IPID4all Doctorate Research Exchange with Columbia University
Feedback report

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Extended robust linear control of storages in transmission networks with nonlinear storage dynamics

Introduction

I have been working as a researcher and PhD candidate at the DLR Institute of Networked Energy Systems (former EWE Research Centre for Energy Technology – NEXT ENERGY) since October 2014. I am writing my PhD thesis in Applied Mathematics at the DLR in the research group System Modelling and Prof. Sebastian Sager from the Otto-von-Guericke University (OVGU) supervises me.

As part of my PhD project at the DLR, we derived a network model to process open data into open power transmission networks for scientific purposes. The model is called SciGRID [1] and it uses open data provided by OpenStreetMap[1]. Using SciGRID, we generated open dataset for different spatial regions and analysed the structure and complexity of these transmission networks. Hereby, we used a graph-theoretical decomposition approach [2].

Further, I am investigating the design of transmission networks and their ability to integrate renewable energy sources. Prof. Daniel Bienstock from the Industrial Engineering and Operations Research (IEOR) Department at the Columbia University is a renowned expert on the analysis and control of power grids, especially in studying vulnerabilities and cascading blackouts. In 2016 we started a new collaboration between NEXT ENERGY, OVGU and IEOR. This collaboration includes research on modelling and solving battery operation problems to partly offset uncertainty of fluctuating renewable energy sources in transmission networks. We published [3] and presented [4,5] our model during and after the first research exchange (March 2016 – June 2016) funded by the IPID4all.

In this short report on the follow-up exchange, I will explain how we extended our model to include nonlinear storage dynamics and how we continue this successful collaboration.

Research Undertaken

As a follow-up project, under the guidance of Prof. Daniel Bienstock I had access to the necessary knowledge and resources to address nonlinear storage dynamics (see Figure 1) that is an extension to our robust optimization framework for storage operation in power transmission networks. The objective of this optimization problem is to minimize the system-

[1]

wide cost for conventional power generation. For computational tractability, it is assumed that control actions are linear in the deviation from the renewable output forecast. To solve

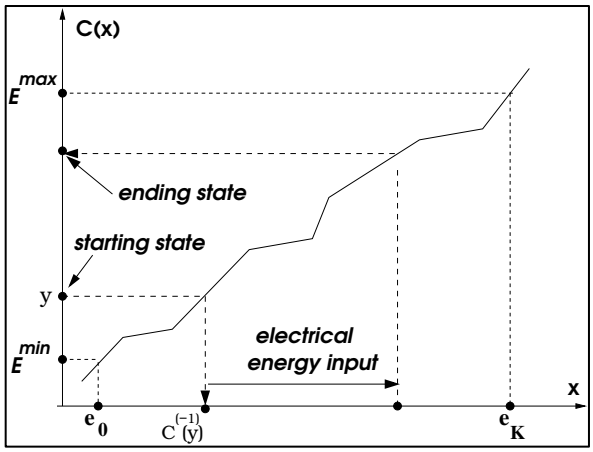

Figure 1 This is a piecewise-constant charging illustration of the storage dynamics (for discharging similar). E^{min} and E^{max} describe the allowed energy levels of the storage. y is the state of charge, C is related to the charging rate depending on y the state of charge of the storage.

this bi-level optimization problem, we propose a cutting-plane based algorithm. With this algorithm we are able to analyse large transmission network with thousands of network nodes.

Personal Experience

Most of the people I met at the IEOR were international students from all over the world. The three PhD Students working in the Group of Prof. Daniel Bienstock came from Singapore, Canada, and Chile. Furthermore, there was a very informal and pleasant atmosphere in the research institute.

Overall, it has been rewarding to be working with an interesting group of international researchers in the Columbia University's IEOR Department located in Manhattan of New York City. Through this exchange I extended my knowledge in mathematical programming and modeling nonlinear storage dynamics. I gained experience, important skills, and methodological input which is crucial to finish my PhD.

Conclusions

I had a very successful exchange period in the Columbia University's IEOR Department. The undertaken research provides important methodological contributions to the research of transmission networks with high share of renewable energy sources. The approach and results of our extended model provide a significant progress for my PhD. Furthermore, the new results are considered to be subject of joint scientific publications.

Outlook

This research is intended to lead to joint scientific publications as a Paper and contributions to upcoming conferences. The aim of this exchange program is to foster the institutional collaborations between DLR, OVGU and IEOR Department. Prof. Daniel Bienstock will be co-supervising my dissertation.

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I would like to express my personal gratitude to Prof. Daniel Bienstock, Gonzalo Munoz, Shuoguang Yang, and Mauro Escobar from the research group at the Columbia University's IEOR Department, for hosting me and conduction research together. I had the great opportunity to be part of this research group that influenced and strengthened my passion for research in many ways.
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