The Optimal Active Method for Stabilization of LC Input Filter and DC/DC Converter

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Abstract

Switching mode power electronic converter with feedback loop control makes itself work as a constant power load (CPL). CPLs have negative input impedance which may cause system instability. This is known as input impedance instability problem. Both passive and active stabilization methods can solve this problem. However, active stabilization methods is more power efficient. Many active stabilization methods have been proposed for DC/AC inverter based CPL. However, active stabilization methods for DC/DC converter in voltage mode control based CPL receive little concern. In this project, a direct active method and the optimal active method for DC/DC buck converter in voltage mode control have been proposed. Comparing with the direct method, the optimal method can make the settling time shorter and have smaller undesirable effect on the load performance. Simulation and experimental results are reported to verify the effectiveness of these two methods.

Introduction

Instability problem of CPL and its LC input filter

Switching mode power electronic converter with feedback loop control are very popular in modern electric power systems. Because, it can provide:

- Fast dynamic response for AC loads (motors).
- Constant output voltage for DC loads.

At the same time, the input power of the converter is regulated to be instantaneously constant as shown in Fig. 1. Therefore, this type of loads are also named as constant power loads (CPLs). They have inverse proportional function v-i characteristic as shown in Fig. 2. In small signal model, it performs as a negative resistance.

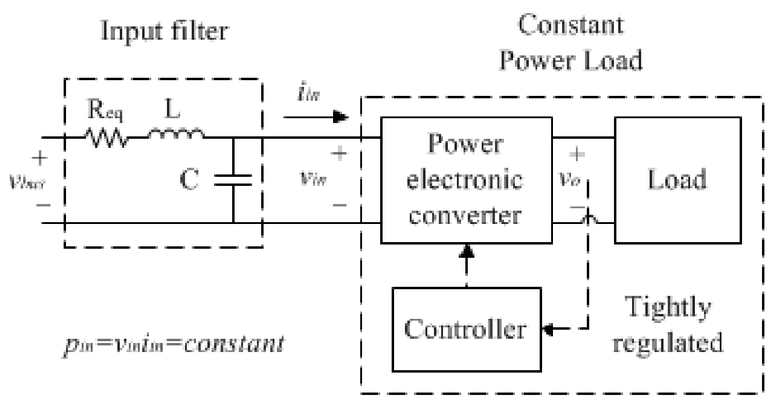


Fig. 1 The CPL and its LC input filter

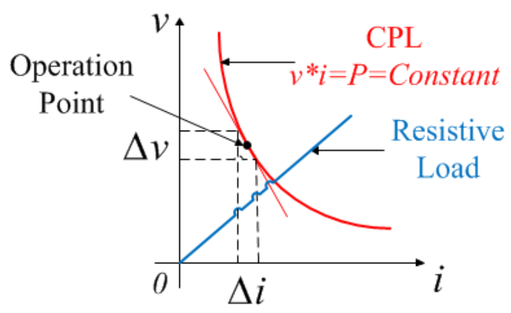


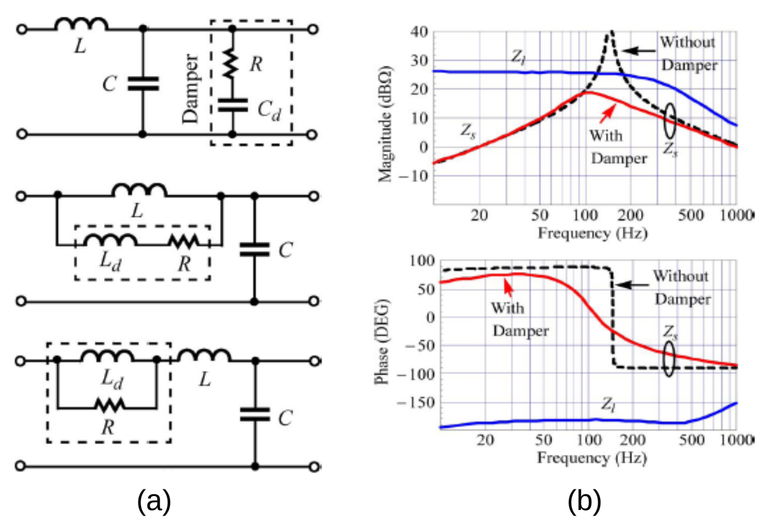
Fig. 2. The v-i characteristic of CPLs

This negative impedance may cause instability problem when the CPL operates with other circuit, for example, its LC input filter. According to the Middlebrook's stability criterion, the output impedance of the LC input filter should be smaller than the input impedance of the CPL, i.e.

$$\|Z_o(s)\| < \|Z_{in}(s)\|$$

Passive Stabilization Methods

In order to solve this instability problem, extra passive component(s) can be added into the LC input filter as shown in Fig. 3(a) to reduce its output impedance as shown in Fig. 3(b) [1].



