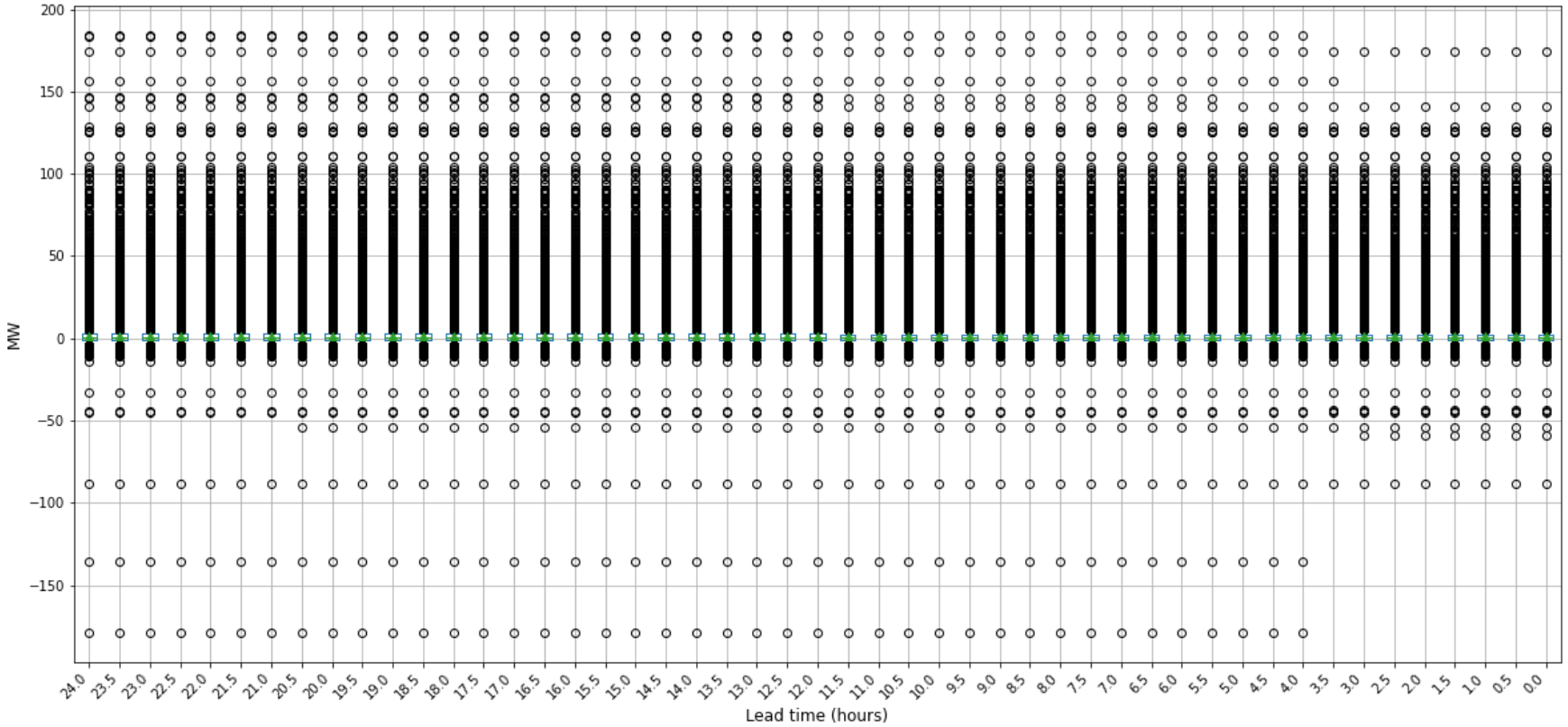
Figure 48: TNG0111 (Winstone Pulp International) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast
6. Truncated at -110%

