A New Active Damping Method for Stabilization of DC Microgrid with Constant Power Loads

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Abstract

In DC microgrids, due to the power efficiency, cost and weight considerations, small resistance and capacitance of the LC input filter are usually desirable. However it makes the operation of the LC input filter and the CPL unstable. Active damping methods for stabilization of DC microgrids with LC input filter and CPLs are preferred because of their advantage in power efficiency over the passive damping methods. This paper proposes an active damping method which builds a virtual resistance in the source side converter, and it can effectively stabilize the DC microgrids with single CPL and multiple CPLs. The advantage of this active damping method over existing active damping methods is that the stabilization effect is from the source side converters and therefore, there is no need to sacrifice the transient performance of the CPL. This paper also proves that the resonant frequencies of LC filters of parallel CPLs have to different to maintain system stability. Simulation and experimental results are reported to verify the effectiveness of the proposed idea.

Introduction

DC microgrids

DC microgrids is recently a hot research topic, because, the technology of microgrids can integrate small scale renewable energy generators into the power system. Moreover, qualitatively, DC microgrids tend to be more efficient than AC microgrids due to less conversion stages if majority of the distributed generators and loads are of DC nature. A typical architecture of the DC microgrids is shown in Fig. 1.

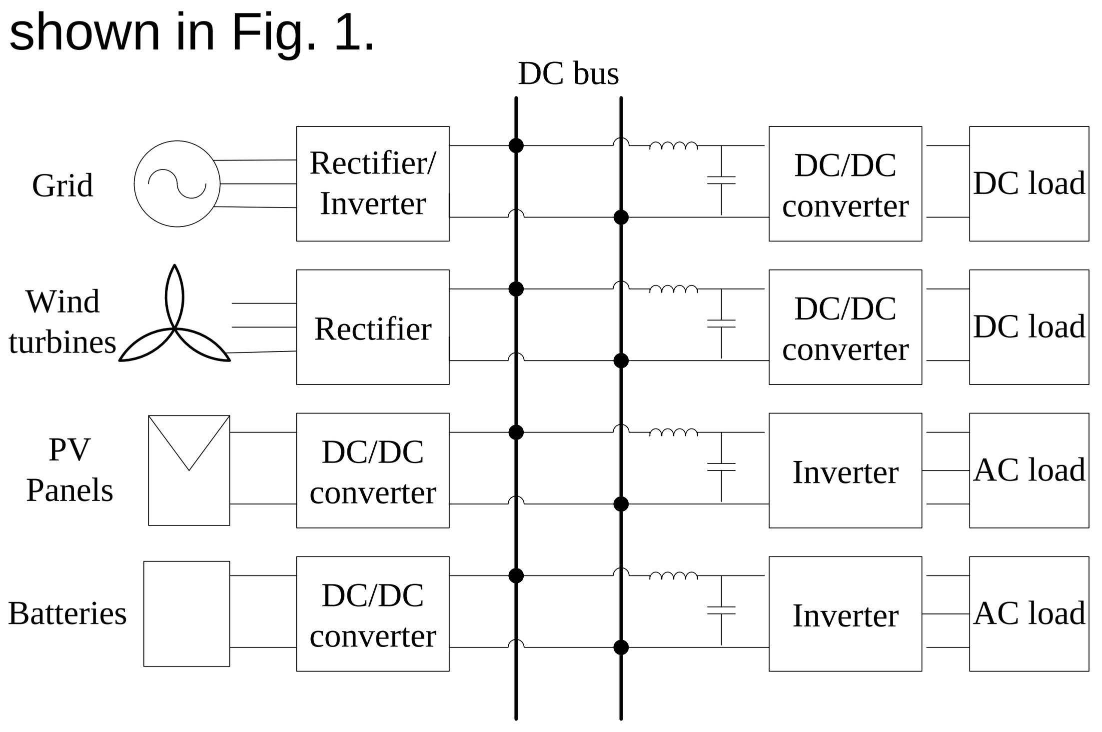


Fig. 1 The architecture of DC microgrids

Constant power loads (CPLs)