(a) (b)

Fig. 3. (a) Three circuit diagrams of passive dampers (b) Frequency response of the output impedance of LC input filter without and with passive stabilization methods

Active Stabilization Methods for Inverter Based CPLs

Several active stabilization methods for LC input filter and inverter based CPLs have been proposed. The basic idea of these methods is to measure the unstable oscillation on input voltage of the inverter and inject this signal into the current or voltage control loop to actively damp the oscillation and stabilize the system [2].

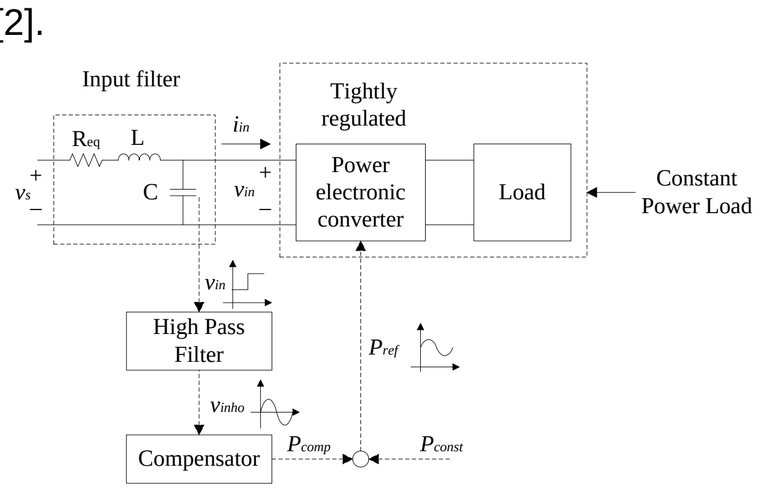


Fig. 4. The active stabilization methods for inverter based CPLs

Proposed Active Stabilization Methods

Similar to the active stabilization methods for inverter based CPLs, in direct method, the unstable signal is used and injected into the feedback loop of the DC/DC converter. In the optimal method, an extra compensator is added into the stabilizing loop as shown in Fig. 5.

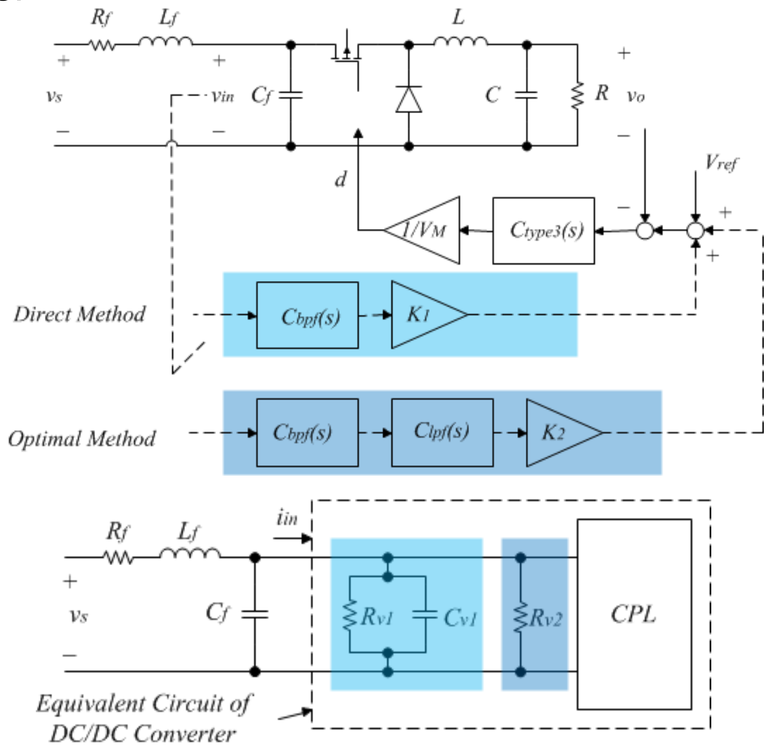
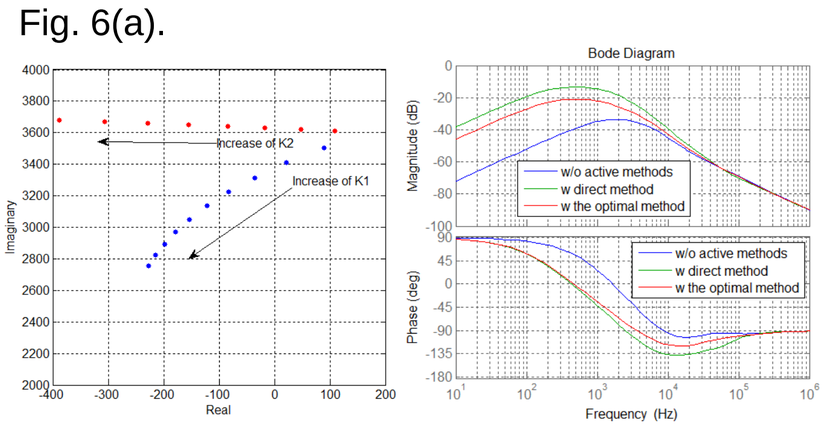


Fig. 5. The circuit diagram of the two proposed active stabilization method and their equivalent circuits

Effectiveness and Sensitivity

The effectiveness of the stabilization methods can be seen from the root locus as shown in Fig. 6(a).