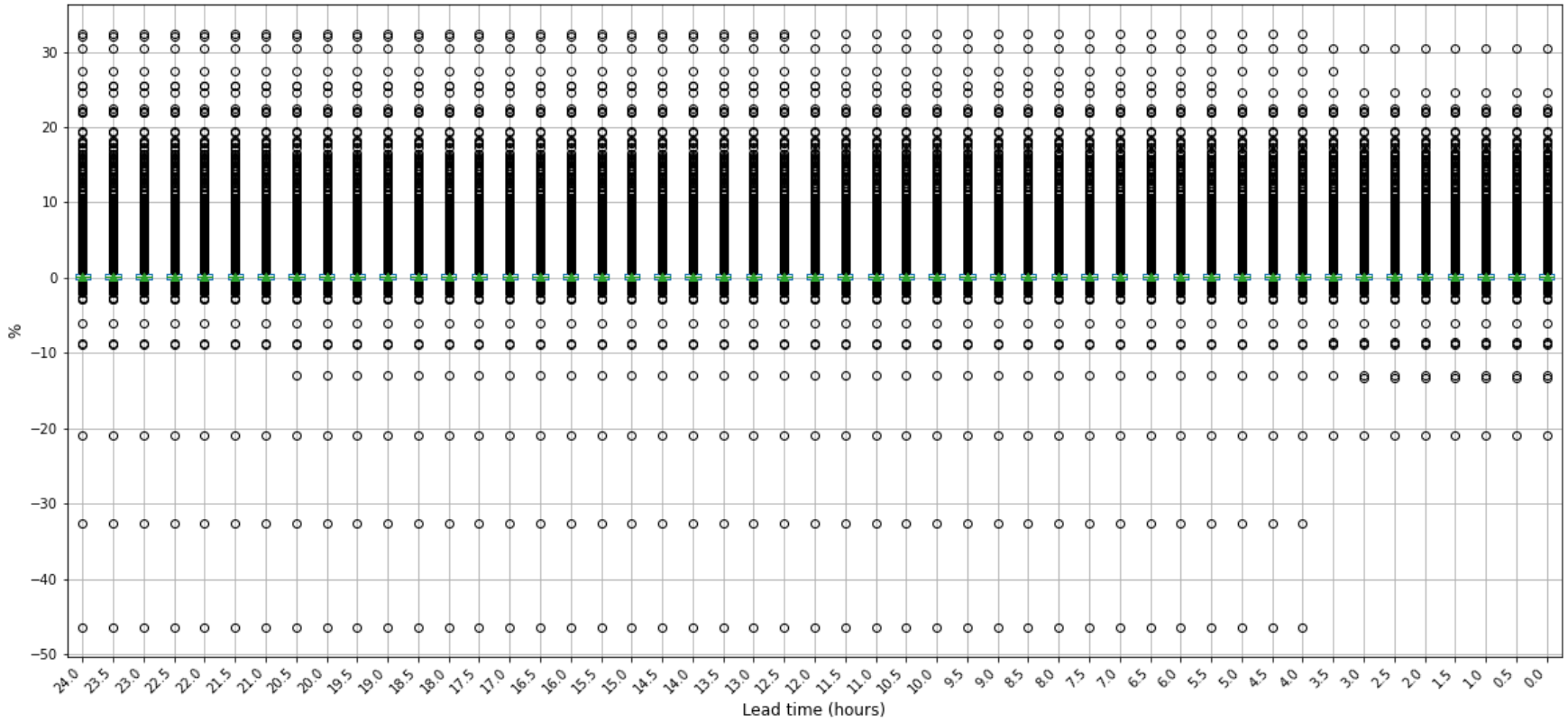
Figure 49: TWI2201 (NZ Aluminium Smelters) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

