Control Strategies for Automatic Generation Control over Multi-Terminal HVDC networks

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Introduction

- Europe has set goals of 20% renewable energy penetration to be achieved internally by each individual country within Europe by 2020. By 2030, this goal has been set to 27%, but this latter goal is to be achieved collectively across Europe. Thus it will be increasingly desirable to collectively share renewable resources across Europe.
- HVDC provides the fastest, and most efficient way to transport large volumes of electricity over vast distances. For this reason it is proposed to build a so-called HVDC "Supergrid" across Europe. By aggregating supply from stochastic renewable sources over large areas, the worst effects of large renewable penetration can then be mitigated.
- One of the enabling technologies in the development of the Supergrid is HVDC-VSC technology as this allows multiple HVDC lines to be connected at one terminal, which in turn enables meshed or radial HVDC grids to be operated. In turn the development of these grids provides a number of control challenges.

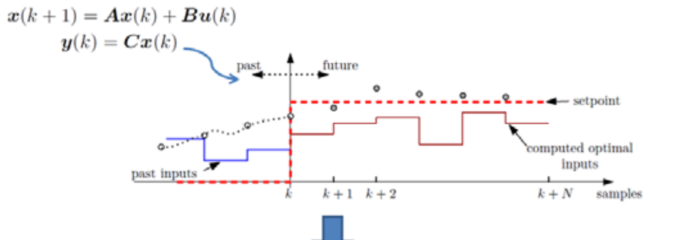
Objectives:

- **Investigate the use of Model Predictive Control for improving frequency regulation in AC areas connected to multi-terminal HVDC grids.**
- **Illustrate the performance difference between centralised MPC, decentralised MPC and decentralised PI control.**
- **Show the effect of using DC voltage offsets on the sharing of secondary reserves.**

Methodology

- A state-space framework was developed for multi-terminal HVDC systems, incorporating secondary voltage offsets and secondary mechanical power offsets.
- MPC controllers are developed based on the state-space model of the system. Decentralised PI controllers are also developed which provide secondary control of the HVDC voltage.
- The reserves used in all control areas are observed in the cases when no voltage offsets are used, and when voltage offsets are used. Of particular interest is the case when HVDC powers are not constrained to meet scheduled values as this implies areas are capable of using secondary reserves across the DC grid to regulate AC frequencies.

Model Predictive Control



$$\min_{\Delta\tilde{u}(k)} J(k) = \tilde{e}^{\mathrm{T}}(k+1)Q\tilde{e}(k+1) + \Delta\tilde{u}^{\mathrm{T}}(k)R\Delta\tilde{u}(k)$$

- Optimal Predictive Control technique. Minimises predicted errors.

Simulation Example

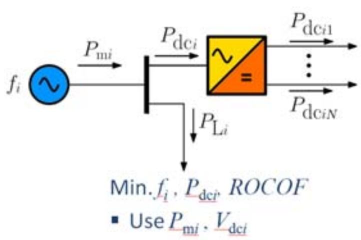


Fig. 1 AC area *i*

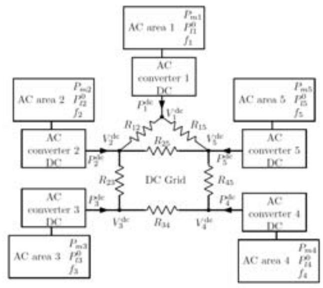
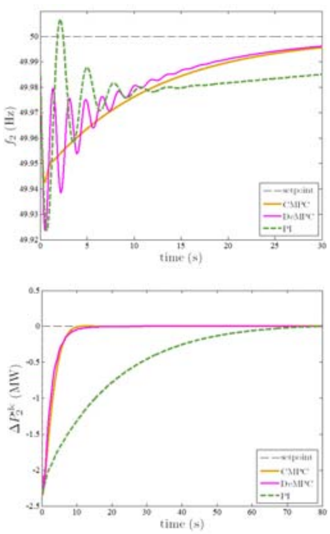
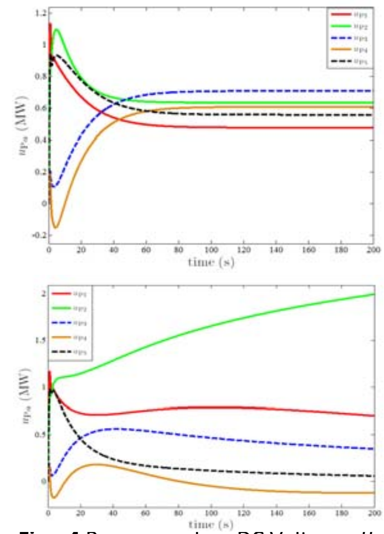


Fig. 2 Simulation testbed

Results



Figs. 3 Frequency and DC power in area 2 when DC power regulation is enforced



Figs. 4 Reserves when DC Voltage offsets (top) and no DC Voltage offsets (bottom) are used in AGC. DC voltage offsets improve secondary reserve sharing.

Conclusions

- **MPC gives improved secondary control performance. In general the use of secondary voltage offsets improves performance and reserve sharing.**
- **Future work: stochastic generation sources, additional constraints, larger testbed.**

Acknowledgement

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