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To: Ing. Marie Duchoslavová
pp . doc. Ing. Milan Polívka, Ph.D.
Vice-Dean for Science and Research
Tel. No. +420 224352791, FAX: +420 224311081
e-mail: duchosla@fel.cvut.cz

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In this report, I will provide my assessment and comments on the thesis manuscript entitled "Demand Side Management System for Optimizing Operation of Power Grids with Renewable Energy Sources" presented by Mr. Ondřej Malík in order to defend his research work and obtain his Doctoral Degree from the Czech Technical University in Prague (in the Faculty of Electrical Engineering).

This thesis manuscript is formed by three introductory background chapters (Chapters 2 to 4) and three chapters corresponding to the three main parts of the research work developed by Mr. Malík, namely a Low-Voltage (LV) Demand Side Management (DSM) System (Chapter 5), then a Medium Voltage (MV) one (Chapter 6) and finally the support to Transmission System ancillary services by using such DSM capabilities (Chapter 7). The structure of this document is very logical, and corresponds to the main contributions of this work, which makes it easy to read. As a general comment, I must also mention that **throughout this thesis a huge effort has been made to relate / compare all models and methodologies introduced to existing electricity systems, standards and practices** (especially in Czech Republic), thus making the majority of described contributions directly understandable and applicable by electricity systems' – real! – operators. **This is very relevant in the scientific community working about DSM where many authors propose stylized models that are sometimes difficult to be used in practical situations.** The main limit about this work would be that providing such practical details has left less room for a more refined theoretical analysis of proposed models / problems and to more extended simulations to obtain a broader evaluation of the interest of proposed DSM three-level system. Because this aspect did not seem to be central in this work, **according to me this thesis fully meets its objectives.**

The remainder of this report provides a comprehensive analysis of this thesis manuscript to support these general comments.

Chapter 2 gives a very detailed presentation of the impact of Renewable Energy Sources (RES) on distribution grids. Following my general comment on the direct link between this work to real systems, this chapter proposes a well documented description of the issue of power quality in DN and associated control methods without/with RES. A substantial amount of details is provided; I must say that I have learned a lot by reading it. However, in certain places, it lacks a quantified analysis of the performance of existing methods / research work to make the contributions of this thesis work easier to assess. With the same aim of introducing the reader to the main concepts of this work, **Chapter 3 proposes a very good description of Demand Side Management potential**, with the choice of distinguishing the presentation depending on the country of application (which seems quite reasonable given the strong differences between electricity systems of described countries and degree of progress in this field). The presentation ends with the case of Czech Republic, as one of the main objectives of this thesis – fully met - was to propose a very practical application in the country where this work was developed. In particular, I found it very interesting to propose a comparative presentation of the potential of industrial and residential consumers. Again, the only drawback of this chapter is that it is a bit descriptive, and it lacks a few key figures in some places.

Compared to both preceding chapters, **Chapter 4 ("Literature survey")** is a little bit short according to me. In particular, a few recent works about decentralized methods to include residential DSM for ancillary services could have been included to complete this survey (see, e.g. Meyn, S., Barooah, P., Busic, A., & Ehren, J. (2013). Ancillary service to the grid from deferrable loads: The case for intelligent pool pumps in Florida. *In Decision and Control (CDC), 2013 IEEE 52nd Annual Conference on (pp. 6946-6953). IEEE*). However, together with Chapters 2 and 3, this chapter makes a very good introduction to the topic of this thesis, and current state-of-the-art in this field of research.

