Abstract

Recently, health-monitoring is an essential part of the converter reliability and protection system. It not only detects the incipient faults but also saves the system from sudden breakdowns. The health-monitoring algorithms basically compare the converter operating signatures with the standard operating signature and find out the degradation level. Generally, these signatures are computed from either the current or voltage signal across the power device placed in the converter. These traditional methods require more number of sensors, results in complex in-circuit measurement and bulky structure of the converter.

The goal of this thesis is to address the issues mentioned above and provide a non-invasive solution in the field of health assessment and monitoring of converters. For which both the conducted and radiated electromagnetic emission generated by the converter are used. The fast switching operation of power device coupled with the circuit parasitic elements results in the electromagnetic emission. These emissions depend on the switching characteristic of the power device. The major focus of the thesis is to extract the degradation parameters of the power device from the electromagnetic emission and implementation of the same for the converter health-monitoring.

In the first objective, evolving stress on the Insulated gate bipolar transistor (IGBT) is observed. IGBTs are one of the most used power devices. However, it suffers from internal degradation due to the rapid power cycle and thermal stress. The degradation of IGBT primarily increases the turn-off time as a consequence of elevated junction temperature. A constant current accelerated aging method is used to induce the deterioration in its operating characteristics. At a specific interval, the IGBTs turn-on and turn-off time are measured, and the variation with the aging time is studied. It has been seen that with an increase in the aging time, the turn-off time of the IGBT gradually increases. Also, the rate of change of turn-off time increases before the complete failure of the device.

In the second objective, we have introduced a unique method for the detection of evolving stress on IGBT through conducted electromagnetic emission signature (CES). The high-frequency operation of the IGBT, coupled with the parasitic inductor and capacitor in the circuit, generates the electromagnetic emission. The change in the operating characteristics of IGBT affects the nature and pattern of the CES power spectrum. A line impedance stabilizing network (LISN) is used to capture the conducted emission from the IGBT based buck-converter. Implementation of the CES method to converter containing more than one IGBT is the third objective. For which, an algorithm to separate the CES of individual IGBTs is developed. The LISN is placed between the power supply and the converter, and the conducted emission is measured across the LISN. This method overcomes the problems associated with the in-circuit measurement of the converter as LISN is installed away from the converter.

In the fourth objective, a novel method based on a radiated electromagnetic emission signature (RES) is proposed for the health assessment of the converters. The radiated electromagnetic emission is the propagation of conducted emission through the air. Therefore, we can detect degraded IGBT characteristics through RES. The fifth objective is to implement the RES method to multiple converters. In a practical scenario, the radiations generated from multiple converters get mixed up. This renders into a near-field source localization problem. An uniform linear array (ULA) is used to capture the electromagnetic emissions near the converters. Subsequently, ESPRIT and MUSIC algorithms are used to localize all the converters. An inverse transformation of the localization algorithm separates the electromagnetic signatures of all the individual converters. In this way, the RES method is implemented for multiple converter health-monitoring.

In the sixth objective, a less complex and high-resolution near-field localization method is developed for continuous monitoring of the multiple converters. Generally, 2D methods based on ESPRIT and MUSIC are used to localize these emissive sources. However, the high efficiency of these methods comes with the cost of a high computational burden. The algorithm which combines ESPRIT and MUSIC reduces the two-dimensional complexity, but with the less number of the snapshots and low signal to noise ratio (SNR), the performance of ESPRIT reduces. In this thesis, a modified two-stage MUSIC (MTS-MUSIC) algorithm is proposed to overcome the aforementioned limitations. MTS-MUSIC utilizes the advantages of MUSIC for estimating the direction of arrival (DOA) and the range of the sources. This method performs better than the ESPRIT-MUSIC combination for less number of snapshots and low SNR.

The seventh objective is to resolve the localization constraints when two or more converters are placed close to each other. For closely spaced converters, the proposed MTS-MUSIC shows poor resolution and some time fails to identify the sources. The proposed method further combines the spatial smoothing method with the MTS-MUSIC to address this scenario. The MTS- MUSIC algorithm reduces the computational burden, and spatial smoothing enhances the resolution.

The eighth objective is to study the effect of large load changes (LLC) on the electromagnetic emission of IGBT. The converters suffer from the temporary short-circuits and the LLCs. As the proposed health-monitoring method is based on the electromagnetic signature, the study of change in this signature during LLCs is essential. Also, it can be used to enhance the EMI filter design and short-circuit fault detection.

The proposed methods in this thesis overcome the problem associated with the existing health-monitoring techniques. In addition, it introduces a method to monitor the N number of the converter at the same time. The proposed less burdensome localization method and spatial smoothing take care of almost every aspect of the converter health-monitoring.

Keywords: Direction of arrival (DOA), Electromagnetic radiation; Estimation of signal parameters via rotation invariance techniques (ESPRIT); Fault-diagnosys, Health-assessment; Health-monitoring; Insulated gate bipolar transistor (IGBT), Line impedance stabilizing network (LISN), Large load change (LLC), Multiple signal classification (MUSIC); Signal

to noise ratio (SNR); Uniform linear array (ULA);