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Reconstructed Droop Control for Peer Current Sharing of Battery Storage in DC Microgrids

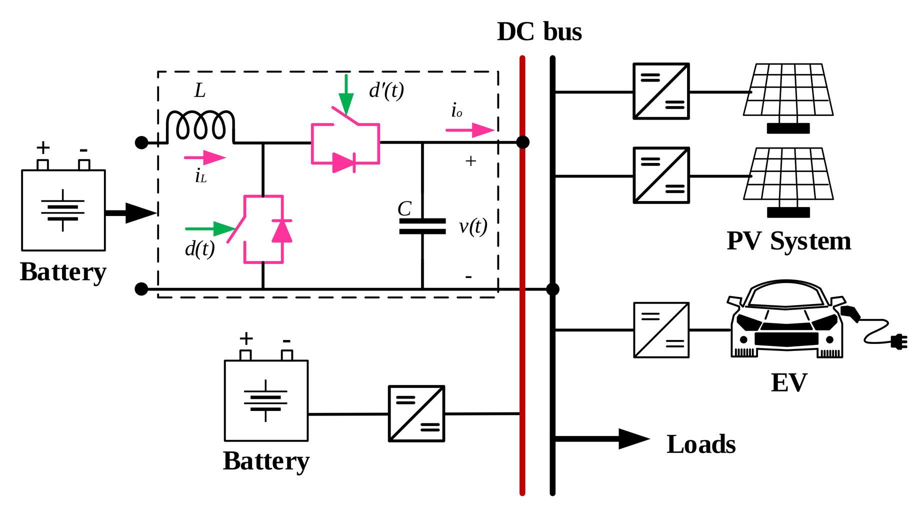
Fulong Li, Haoge Xu, Zhengyu Lin

School of Mechanical, Electrical and Manufacturing Engineering, Loughborough University, Loughborough, United Kingdom, LE11 3TU

f.li@lboro.ac.uk

1. Introduction

Droop control has been widely applied in DC microgrids for regulating the power sharing of battery storage. However, conventional droop control needs to select appreciate droop coefficients and large droop coefficients could have the potential to change the system quiescent operating point, thus causing instability.



This paper proposes a method to automatically stabilize the system by adapting the bandwidth of closed voltage loop when load changes. To achieve that, we reconstruct the droop control and make droop coefficient participate in the voltage closed loop control. Compared with conventional droop control methods, the reconstructed droop control has two improvements:

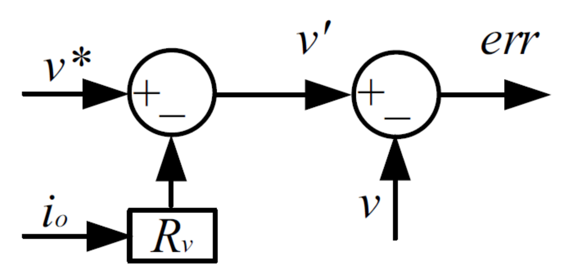
1. Introduce a deterministic droop coefficient (can be modified certainly);

2.Adaptively decrease the voltage closed loop bandwidth when the load increases such that stability operation can be promised.

2. Background and Problem

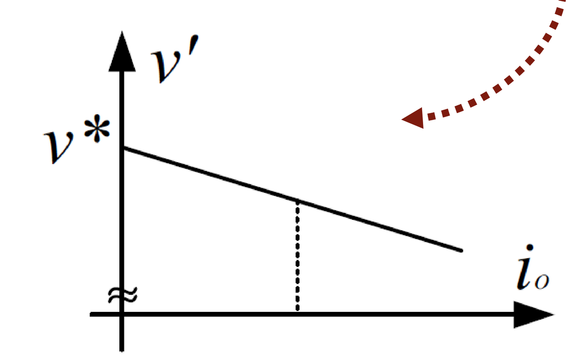
Formalization of Conventional droop control:

$$v' = v^* - i_o R_v$$



Control blocks out of double loop control

V-I curves of a typical droop control

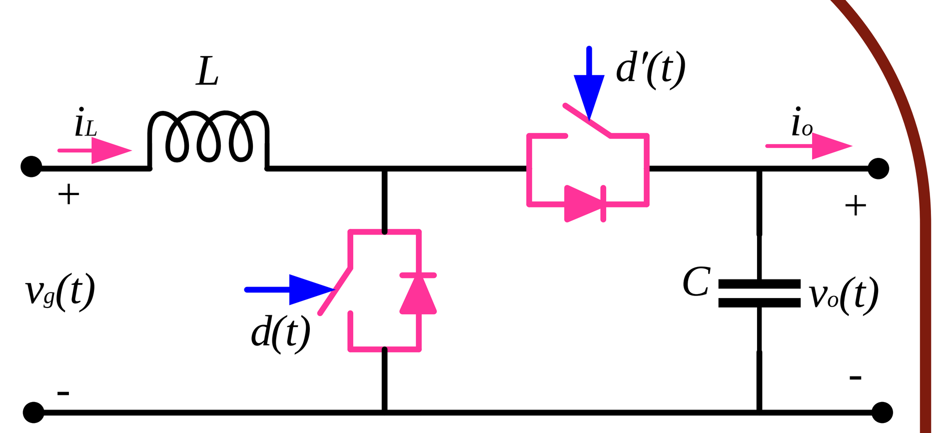


Conventional droop control has two main drawbacks:

- First, the voltage droop caused by the droop control is not desired in many applications need a constant DC bus voltage.
- Second, the combination of the droop coefficient affects the accuracy of the power/current sharing between energy storage and may be affected by the line resistance. Fortunately, those issues can be solved by the secondary control.

3. Modelling and Control Design

Boost converter is used in this paper. Through analyzing the power switch ON and OFF state, average state equations can be written as:



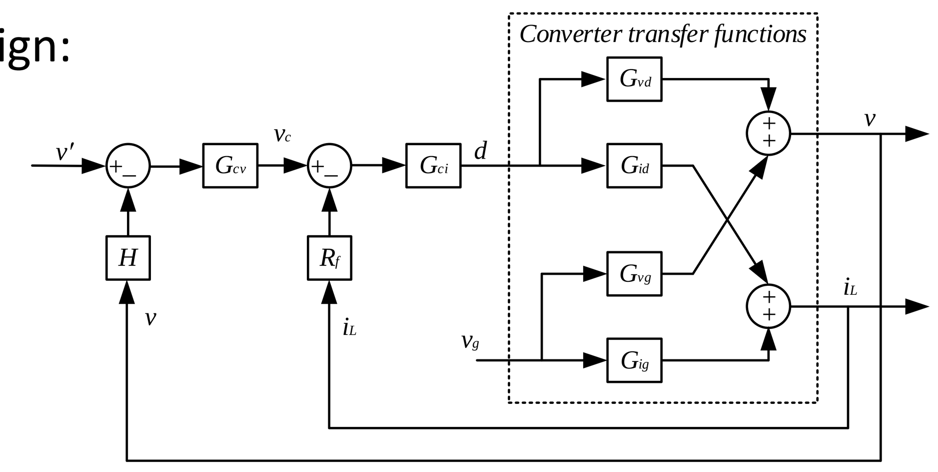
$$\begin{cases} L\dfrac{di_L(t)}{dt} = v_g(t) - d'(t)v(t) \\ C\dfrac{dv(t)}{dt} = d'(t)i_L(t) - i_o(t) \end{cases}$$

Transfer function used to assist control design:

$$G_{vd}(s) = \frac{V}{D'} \cdot \frac{1 - s\frac{L}{D'^2R}}{den(s)}$$

$$G_{id}(s) = \frac{2V}{D'^2R} \cdot \frac{1 + s\frac{RC}{2}}{den(s)}$$

$$G_{vc} \approx \frac{1}{R_f}\frac{G_{vd}}{G_{id}} = \frac{D'R}{2R_f}\frac{1 - s\frac{L}{D'^2R}}{1 + s\frac{RC}{2}}$$



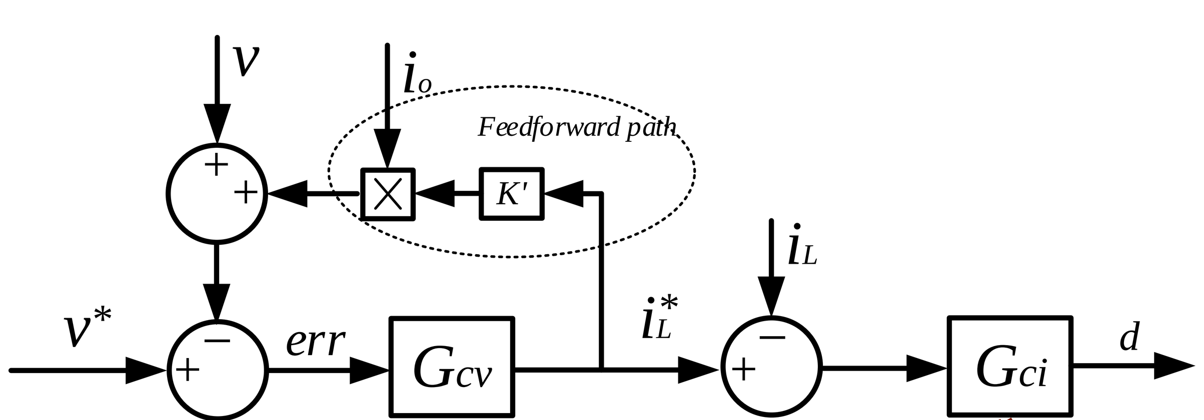
Problem statement:

$$s \to 0, G_{vc} \to \frac{D'R}{2R_f} + K$$

$$s \to +\infty, G_{vc} \to K - \frac{L}{R_f D'RC}$$

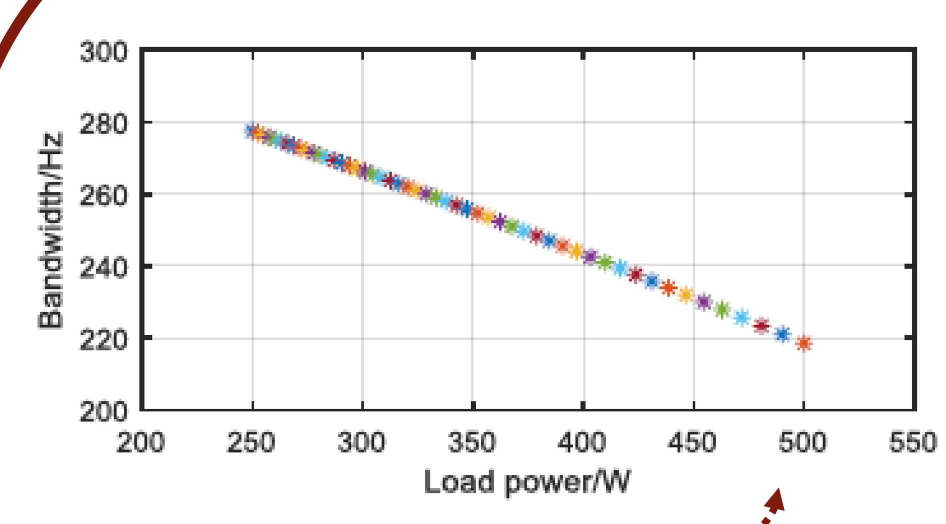
Forming the controlling path:

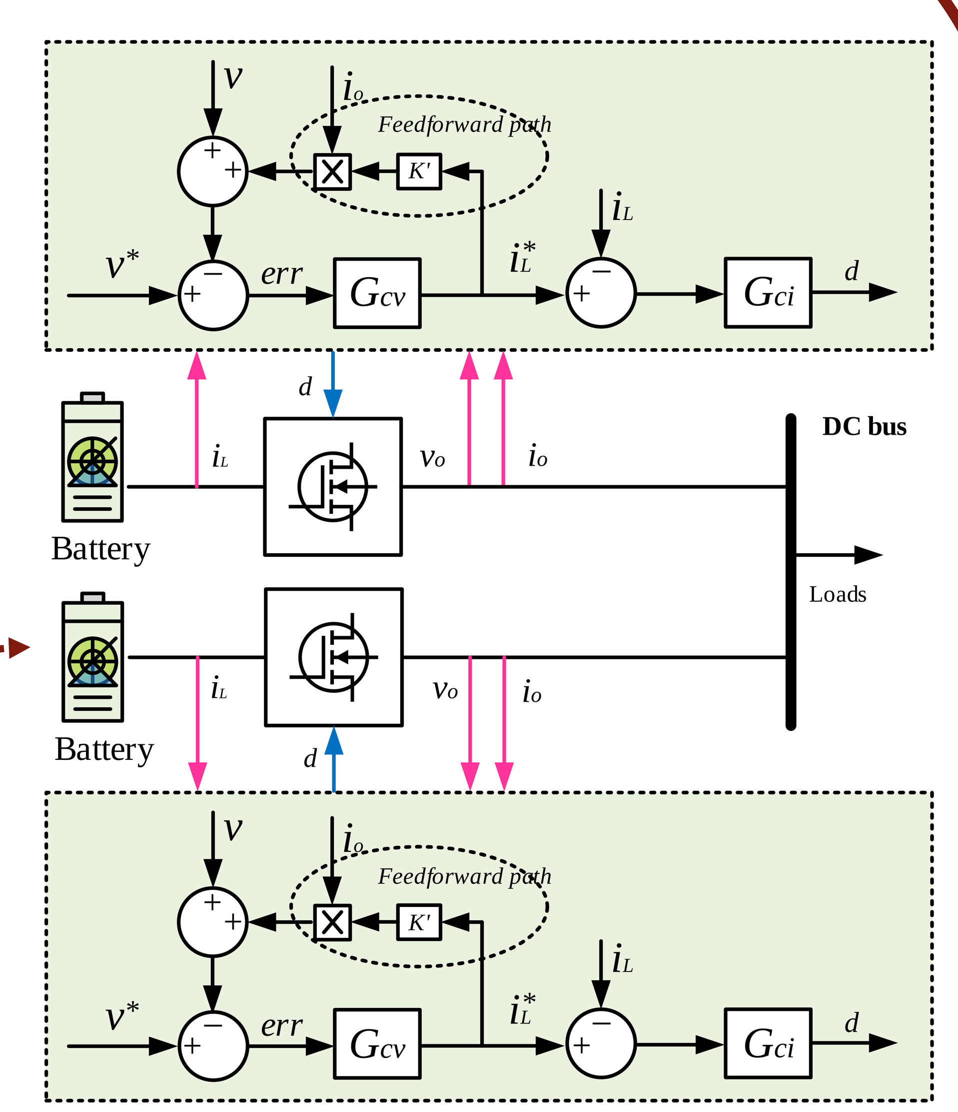
$$K = i_o K' = \frac{L}{R_f D'RC}$$



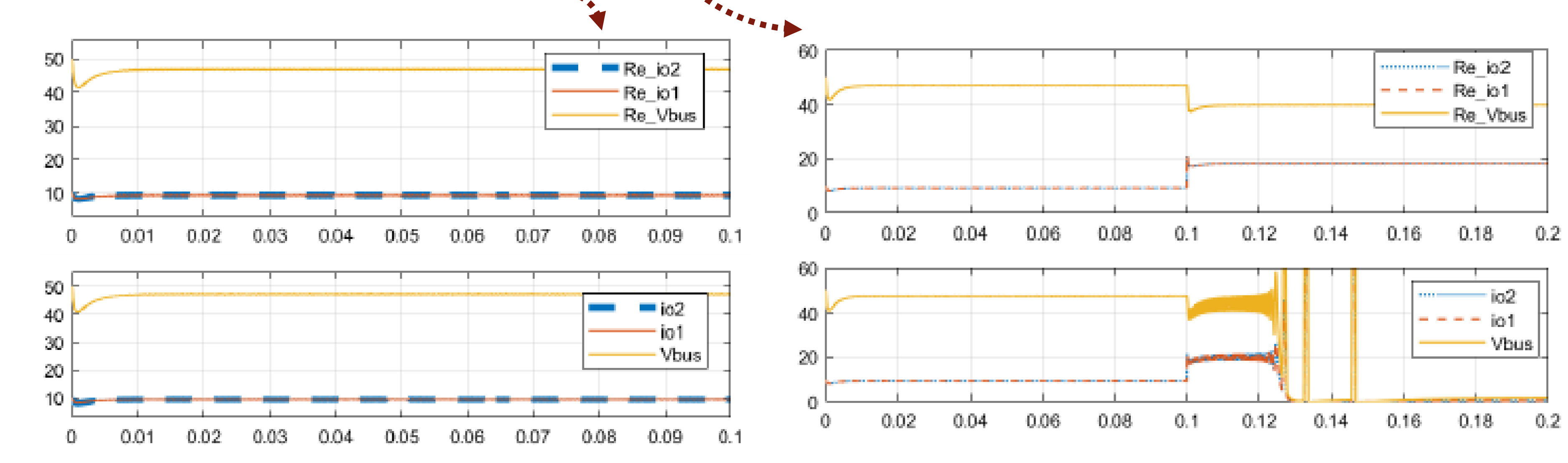
$$G_{cv} = G_{vm}\left(1 + \frac{\omega_{zv}}{s}\right) \qquad G_{ci} = G_{im}\left(1 + \frac{\omega_{zi}}{s}\right)$$

4. Simulation Results





- Relationship of bandwidth of outer voltage loop and load power
- System test configuration
- With heavy load stepping
- Without heavy load stepping



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