- Motors need fast response
- Consumer electronics require constant voltage

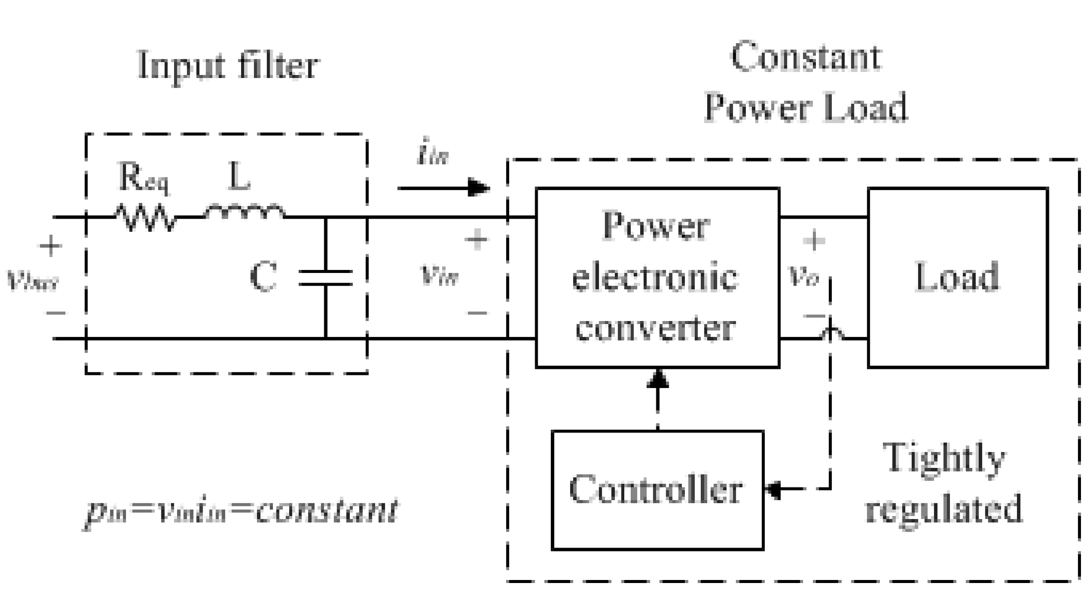


Fig. 2 The CPL and its LC input filter

Stability of CPL and LC input filter

- Simplified model of the CPL and its LC input filter

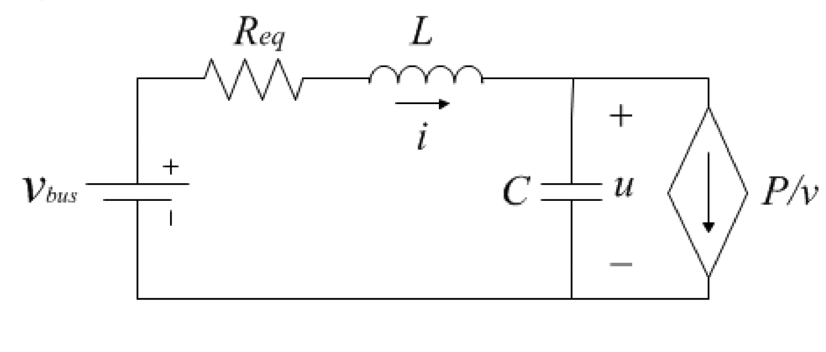


Fig. 3 The simplified model of the CPL and its LC input filter

- Differential equations

$$\begin{cases} \frac{di}{dt} = \frac{1}{L}V_s - \frac{R_{eq}}{L}i - \frac{1}{L}u \\ \frac{du}{dt} = \frac{1}{C}i - \frac{P}{Cu} \end{cases}$$

- Instantaneous negative resistance

$$r = \frac{dv}{di} = \frac{d(P/i)}{di} = -\frac{P}{i^2} = -\frac{v}{i} = -R$$

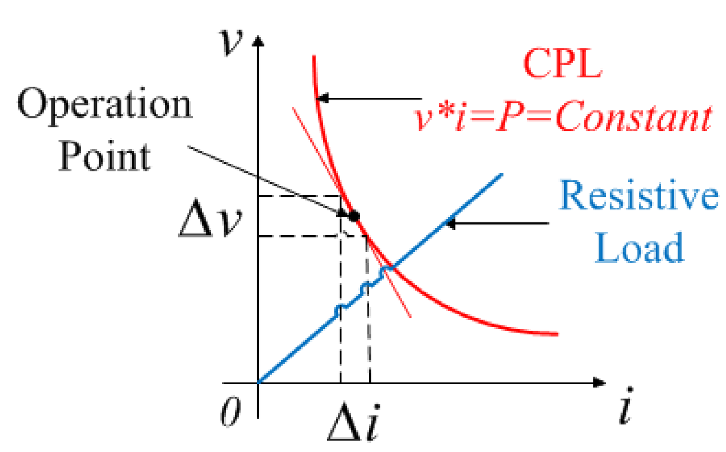


Fig. 4 The characteristic of CPL

- Linearized model

$$\begin{cases} \frac{di}{dt} = \frac{1}{L}V_s - \frac{R_{eq}}{L}i - \frac{1}{L}u \\ \frac{du}{dt} = \frac{1}{C}i + \frac{u}{CR} \end{cases}$$

