

Electrical and Computer Engineering

Comparing Multi-Step Approaches in Load Forecasting

A proposal in partial fulfilment of the MScE

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Contents

Contents i

1 Focus 1

1.1 General Overview of Load Forecasting 2

1.2 Literature Review 3

1.3 Multi-Step Load Forecasting 3

1.3-a Types of Multi-Step Approaches 5

1.4 Evaluation Metrics 6

2 Investigation 6

3 Contributions 7

Appendix A: How to use this Template 1

1 Styles 1

1.1 Regularly used styles 1

1.2 Heading and Numbering 2

2 Inserting Equations and Figures 3

3 Referencing 3

4 Title Page and Headers and Footers 4

Comparing Multi-Step Approaches in Load Forecasting

Updated: 2020 Sep-02 by Tolulope Olugbenga

# Focus

// Make this as detailed as you can

// Try to make it about 5 pages

* Multi-step load forecasting in context – What is it, and what makes it important. The difference between it and single-step forecasting; and when one is more important or needed than the other.
* Different load forecasting horizons, and how they differ from one another.
* Different multi-step forecasting approaches – Shallow (Jha et al., 2019) and deep approaches.
* What makes an approach good and how do we measure it? (Detail the most used metrics (MAPE, MAE, RMSE…)). What are these metrics (Mathematically, …), and what do they tell you? What are the disadvantages or limitations of using each metric?
* How do you propose to solve the problem?

<Pose the research problem here – aim for 3 pages. Provide enough background information for the reader to understand why the problem exists, and why it is useful to solve – make sure you back up all your information with literature references. Conclude this section with a brief explanation about the approach you are researching to solve the problem.>

## General Overview of Load Forecasting

Electricity is one of the driving forces of economic development and is essential to our daily life and wellbeing. Load forecasting is an integral part of the process of the planning and operation of electric utilities; it has played a vital role in the power industry for over a century. In terms of power supply and demand; for the stable supply of electricity, the reserve power must be prepared to serve consumers, e.g. in case of high demand or failure in the current grid supply. Businesses' needs for load forecasting include power systems planning/operations, revenue projection, rate design, energy trading, and so on. Load forecasting is needed by many business entities other than electric utilities, such as load aggregators, power marketers, independent system operators, regulatory commissions, industrial/commercial companies, banks, trading firms, and insurance companies (Hong & Fan, 2016b)(Saurabh et al., 2017). Electricity load forecasting still receives attention from researchers today, because the need for more accurate forecasts arises, particularly with the advent of new smart grid technologies.

The demand pattern is very complex due to the deregulation of energy markets and the number of the different random variables that need to be taken into consideration to predict human behaviour; therefore finding an appropriate forecasting model for a specific electricity network is not a trivial task (Almeshaiei & Soltan, 2011)(Hong, 2010)(Khotanzad et al., 2002). People often use electricity at any time that suits their lifestyle and for the most part, we all happen to use electricity at the same time. Most people share a similar lifestyle pattern, from when we wake up, to having a shower, making some breakfast, leaving for work, coming back at night, going to bed, doing our laundry on weekends and so on.

Electricity demand is assessed by accumulating the consumption periodically; it can be considered for hourly, daily, weekly, monthly, and yearly periods. The forecasting processes can be grouped into four categories based on their horizons namely: very short-term load forecasting (VSTLF), short term load forecasting (STLF), medium-term load forecasting (MTLF), and long-term load forecasting (LTLF). The cut-off for these categories are 1 day, 2 weeks, and 3 years respectively (Deng et al., 2019). A rougher classification would consider only two categories: STLF and LTLF, with a cut-off at two weeks. Short term load forecasting has been the major point of focus in most literature; the main focus has been on horizons of less than 2 weeks (Hong et al., 2014)(Deng et al., 2019)(Hong & Fan, 2016a).

Different factors can affect load forecasting such as; the location of the area, the type of customers in the region, weather factors (temperature, etc.), a trend in the data, the time of the day, day of the week, and other unpredictable factors (coronavirus outbreak, etc.).

## Literature Review

## Multi-Step Load Forecasting

* Multi-step load forecasting in context – What is it, and what makes it important. The difference between it and single-step forecasting; and when one is more important or needed than the other.

////////////

Multi-Step forecasting is a process that predicts a sequence of values in a time series. In application to electrical load forecasting, the sequence of values refers to future demand values for the time horizon of interest. Much of the literature on load forecasting focuses on short term load forecasting, and also on single-step ahead forecasting. Single-step forecasting is a process that predicts only one value into the future; it’s sometimes referred to as a one-step ahead method.

