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DISSERTATION THESIS EVALUATION

Author: Ondřej Malík

Opponent: doc. M.Sc. Daniel Georgiev, Ph.D.

General comments

The work studies conceptual design, development, and simulation of demand side management systems (DSMs) within the context of electrical system operation. The overarching goal is to develop a DSM system that utilizes energy capacity of household appliances, such as electrical water heaters (EWHs) to alleviate effects of intermittent energy sources, such as household photovoltaics.

Relevance of the proposed topic

The work addresses a relevant and unresolved problem in electrical system operation. Recent changes in European energy policies have pushed for greater utilization of renewable energy sources. This change generates potential problems in system operation caused by the shift in power production from reliable and centralized units to intermittent and distributed units. Two potential solutions are often debated: a long-term and high-cost solution comprising an upgrade of the electrical system architecture, and a mid-term and low-cost solution comprising an upgrade of the electrical system control. The author focuses on aspects of the second solution.

Fulfillment of proposed goals

The presented work proposes to address this problem by direct load control of household appliances. In particular, a hierarchical system is proposed wherein appliances installed at the low voltage (LV) level are scheduled to meet power balance targets generated by a control system installed at the mid voltage level (MV). In addition, a decision support system for transmission system operators (TSOs) is considered to offer DSM as an ancillary service.

Development and deployment of DSM is quite complex primarily because it involves technical, economic, and legislative issues. In the presented work, the author largely focuses on the technical/computational parts of the problem. Following the introductory chapters, wherein the author reviews related works on DSM, a hierarchical control concept is proposed. The computationally most intensive task, the scheduling of individual EWHs, is partitioned amongst individual LV networks. The reference targets for the LV networks are subsequently generated at the MV level using a linearized system model. The corresponding LV and MV problems are solved using standard mixed-integer linear program (MILP) and linear program formulations, respectively.

As such, the work fulfilled the goals as defined in Chapter 1.3.

Fakulta aplikovaných věd
Technická 8, 306 14 Plzeň

Email: georgiev@kky.zcu.cz
Telefon: +420 377 632 552

Adequacy of the employed methods

Beyond the conceptual development of the DSM system, the works implements standard methods from linear programming and mixed-integer linear programming. The formulated problems are cast into a standard form and then solved using freely available tools. Within the conceptual development, the authors consider many practical issues (e.g., data transfer and transmission) considering technical implementation of the proposed system. While it is not clear how these consideration effected the theoretical formulation of the problem, the validity of the formulism is partially proven through several case studies.

Due to the many approximations that are inevitable in electrical system modelling, the work would benefit from a more thorough analysis of model and simulator fidelity as well as application driven improvements in the mathematical methods.

Quality of the results and impact

Value of the proposed DSM system is measured through a series of case studies (approximately one for each substantive chapter of the thesis). Two variants of DSM (autonomous and hierarchical) are compared to ripple control (the current DSM system implemented in the Czech Republic). It is shown that using the defined performance indicators (e.g., MV network balance), the proposed DSM system brings significant improvements over ripple control.

The primary impact of the algorithmic and simulation results is the development of a computational platform for a large network spanning multiple voltage levels. It is foreseeable that this platform would be valuable for the evaluation of a large family of discrete control and monitoring strategies.

Beyond technical contributions, the work puts significant effort into mapping out DSM practices in Europe and USA. In addition, hardware challenges and computational complexity is also briefly discussed. The demonstration of computational feasibility is a valuable result for future developments. Further discussion on computational robustness would be welcome.

Questions

1. In Chapter 6.4, the unregulated system out-performs both ripple control and DSM systems. Can you explain this?
2. The proposed DSM system is based on a linearized network model. While it is common to use linearized models in market transactions, it is not common to use DC models in short-term network operations. What are the potential pitfalls of this approach and how can they be avoided?
3. In Chapter 7, the system is proposed as an ancillary service. However, the use of a decision support system is required to account for the dynamic constrains associated

Email: georgiev@kky.zcu.cz
Telefon: +420 377 632 552

with the proposed DSM system. What deviation from today's practices does this present and, in your opinion, what are the biggest challenges in adopting such a new approach?

Overall, I consider the work of significant technical and practical value with high potential impact on future formulation of DSM systems. I thereby recommend the work for defense.

In Pilsen, ...

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Technická 8, 306 14 Plzeň

Email: georgiev@kky.zcu.cz
Telefon: +420 377 632 552