- Stability criteria

$$\frac{L}{CR} < R_{eq} < \frac{V_s^2}{4P}$$

Existing active damping methods

- Method

Add extra compensating power to control loop [1],[2]

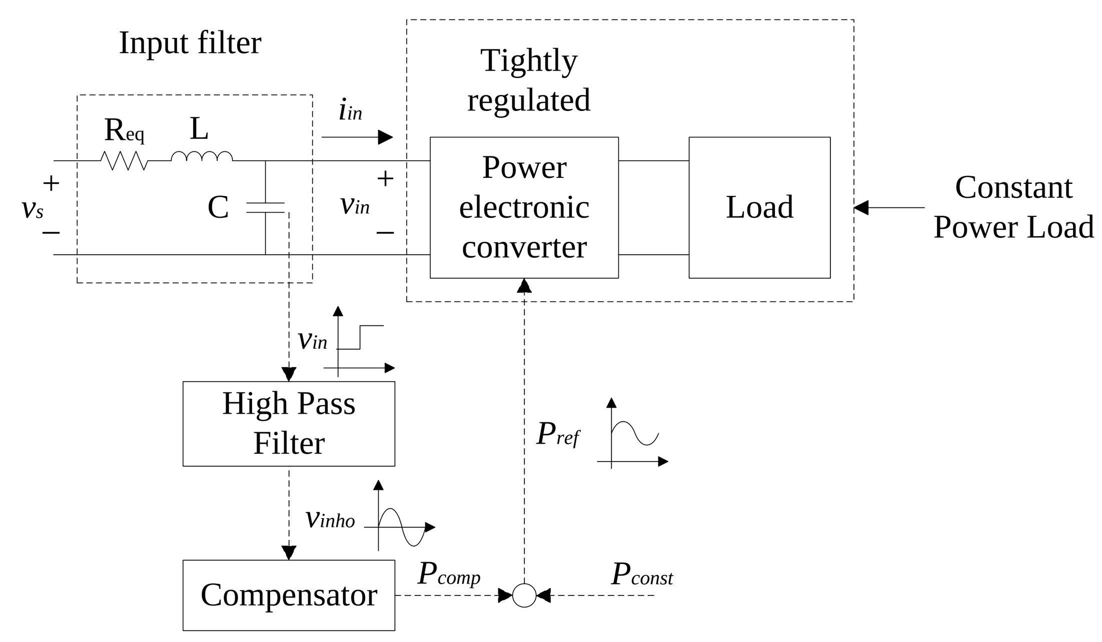


Fig. 5 The existing active damping method for stabilization of CPLs

- Main drawback

Causes variation of consumed power (current, speed and torque)

Proposed Active Damping Method

In the proposed active damping method, a sufficient large virtual resistance is added in source side converter for stabilization of CPL and its LC input filter. The stabilization effect is from the source side converter instead of the CPL itself.