Let’s take an instance where we need to forecast the hourly demand for the next 24 hours. The single-step approach could run 24 times, whereby at each current hour it only needs to forecast the demand of the next hour. The multi-step approach could run 1, 2, or 3 times to forecast horizons of 24 hrs, 12 hrs, or 8 hrs respectively; depending on the method the forecaster would like to use. The errors of the multi-step forecasting approach will be considerably much higher as compared to the single-step approach. The limited information about future circumstances as well as the aggregation of errors in the multi-step approach has a role to play in this. This makes multi-step forecasting more difficult as compared to single-step forecasting (Ben Taieb et al., 2012). Also, multi-step forecasting is very essential for most utilities.

### Types of Multi-Step Approaches

There are five major strategies used for multi-step forecasting namely; the recursive approach, the direct approach, the direct-recursive approach (DirRec), the multi-input – multi-output approach (MIMO), and the combination of the direct and the MIMO approach (DirMO) (An & Anh, 2016; Ben Taieb et al., 2012; Bonetto & Rossi, 2016; Jha et al., 2019). Details of each approach would be detailed below. The five strategies mentioned above can be used with any underlying prediction models, such as ANN, support vector machine (SVM), ARIMA, etc.

1. The Recursive Approach:

The recursive strategy is the oldest and the most intuitive forecasting strategy (Ben Taieb et al., 2012)(Hamzaçebi et al., 2009)(Kline, 2011)(Sorjamaa et al., 2007; Sorjamaa & Lendasse, 2006). In the recursive approach; only one model is prepared. The model is trained to perform one-step ahead forecasting. To forecast  steps ahead; the first step is forecasted and then the forecast is used as an input for the next step. This loop continues until a total  steps has been forecasted.

Let  be the one-step ahead model that was prepared; the forecasts are given by:



Where, is the forecast, is the amount of previous values that is used for future forecasts,  is the total horizon for prediction. The larger the horizon gets, the harder it becomes to make multi-step ahead predictions, therefore the accuracy of the predictions suffer. This can be seen when the forecasting horizon  exceeds the variable ; as all the inputs are forecasted instead of the actual observations. The recursive approach is susceptible to the aggregation of errors with longer horizons, as the errors in intermediate forecasts are propagated forward.

1. The Direct Approach:

In the direct approach, separate models need to be developed to forecasting each horizon independently. This means in a time series ; models  are trained, with one for each horizon



where  and  Let  be the learned models, then the forecast is calculated as:



The direct approach is immune to the aggregation of errors because it doesn’t use any forecasted values for its computation of forecasts. This however prevents the model from considering complex relations in the forecasted values (); which in turn affects the accuracy. The direct strategy uses large computational time because we have to create models in relation to the size of the horizon for prediction.

1. The Direct Recursive Approach (DirRec):

This strategy is a combination of the Direct and Recursive strategy, which means that different models are created for each horizon (like in the Direct) and at each time step (), the forecast of the previous hour is used as input for forecasting this new step (like in the Recursive). In this strategy,  models  are trained from the time series ,



where  and  Let  be the learned models, then the forecast are calculated as:



The DirRec strategy was tested against the Direct and Recursive strategies and it was found to outperform both of them, on two real-world time series; Santa Fe and Poland Electricity Load datasets (Ben Taieb et al., 2012; Sorjamaa & Lendasse, 2006).

1. The Multi-input Multi-Output (MIMO) Approach:

The previous three strategies can be referred to as single-output strategies as they model the data using a multiple-input single-output approach; this however, pays no regard to the existence of stochastic dependencies between the future values, which therefore could affect the forecasting accuracy. This led to the invention of the MIMO strategy. In this strategy, one multiple-output model is trained from the time series . The forecasts are gotten in a single step using a multiple-output model 



where , and is a vector-valued function. The MIMO method preserves the stochastic dependency in the time series for the forecasted values. The MIMO doesn’t have the conditional independence assumption that was seen in the direct strategy, and also the aggregation of errors that was noticed in the recursive strategy. The major drawback of the MIMO strategy is the flexibility, as all horizons are forecasted at once by a single model.

1. The Direct and Multi-Input Multi-Output Approach (DIRMO):

The DIRMO approach is a combination of the DIRect and miMO approaches. The DIRMO strategy forecasts the horizon  in blocks, and each of these blocks are forecasted in a MIMO fashion. The forecasting horizon  is segmented into  multiple-output tasks using , the size of the blocks are denoted by .

Therefore, when the value of  is 1, the number of forecasting tasks  is equal with , which means only the direct strategy will be implemented. But when the value of  is , the number of forecasting tasks will be equal to 1, which means only the MIMO strategy will be implemented. Adjustment of the parameter gives a trade off between the preservation of a large degree of the stochastic dependency between future values and having better flexibility of the predictor.

