Modelling of Common-Mode EMI Emission in Fuel Cell integrated Maritime Power Conversion System

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Abstract
Increased switching speed and lower on state resistance of wide band gap (WBG) semiconductors devices have made them an ideal replacement to the pre-existing silicon(Si) devices used for the power converter application[1]. Although EMI issues been earlier acknowledged by the Si-based power converters development, it has become more challenging in the present years due to the high frequency operation and shorter rise/fall times of the WBG-based power converters. EMIs are classified into conducted and radiated EMI based on the medium of propagation[2]. common-mode(CM) and differential-mode(DM) EMIs are two major sub-categories of the conducted EMIs[3]. Due to the higher amplitude and frequency of occurrence, CM EMI are considered as more detrimental than DM EMI.

Several research work have been conducted earlier to analyse the impact of CM EMI generation in motor drive application using voltage source inverters(VSIs) [4, 5].In addition studies have been also conducted to investigate and mitigate CM EMI in fuel cell integrated Power Conversion System which identified neutral point shifting issue caused by CM EMI emission[6]. These studies provide background for EMI supression of WBG power converters such as passive EMI filters[5], active EMI filters[7], and modified PWM generation.

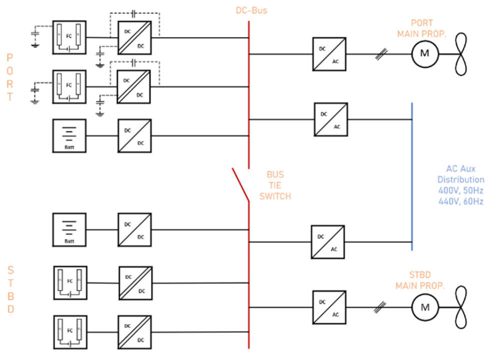

Fig.1. fuel cell battery hybrid power system

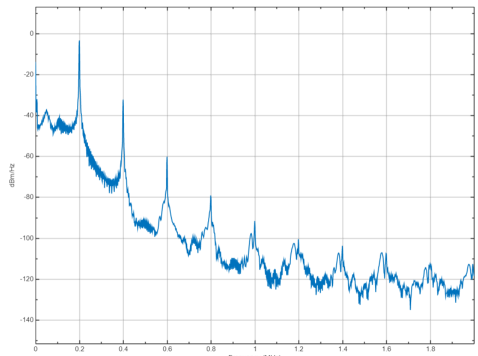

Fig.2. CM EMI spectral component

Despite the above discussed research works, CM EMI generation and suppression in fuel cell fed maritime power system is missing in the literature. Specifically, the following knowledge gap exists in the literature 1) limited research showing the EMI generation in multi stage power conversion system; 2) limited research showing EMI generation impact in fuel cell present in the CM EMI conduction path 3) lack of tools to accurately estimate CM EMI in multi stage power conversion system 4)limited analysis showing the relationship between the predicted CM EMI and it's measured counter part using line impedance stabilization network(LISN) 5) limited knowledge of using optimal suppression techniques combination to reduce filter size and meet certain EMI standard.

This research work addresses the above discussed limitation. A detailed modelling approach is presented to capture the CM EMI generation & parasitic oscillations in a fuel fell integrated Power Conversion System. A maritime micro grid consisting of fuel cell and Battery hybrid system is modelled in the MATLAB simulink environment with the corresponding power conversion stages. EMI obtained from the model is then compared with the LISN measured CM EMI. A detailed analysis of the CM EMI impact on the fuel cell is performed to understand the fuel cell degradation caused by the EMI. Soft switching techniques, multi level VSI, active EMI Filter, and modified PWM techniques are optimally combined and implemented in the simulation to analyze the possible EMI suppression level.

Fig.1 shows the fuel cell and battery hybrid plant schematic overview used for the discussed case study while Fig.2 shows the frequency component of the common mode current in the ground conductor of the maritime power system. The common mode current appears at the switching frequency of 200kHz and it's even harmonic component. Increasing switching frequency shows a rise in common mode current through the ground conductor until the resonance frequency of the system. Beyond resonance frequency, the decline in amplitude of the common mode current is caused by the rise of capacitive reactance of the parasitic element.

In this research work a detailed modelling approach to predict the CM EMI in fuel cell integrated power system was proposed along with an EMI suppression method. Simulation result showed that increasing the converter switching frequency results in rise of common mode circulating current in the ground conductor. Also, the impact of parasitic resonance on the CM EMI was analyzed. To achieve optimal EMI reduction at high operating frequency of the power converters, both topological modifications and PWM-based algorithms should be used along with the EMI filter.

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