Advantages

- Power efficient
- No effect on the performance of CPLs

Stabilization by proposed method for DC microgrids with single CPL

- Circuit

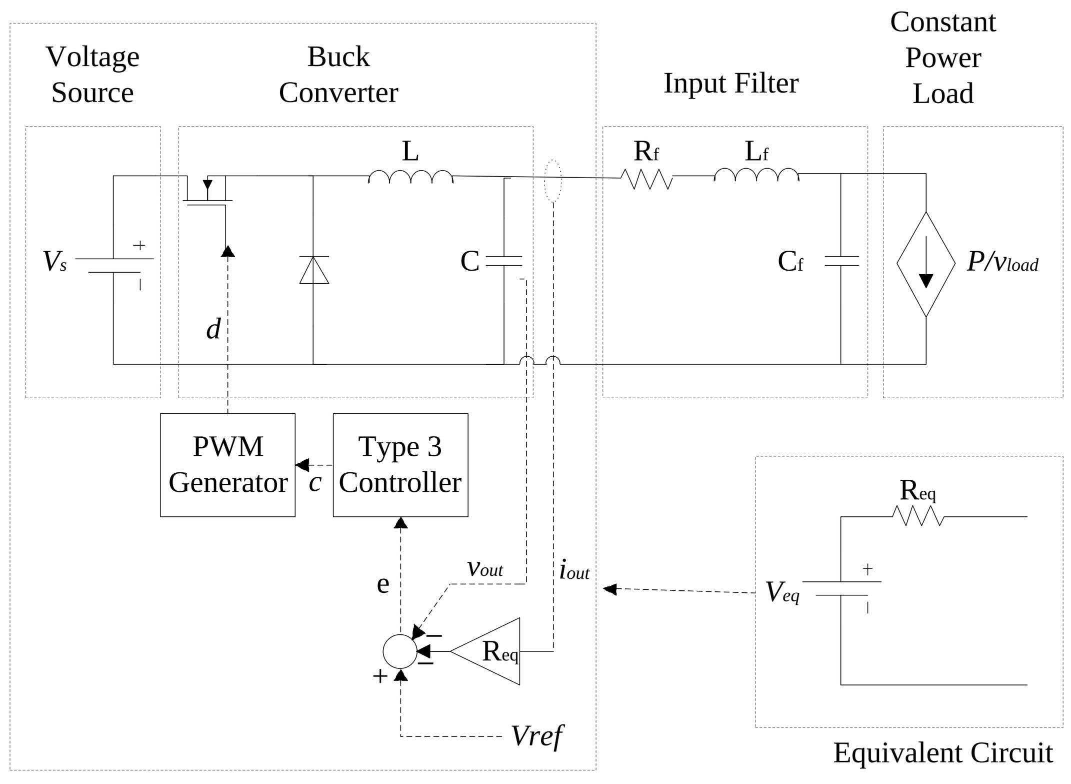
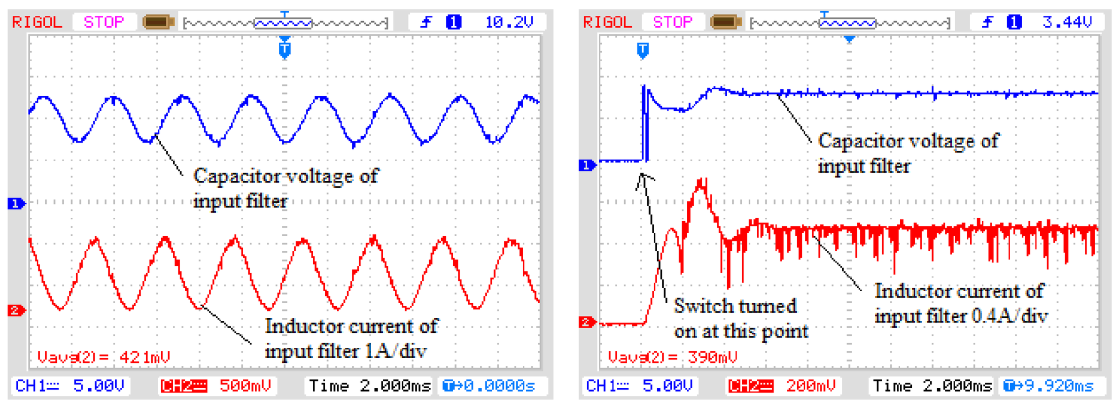


Fig. 6 The structure of the cascaded system and the proposed active damping method

- Experimental results



(a) (b)

Fig. 7 The operation of the system (a) without damping method (b) with the proposed method