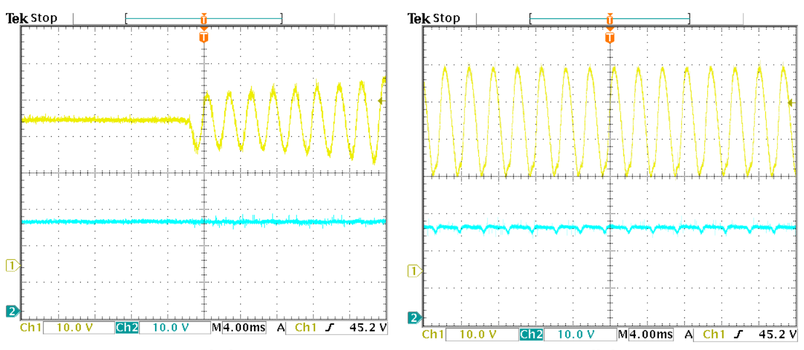
(a) (b)

Fig. 6. (a) The root locus of the system (b) the sensitivity

Comparison of the direct method and the optimal method

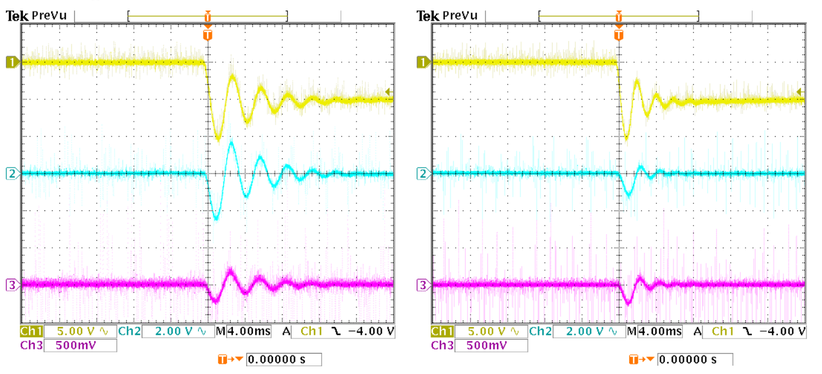
- The optimal method is more effective and efficient
- The optimal method has small sensitivity problem on the load performance.

Experimental Results



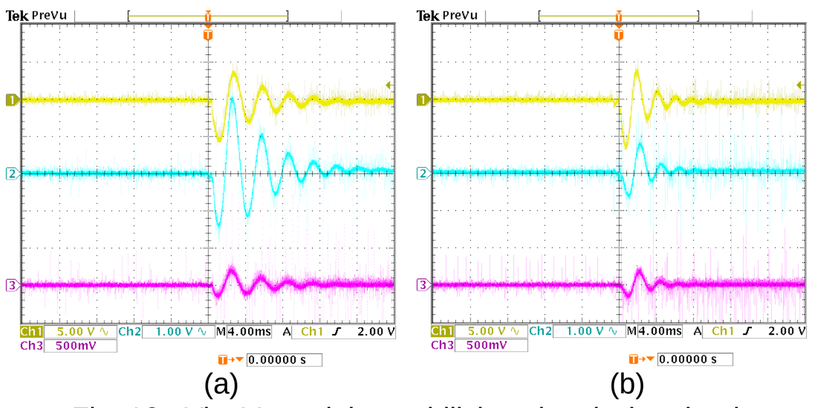
(a) (b)

Fig. 8. Vin and Vo without active stabilization method



(a) (b)

Fig. 9. Vin, Vo and the stabilizing signal when Vin changes from 40V to 35V (a) in direct method (b) in the optimal method



(a) (b)

Fig. 10. Vin, Vo and the stabilizing signal when load changes from 28.5W to 110W

Conclusion

This project proposed two active methods, direct method and the optimal method for stabilization of LC input filter and DC/DC converter with voltage mode control. The optimal method can achieve shorter settling time and cause smaller undesirable load performance.

References

[1] M. Cespedes, L. Xing, J. Sun, "Constant power load system stabilization by passive damping," IEEE Trans. Power Electron., vol. 26, pp. 1832-1836.

[2] L. Xinyun, A. J. Forsyth, and A. M. Cross, "Negative input-resistance compensator for a constant power load," IEEE Trans. Ind. Electron., vol. 54, pp. 3188-3196, 2007.