Analysis of Dynamics and Stability of an Autonomous Voltage Source Inverter

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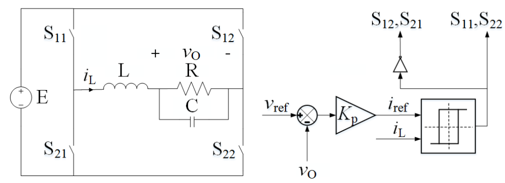
The operation of autonomous switching converter is characterized by the absence of any external forcing clock pulse. Here we consider a full-bridge voltage-source inverter under hysteresis current mode control as shown in Figure 1. The switching action is performed when the controlled state variable, which in this case is the inductor current, hits the upper or lower boundary of the hysteresis band. No control action is performed when the controlled state variable is within the hysteresis deadband. The second order system (due to the presence of output LC filter) under consideration cannot exhibit chaotic or torus dynamics. A typical waveform of the system is given in Figure 2. Such free-running converters are inherently more robust, simpler to implement (without even having any knowledge of the load parameters) and provide faster dynamic response than the non-autonomous converters. However the variable switching frequency results in difficulties in designing the input and output filter. In motor drive applications, the dynamic load directly affects the switching frequency of the hysteresis controller [1].

Slow-timescale Hopf bifurcation is the prevalent phenomenon in the autonomous power electronic converters, through which stability of the period-1 orbit is lost. Occurrence of Hopf Bifurcation has been reported in Ćuk converter [2] and photovoltaic cell fed cascaded-boost converter [3]. By employing Filippov's method, stability analysis was carried out and by manipulating the switching manifold, two control methods were proposed to extend the range of stable period-1 operation in the Ćuk converter [4] by controlling the Neimark-Sacker bifurcation.

Through extensive simulation we have witnessed that the input voltage as well as the deadband width of the hysteresis controller bears almost a linear relationship with the fundamental switching frequency. With the doubling of the input voltage the fundamental switching frequency also got nearly doubled whereas with the doubling of the hysteresis width the fundamental switching frequency got halved. Increase in deadband width resulted in increase of ripple content of the output inductor current. However no such linear relationship was observed between the load resistance with the switching frequency where with the increment of the load resistance, monotonic decrease in fundamental switching frequency was observed. The most important observation we have made in this system is that the stability of the period-1 orbit was never lost even under a large scale parameter variation. Under increased values of the gain parameter (K_p) and deadband width, the controlled state variable overshoots the hysteresis boundary and even then the period-1 orbit remains stable. Moreover, comparative results for different control methods have been given to show the distinct features of the hysteresis control method.



(a) Power Circuit of the Voltage Source H-Bridge Inverter (b) Control Circuit implementing Hysteresis Current Control

Figure 1: Hysteresis current controlled H-bridge voltage-source DC-AC inverter.

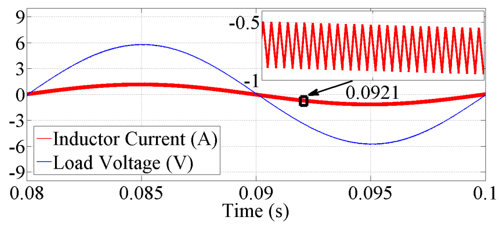


Figure 2: Waveforms of output voltage and inductor current indicating stable period-1 operation.

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