Stabilization by proposed method for DC microgrids with multiple CPLs

- Circuit

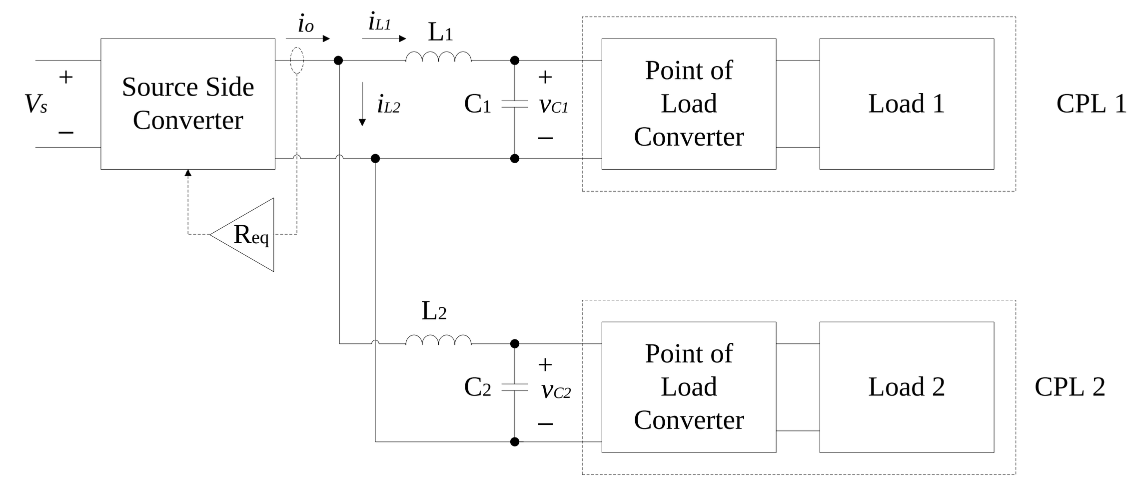


Fig. 8 The structure of the two parallel connected CPLs and source side converter

- Experimental results

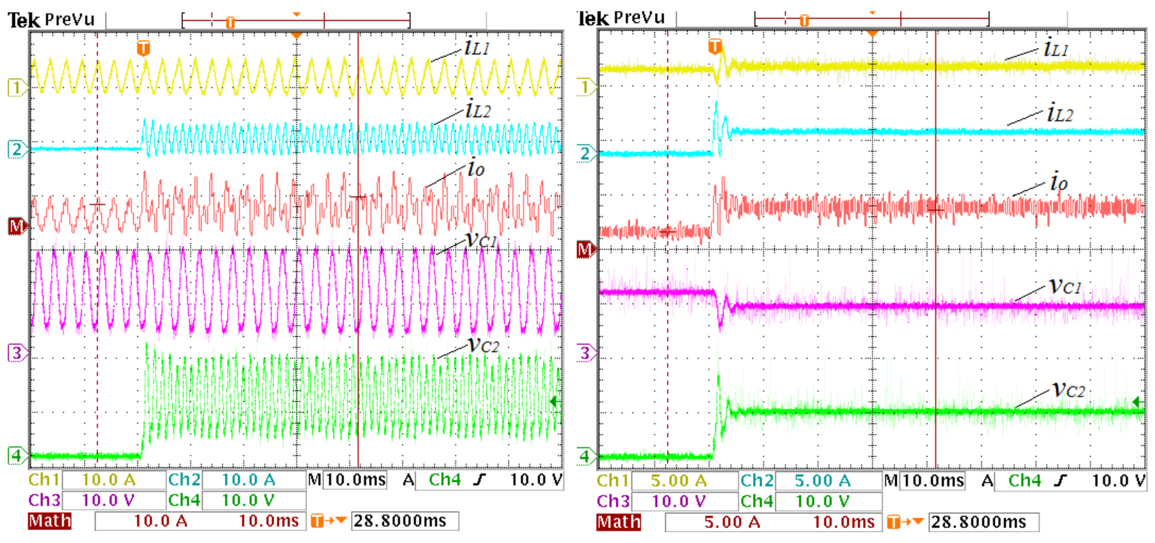


Fig. 9 The operation of the DC microgrids with two parallel connected CPLs (a) without damping method (b) with the proposed method

Conclusion

This project proposed a new active damping method by adding virtual resistance in source side converter to stabilize the DC microgrid with CPLs. The proposed method is power efficient and does not effect the performance of CPLs.

References

[1] P. Magne, D. Marx, B. Nahid-Mobarakeh, and S. Pierfederici, "Large-Signal Stabilization of a DC-Link Supplying a Constant Power Load Using a Virtual Capacitor: Impact on the Domain of Attraction," Industry Applications, IEEE Transactions on, vol. 48, pp. 878-887, 2012.

[2] L. Xinyun, A. J. Forsyth, and A. M. Cross, "Negative Input-Resistance Compensator for a Constant Power Load," Industrial Electronics, IEEE Transactions on, vol. 54, pp. 3188-3196, 2007.