Politechnika Łódzka

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PhD Dissertation

(Synopsis)

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Sliding mode control of power converters with low damped input LC filters

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The theory of variable structure systems (VSS) and its use for control design purpose have been extensively developed over last 70th years. Sliding mode controllers (SMCs) are well to be robust and computationally efficient solution for growing number of application areas. The main idea of SMC is to force the system to reach a prescribed surface knows as sliding surface. As a consequence for this method of control the system order is reduced and the sliding surface imposes the system behaviour during the sliding motion. The aim of the dissertation is to present a new approach for sliding mode control of DC-DC buck converter with low damped input LC filter. The main objective of control was to reduce voltage and current oscillation in input LC filter without compromising the dynamic behaviour of output voltage. Two new sliding surfaces suitable for resistive and constant power load were proposed:

$$s = \left(U_{zad} - U_{C2}\right) + c_2\left(-\dot{U}_{C2}\right) + c_3\left(U_{C1} - U_w\right) \tag{1}$$

and

$$s = \left(U_{zad} - U_{C2}\right) + c_2\left(-\dot{U}_{C2}\right) + c_3\left(E - E_{zad}\right) \tag{2}$$

In each of the proposed solutions, a sliding variable is a function of an incomplete state vector. For both studied cases, a synthesis of equivalent control was carried out, by means of mathematical calculations. The equivalent control obtained in this way is described by a nonlinear relationship. Substitution of the obtained equivalent control form to the system equations leads to the description of the dynamics of the object, which is also nonlinear. Using the linearization and iteration operations of the system by a set of boundary parameters determined by the load value, it is possible to show which parameters of the proposed sliding variables ensure the stability of the control system in a wide range of operating points (loads).

In order to verify usability of the proposed regulation algorithms, the author decided to perform simulation tests of the discussed DC-DC power converter with selected types of loads. Positive simulation tests confirmed the validity of the stability analysis of the presented control structures. In the results of these tests, one can notice elements that confirm both the first thesis and the second thesis saying that the proposed regulation method with active attenuation of the LC input filter oscillation only slightly compromises the dynamics of the converter output voltage

In order to check how the proposed control structures behave in the case of a real converter, a laboratory stand with a DC-DC buck power converter with the input LC filter was prepared. The stand has been equipped with a dSPACE card, necessary power, control and measurement elements. Then, tests of the real converter with implemented control structures were carried out for two types of loads (resistive load and constant power load). The laboratory stand developed during research is presented in figures below.

Figure 1. Laboratory stand of buck DC-DC power converter with low damped input LC filter.

Conducted research showed that the proposed control algorithms can be used in real buck DC-DC power converter with lowed damped input LC filter. Both laboratory and simulation trials results proved thesis.