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Spectral shaping in DC-DC converters using maximum entropy random pulse width modulation

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Abstract

This work investigates the impact of probability distribution functions (PDF) on spreading the harmonic power in the power density spectrum (PSD) of Random PWM (RPWM) switching signals. Periodic switching is known to result in conducted electromagnetic interference (EMI) in switched-mode power converters. The main benefit of using RPWM signals is the ability to reduce the amplitudes of harmonics that cause conducted EMI. This helps in minimizing the dependence on sophisticated EMI filters that are typically used for mitigating this problem. This contributes to reduced volume and cost of power converters. With these benefits, a RPWM signal with the *'most reduced'* harmonics, and results in the desired power conversion, can be considered an ideal switching signal. In the PSD of RPWM signals, the reduction in the amplitude of harmonics does not imply that their harmonic power is lost. Instead, it is spread throughout the spectrum. This phenomenon establishes the relation that spreading out harmonic power reduces the high amplitude harmonics. As a result, it can be similarly said that *maximally* spreading out harmonic power in the PSD is an ideal requirement. This requirement is a key property that this research seeks to achieve, while ensuring that the RPWM signal maintains its properties that allow it to be used in a DC-DC converter the same way a traditional PWM would be used to convert electrical power. This is a constraint that is mostly governed by the duty ratio and, in the case of RPWM signals, by the nominal duty ratio. RPWM behaviour is governed by probability distribution functions that determine the nominal behaviour of the signal. This means that by using PDFs, the ability to alter both the time-domain nominal properties and frequency domain properties (in the PSD) is granted. The Method of Maximum Entropy in itself grants the very ability to obtain a PDF that has a maximally spread out distribution of probability while maintaining those time-domain nominal switching constraints. This idea ignited the initial investigation into how Maximum Entropy probability distributions result in the maximal spreading out of the PSD, given time-domain constraints. Before this, an investigation into the relationship between spreading out of probability in the PDFs and spreading out of harmonic power in the PSD is presented. Where it was found that increasing spreading of probability (quantified by entropy) of RPWM causes more spreading out of harmonic power in the PSD. This finding then qualified the use of Maximum Entropy (MaxEnt) PDFs to maximally spread out harmonic power, while maintaining time-domain constraints. With this, a method for computing MaxEnt PDFs given the time domain constraints - was formulated, and their ability to spread out harmonic power and yet maintain the constraints - was demonstrated. Additionally, MaxEnt PDFs coupled with varying the strength of time-domain constraints, revealed the limitations of spectral spreading using RPWM PDFs. Wherein stronger time-domain constraints of the PDFs restricted the maximum spreading level that can be obtained in the PSD.