

# PhD Examination – proof of amendments

I thank you for your comprehensive list of required amendments. To the extent described below, these amendments have been applied to the thesis. All changes in form of added and remove text have been highlighted in, respectively, green and red.

## **I. Abstract**

- a) The expression “e.g.” has been removed and was replaced with “for example”. Other instances in the subsequent paragraphs are highlighted accordingly.
- b) A reference to the average power is made and the same amendment is made on pages 29 and 36.
- c) The word count of the abstract has been reduced from 400+ to only 328 Words.

## **II. Introduction**

- d) The reference to larger customers that may not be located in the distribution network is added and “grid” is corrected.
- e) The objectives have been amended in line with the required amendments.
  - O1 specifies that half-hourly real power schedules were kept constant
  - O2 specifies that the above schedules are no longer kept constant
  - O4 clarifies that AIMD was modified (not just extended) by using a scaling factor and individualised threshold values
- f) Although this was only a suggestion, I decided to write a short paragraph acknowledging the field trials and citing the website where the close down reports may be read.

## **III. Literature Review**

- g) The list of storage benefits has been reorganised as requested. The power quality aspect has been limited to be seen as an “additional feature” that comes with provided power electronics.
- h) Distinction between DNOs and energy suppliers is made clear when citing the showcase examples by introducing an itemised list for each group.
- i) The statement claiming that reactive power impacts frequency was falsely cited and has been corrected accordingly.

- j) The limitation to the UK transmission system is implemented now. Also, according to archive.org<sup>1</sup>, the number of 9s was published as such by National Grid in September 2017 and is therefore cited correctly. However, this quote has been removed on the most recent version of the website<sup>2</sup> (visited 25<sup>th</sup> of March 2018). Therefore 2017 is also included next to the quote.

#### IV. Chapter 3

- k) The contradiction in reference to “the LV network losses being negligibly small” is removed by using “comparatively small” instead. This is illustrated by some typical figures (500kW at LV and 60GW on a national level). Also, by “... nobody pays ...” it was meant that “no customer pays” or “no customer can be charged”. This phrase has been changed accordingly.
- l) The small discussion that a binary choice vector may be changed into a multi-objective weight is briefly included. For a full assessment of this topic, a reference to the future work section is now included, too.
- m) The figures and according text have been updates as follows:
- The substation reference voltage is added into the description (an additional line and legend information may make the small figure less readable)
  - The three colour approach for six lines is better explained in text.
  - An error where “base” and “normal” were exchanged is corrected
  - The energy losses were recalculated and it turns out that the caption was not updated in accordance to the changed figures. Now the losses are corrected and the text is updated accordingly.
- n) An explanation of the box-plots is included in section 3.5.2.
- o) The equation is better annotated. It came to my attention that  $\Delta t$  equates to 1min and may be omitted if necessary. The reason for including it was to allow formula scaling. This argument is briefly made and also included below equation (3.21). The explaining text surrounding equation (4.2) is not updated as much, but a back reference is made instead.
- p) The term “neutral power” is replaced in the small introduction paragraph ahead of the corresponding cost function. Now, references are made to “neutral current” instead, and the unconventional definition of neutral power is then highlighted to the reader before stating the equation.
- q) The phrase “Experts would agree...” has been removed.

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<sup>1</sup> <https://web.archive.org/web/20170912231817/www2.nationalgrid.com/UK/Our-company/Electricity/Managing-the-network/>

<sup>2</sup> <https://web.archive.org/web/20180204182323/https://www.nationalgrid.com/uk/about-grid/our-role-industry/about-electricity>

## **V. Chapter 4**

- r) The legend in Fig. 4.2 has been changed from “demand” to “load” and the caption clarifies that this load is measured at the substation.
- s) The term “MPC” is changed to “predictor” and the corresponding text is also updated to reflect this amendment.
- t) The unconventional PID formulation has been flagged to the reader and the definition of “converging” and “stable” (that were outlined during the viva) is included in the corresponding text.
- u) The “guaranteed” convergence and stability is rephrased in line with point t).
- v) It was unclear which part of the chapter this remark addressed. I added a quick “reminder” why reducing peak load is of benefit in the beginning of Section 4.5. If more details are needed or this was not appropriate, please let me know.
- w) In Section 4.5.2, the case designations are now included in the text.
- x) The two percentages were mixed up (I think I confused myself when writing this paragraph). Now I added a remark regarding the difference between perfect foresight and simple “power repetition”. By adding case descriptors, references to the figures are now clear.