From the time series , this strategy learns models ;

## Evaluation Metrics

# Investigation

<Describe in some detail how you plan to investigate your approach to solving the problem – aim for 4 pages. Be specific about exactly what aspects of the approach are under examination, and provide as many details as you can about the approach. Include any details you can provide about planned simulations or experiments, including the factors which are being evaluated, and performance metrics used for evaluation. If you borrow simulation/experimental data or methods from previous research, be sure to reference them.>

# Contributions

<Briefly list what contributions are made by completing this work – aim for 1 page. Don’t focus on what you learn by completing the work; instead, focus on what researchers will learn by reading the work.>

Appendix A: How to use this Template

# Styles

Use this template to handle all of your formatting issues. They will ensure consistent fonts, spacing between sections etc. To select a particular style, open the *styles* pain as depicted below:

|  |
| --- |
|  |
| Figure : a) Where to find the Formatting Styles b) where to find ‘references’ to insert captions |

## Regularly used styles

Avoid using the Normal style. It is in place as a reference for other styles. Here is a list of regularly used text styles:

Body Text: your main text should be formatted with this style

Block Text: used to indent content from the left and right

Captions: Use Figure Captions, Table Captions and Equation Captions by navigating to: >references>insert caption>…

Nlists and BLists (for numbered and bulleted lists)

Heading 1

Heading 2

Heading 3

Specialty formats: Strong, Emphasis, Subtle Emphasis, Intense Emphasis

There are also a set of styles included in the list for one-time use:

Cover styles: Pretitle, Title, Subtitle, authorship…

Header and Footer

Table of Contents styles, TOC1, TOC2, and TOC3 (These are linked to Sections to automate your table of contents)

## Heading and Numbering

This is a bit tricky, but here is a brief explanation. Section Headings should be formatted according to Heading 1, Heading 2 and Heading 3 (Heading 2 and 3 are sub-heading formats). These styles are linked to the ‘list style’ called Headings so when you use a Heading style they are properly numbered.

|  |
| --- |
|  |
| Figure : Example of Properly formatted 5th section headings |

The template should apply the list style automatically, but if it doesn’t, when you select your first heading, go to the list style menu and select the Headings list style to apply it.

|  |
| --- |
|  |
| Figure : Where to find the List Style menu |

# Inserting Equations and Figures

Use the quick part tables to insert an equation or a figure. You can access these from the short cut icon indicated in Figure 1. When you navigate to this icon, it provides a list of tables. Use the Equation Table and the Figure Table as in the examples below: The first table is an equation table. The last column is an equation number, inserted by navigating to >references>captions>equation. The second table is a figure table. The last row is a combination of figure number with text describing the figure. To insert the number, navigate to >references>captions>Figure. Then add your text.

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| --- | --- | --- |
|  | [use equation tool to place equation here] | ( ) |

|  |
| --- |
| [place figure here] |
| [place caption here…if it is less than 1 line, center it] |

# Referencing

Use inline referencing according to IEEE referencing style [1, 2]. For instance, I have included the reference numbers after ‘IEEE referencing style’ and I will include a separate referencing section where I will list the sources in the order which I cite them. Use the *Rlist* style to create your reference list. If you want, you can automate their links with the inline citation by navigating to >references>cross-reference and choosing ‘Numbered Item’. Make sure you set ‘Insert Reference to’ paragraph number. The following are typical examples of items in a references list (I am not too particular about the detailed formatting in the citations, but include the standard information, and be consisten):

1. D Graffox (Sep-2009), IEEE Citation Reference, <http://www.ieee.org/documents/ieeecitationref.pdf>, last accessed, 2015-MAR-13.
2. (no author/date available), IEEE Citation Style, <http://library.queensu.ca/book/export/html/5846>, last accessed, 2015-MAR-13.
3. D MacIsaac, C Hrabi, “Our Favorite Topics”, Journal of Interesting Information, 1(24), 2010.

# Title Page and Headers and Footers

Don’t forget to update the standard content of each of these sections. Of special note is the #-of-pages field in the footer which should be updated manually at the completion of the document so that the Tite and Contents pages are not included. The Reference page should be included (even though it is NOT included in the page count of 10 pages). Also of special note are the ‘created’ and ‘updated’ fields on Title page AND in the footer. In the title page, these fields can be edited by double clicking them. In the footer they are linked to the title page fields through a cross-reference. To update them, simply double click them.

One final note – take a close look at the footer in this appendix compared to the footer in the main body. The paging is different in the appendix. This is because the appendix is a NEW SECTION and the footer for this section has been unlinked to the previous section. Be careful not to mess sections up, but if you do, you can reinstate them using >Page Layout>Breaks>(Section Break) next page. Another interesting thing about this Appendix is that its title uses the stye ‘Contents Heading’. If you don’t do this, it won’t show up in the table of contents properly.