

ABSTRACT

Power electronic converters, being time-varying nonlinear dynamical systems are found to exhibit several periodic steady state responses as well as chaotic responses. In power electronic applications, the desired behaviour of the system is a stable periodic motion around a predefined value of periodicity equal to the period of the external clock, which is used to control the system. However, there are cases wherein some external parameters (like the input voltage or the load) fluctuate while the converter is in operation and cause the limit cycle to lose its stability and enter into other operating regimes. Such changes may also occur due to accidental loss of components or due to some design requirements. Such a phenomenon, where one mode fails to operate and another picks up, is termed as bifurcation. Hence it is of practical importance to know the conditions that ensure a desired operation and ways a desired operating mode may give way to an undesirable one. In reality, bifurcation is to be avoided, but it is also known that designing a system too remote from bifurcation boundaries may degrade other performance characteristics. Therefore, design-oriented bifurcation analysis has a significant impact on the practical methodologies taken to make design trade-off and performance optimizations.

Generally, two distinct types of bifurcation behaviour have been identified for power electronic circuits, namely slow-scale bifurcation and fast-scale bifurcation. The slow-scale bifurcation can be regarded as a kind of

low-frequency instability which is caused by the outer voltage feedback loop permitting low-frequency oscillation and the fast-scale bifurcation can be regarded as a kind of high-frequency instability which is caused by the inner current loop instability. The fast-scale and slow-scale bifurcations have been independently investigated as it has been generally believed that the outer voltage loop is much slower than the inner current loop and the two loops can be considered non-interacting. As a result, slow-scale bifurcation and fast-scale bifurcation have been studied separately. Many papers in the literature have reported the analysis of fast-scale bifurcation in the elementary DC-DC converters like buck, boost and buck-boost converters with simple and advanced control techniques. However, detailed analysis of fast-scale bifurcation in higher order converters like Ćuk converter with recent control techniques which has not been done extensively so far is presented in this thesis with a detailed mathematical analysis.

Until now, much work has been reported on the fast-scale instabilities of non-autonomous switching converters, while very little work has been performed on the slow-scale instabilities of autonomous switching converters. In this thesis, slow-scale bifurcation in a hysteresis current-controlled cascaded-boost converter which is widely used in solar energy systems is investigated in this thesis with a detailed mathematical analysis. In practice, under certain conditions, slow-scale and fast-scale bifurcations can occur simultaneously. In this thesis, the coexistence of slow and fast scale instabilities in a nonlinear carrier controlled Power Factor Correction (PFC)

Ćuk converter used to regulate the output voltage and to achieve a near Unity Power Factor (UPF) is also investigated.

Intermittent operation, heard as a sizzle with rather long period which clearly distinguishes it from other noise signals, is a phenomenon which may arise frequently in periodically driven nonlinear systems, where the frequency of the interference signal may not be consistent with the system's driving frequency. As this unwanted phenomenon is of practical importance and is comprehensible, a thorough understanding of the mechanism and the various possible conditions under which it occurs is vital to enhance reliability of switching converter operations. Hence, it is significant to consider different types of periodic signals and also the influence of interference signals in different vital places. In this connection, presently, the effect of sinusoidal, triangular and saw-tooth interference signals in input and control voltages are studied in a voltage-mode controlled buck converter.

Last of all, the intermittent period-bubbling instability and mode-locking instability in a full bridge DC-AC inverter controlled by fixed frequency PWM which is widely used in solar energy systems are also investigated in this thesis. The mode-locked instability is theoretically verified using Jacobian matrix derived from an averaged model and that of period-bubbling instability is verified using monodromy matrix based on Filippov's method of differential inclusions.