Chapter 5 presents the first contribution of this work: the proposal of a LV DSM system. Starting with the basic principles, this DSM system is then formulated with two different optimization problems, respectively referred to as "Dispatch reference optimization" and "Dispatch schedules optimization". These two problems correspond to the two stages of the proposed approach: 1. "Dispatch reference optimization" minimizes import and export of considered LV area based on predicted uncontrolled (all but Electric Water Heaters (EWH) here) power balance. It is formulated as a Linear Program; 2. "Dispatch schedules optimization" minimizes the difference between dispatch reference and final power balance. This problem is solved closer to real-time, replacing prediction on power balance by measures or estimated values, and including a finer model for EWH – e.g. with minimal on-time constraint. In turn, the obtained problem is a Mixed Integer Linear Program. The formulation of these problems seems very realistic and accurate – from what I know, not being an expert on this matter. **A major effort has been made to make these problems very easy to relate to the physics of EWH** (see, e.g. Paragraph 5.3.2.1), **hardware implementation constraints** (see 5.3) **and the construction of a realistic LV network model** from real data (see 5.5). All this work has been done in relation to existing standards and practices (e.g. describing "Centralised Ripple Control", routinely used to control EWHs in Czech distribution system) to make the contribution of this work clear. Again, **the level of description / realism of considered problems is very impressive.** The only drawback I would mention is that it lacks an in-depth theoretical study of proposed optimization problems: 1. Are there any theoretical result to be mentioned with obtained LP / MILP structure? Is there any robust optimization formulation that could be used to facilitate the link between both "Dispatch reference" and "Dispatch schedules" problems (with less effort needed in second stage, "schedule")?

Chapter 6 follows the hierarchical logic of the presentation, with the introduction of a Medium Voltage DSM system. The structure of the presentation is similar to the one of Chapter 5, which makes it easy to be understood. The considered optimization problem is well formulated, and the considered case study well described. I find it very interesting to distinguish an "autonomous" operation mode from a "hierarchical" one (P98); according to me, it raises a key question about the future architecture of DSM operation systems depending on data availibility, complexity issues, etc. This point is very well described; it could go more into detail on the complexity aspect with respect to operational (real) time allowed to solve considered problems. Simulations done are very interesting; they are based on realistic (from reality, which is not always the case!) data and show promising results. To make the performance of the proposed methodology even clearer, it could be interesting to extend the simulation setting to a larger set of days (to capture seasonal or weekdays versus week-ends effects), to distinguish results by LV area and by node (not only the "terminal node" considered here).

Finally, **Chapter 7 makes the whole work very coherent and complete, introducing ancillary services for Transmission System (3rd level) as a possibility with the proposed DSM system.** Again, the presentation is very easy to follow, and a huge effort has been made to connect considered models to real systems. In this direction, **it fully meets the objective of proposing a realistic "three-level control system (...) which utilizes DSM"** (see P3 in Section Introduction), **considering explicitly its hierarchical structure while many works in literature only rely on a stylized structure.** Again, the simulations that have been made are promising and pave the way to potential real applications. A few sensitivity tests could have been added to complete the analysis and identify more easily the best real cases of implementation: performance/robustness with respect to the number of "dedicated (for DSM) EWHs"? Tradeoff between communication – investment and real-time – costs and ancillary services gain? From a theoretical perspective, a more detailed study of the

bi-objective structure in Eq. (7.25) P132 could be interesting (I just mention this point as a potential future study because it was not one of the stated aims of this work from what I understood from the Introduction).

Chapter 8 gives a very clear conclusion of this document and mentions relevant extensions. Among them, I would like to point out a promising one according to me: the issue of the business model that should correspond to the proposed DSM system and motivate all stakeholders to take part in it. It could be very interesting to build on the quality and the precision of the proposed DSM model to adress such a question in Czech context.

As a minor comment, the thesis manuscript contains a few typos and few mathematical symbols / expressions that could be improved. I have marked them down and advise the candidate to take a look and correct before submitting the final version for publication. For example, "power" is repeated twice in the legend of Figure 5.10 (b) P 79.

Nevertheless, the thesis is overall well written, it presents several very creative and realistic models, and associated promising simulation results. It seems to have been closely related to the development of a pilot site within SIRES project, which in itself is a strong acknowledgment for such a thesis work and benefits also to all the realistic cases studies analyzed here. Finally, several of its results have already appeared in journal papers (3) and conference papers (3).

For all of these reasons, the author of the thesis proved to have an ability to perform research and to achieve scientific results. I do recommend the thesis for presentation with the aim of receiving the Degree of Ph.D.

Yours sincerely,

Olivier Beaude, Ph.D., Research-Engineer
EDF – R&D
60 rue de Turbigo
75003 Paris
France
e-mail: olivier.beaude@edf.fr