## **VI. Chapter 5**

- y) The definition of  $\alpha$  is included in the nomenclature (and was already included in text below equation (5.2): the relevant section is highlighted in yellow).
- z) A reminder that perfect foresight is used for the baseline load and the implications of doing so (or more specifically, the implications of no perfect foresight) are highlighted and justified. Instead of “base load” it now reads “baseline load” throughout the chapter.
- aa) The algorithm caption is completed.
- bb) Irish dataset is now briefly introduced and cited accordingly in section 5.3.1.
- cc) References to figures 5.6 and 5.7 are included in table 5.1.
- dd) The reference to “north-eastern quadrant” is replaced with “top right quadrant” and an explanation as to why this quadrant indicates good performance is included, too.
- ee) The smoothening effect is put into relative perspective and better compared to the synchronised cases.

## **VII. Chapter 6**

- ff) Title is amended as requested.

- gg) The choice of three normal distributions is better explained. Now “starting a trip” is clearly understood as leaving a location and not just leaving home, where the origin of this location is based on the time of day.  
Regarding equations (6.2) and (6.3), it was found that the equalities for  $\hat{n}_m$  and  $\hat{n}_l$  were not defined when originally formulating the minimisation problem. This mistake is addressed by removing the two equality constraints and only maintaining  $\hat{n}_m + \hat{n}_l - \hat{n}_e = 0$  and  $\hat{n}_e = 0$  (notation is simplified here).
- hh) The shape of the Weibull distribution in figure (6.2) is correct. When returning back to the definition of this distribution, only shape values where  $k > 1$  result in a continuous function tending towards zero when  $x \rightarrow 0$ . For example, when  $k = 1$ , then the function tends towards the scale parameter  $\lambda$ , and when  $k < 1$  then the function tends to infinity. The last case is plotted in figure (6.2).
- ii) Regarding the calculation of EV energy demand, this was falsely cited and should instead read 0.21 kWh per mile (from which the kWh per km was derived), based on a BWM i3 tests in New European Driving Cycle (NEDC)<sup>3</sup>. Using this and the predicted driving distance, and estimated energy demand could be generated.  
It is worth mentioning, that I originally wanted to use a dynamic model including driving speeds, which is why driving speed was included in the paragraph. However and as stated during the viva, such a polynomial model is difficult to validate and probably no more accurate than a best estimate taken from real data. This fact is briefly discussed, too.
- jj) The term “optimised” is removed in section 6.5.1.
- kk) Explanation of the area plots and box-plots in figures (6.13) and (6.14) is included now.
- ll) Different ownership models to maximise asset utilisation is mentioned in section 6.5.2.2, and a reference is made to the future work section.
- mm) The statement to “half” of the BESSs not taking part is changed to “a third” since this is a more accurate estimate.

## VIII. Discussion / Conclusion

The following corrections have been applied in line with the suggestion that was sent in the email dated 2<sup>nd</sup> of May 2018.

- nn) The section 7.3 has been limited to only address the limitations of the presented work and no longer discusses topics like AI and cyber security (former Sections 7.3.5 and 7.4.6). Instead, greater emphasis is put on:

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<sup>3</sup>

[https://web.archive.org/web/20160918213333/https://www.press.bmwgroup.com/united-kingdom/article/detail/T0144135EN\\_GB/the-new-bmw-i3—born-to-be-electric?language=en\\_GB](https://web.archive.org/web/20160918213333/https://www.press.bmwgroup.com/united-kingdom/article/detail/T0144135EN_GB/the-new-bmw-i3—born-to-be-electric?language=en_GB)

- what limits the presently chosen approaches
  - why these approaches were chosen
  - what could be done to improve the approaches – particularly when making them “industry ready” (discussed in Future Work section, see point mm)
- mm) A new Future Work section (Section 7.4) has been added to address possible next steps for the proposed approaches. Particular focus and recommendations DNOs are included in the 2<sup>nd</sup> subsection (Section 7.4.2) where considerations for realisation are discussed.
- pp) The conclusion section (Section 7.5) is only briefly amended since it only needs to summarize the points made in Section 7.4.2 regarding the DNO recommendations.