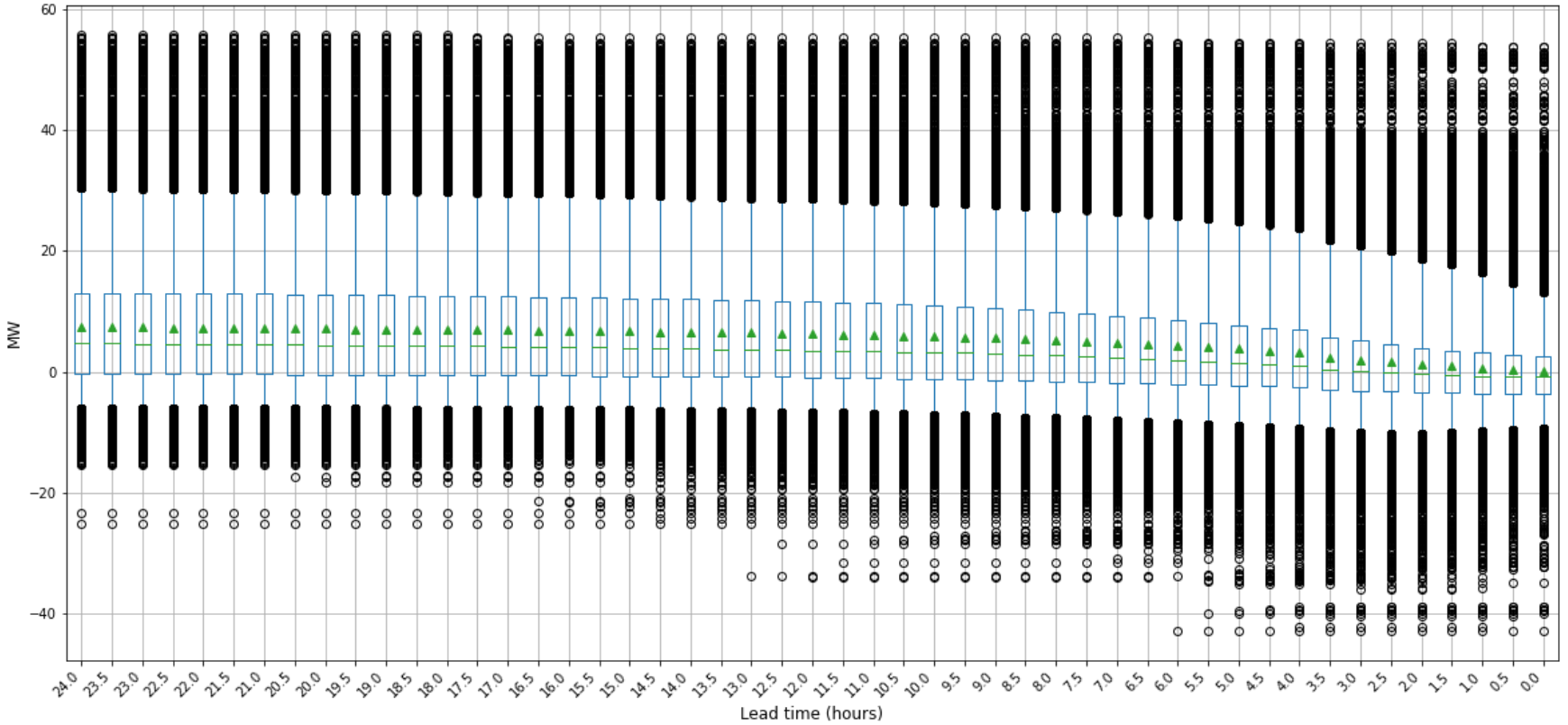
Figure 50: TWI2201 (NZ Aluminium Smelters) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast

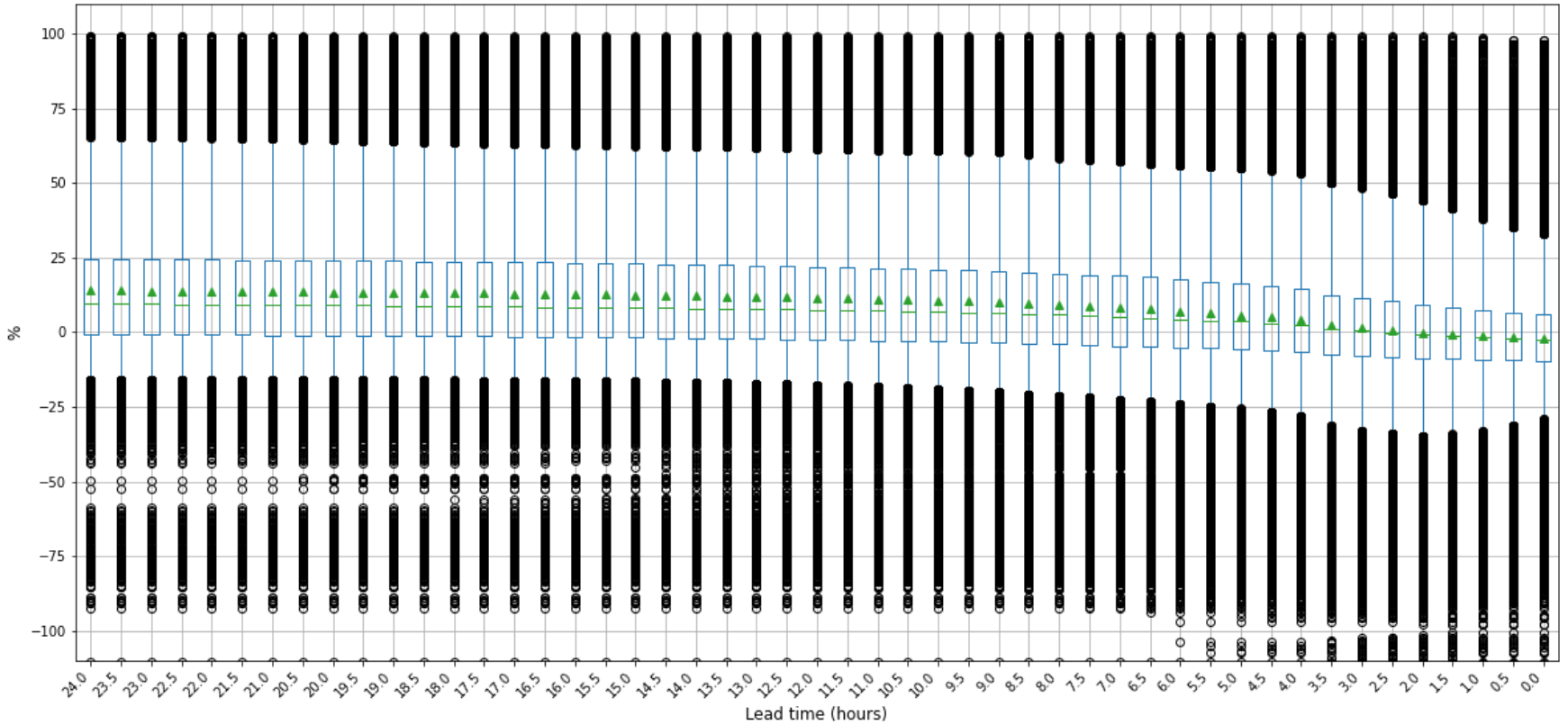
Figure 51: WHI0111 (Pan Pacific Forest Industries) forecast error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast error ≡ Forecast minus Actual

Figure 52: WHI0111 (Pan Pacific Forest Industries) forecast percent error over April 2021 to March 2022



Source: Electricity Authority

Notes:
1. Blue boxes indicate lower and upper quartile and median
2. Blue whiskers extend to 5th and 95th percentiles
3. Black circles indicate outliers beyond 5th and 95th percentiles
4. Green triangles indicate mean
5. Forecast percent error ≡ 100x(Forecast minus Actual)/Forecast
6. Truncated at -110%

Appendix C Machine learning methods for predicting wind generation

Glossary of abbreviations and terms

Code	**Electricity Industry Participation Code**
demand	**load and demand are used interchangeably**
EIPC	**Electricity Industry Participation Code**
FOGP	**forecast of generation potential**
GIP	**Grid Injection Point**
GXP	**Grid Exit Point**
load	**load and demand are used interchangeably**
NRSL	**Non-Response Schedule Long**
NRSS	**Non-Response Schedule Short**
SO	**System Operator**