Technological bricks and predictive tools for power conversion chains

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Abstract

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Abstract

Despite advantages in electrical and mechanical parameters controllability, the use of power inverters in MEA brought a number of major EMI issues. These impediments are such as high frequency leakage currents flowing to the ground, premature ageing of motor winding insulation, shaft voltage and bearing current in motor, and radiation of electrical harnesses. To treat these problems, it is necessary to simulate the global electrical power chain in the first development phases. Then, a global optimisation approach is used to specify and distribute EMC constraints over the entire system. We present here two complementary modelling approaches: behavioural and predictive with their drawbacks and advantages. Frequency and time domain model are compared in terms of limitation and frequency range validity of noise spectrum. Technological bricks identified as levers of optimisation, such as input filters components or innovative power harnesses, are also introduced.

Introduction

In aeronautics, technological developments are governed by the need to increase reliability and performances and by the reduction of costs and weight. For this reason, systems previously feed by pneumatic or hydraulic source are changed by systems fed by electric source. These systems are usually composed by an inverter, an electrical harness and an electromechanical actuator. With the high progress of electric power and semiconductor elements (i.e., insulated gate bipolar transistor (IGBT)), the switching frequency of voltage-source pulse width modulation (PWM) inverters has increased. This has brought significant improvements in controllability of voltage, current, and torque to variable-speed motor drive systems. Nevertheless, it causes a number of major EMI problems in electrical systems [1]. These impediments are such as high frequency leakage currents flowing to the ground, premature ageing of motor winding insulation, shaft voltage and bearing current in motor, and radiation of electrical harnesses [2]. To solve these problems, it is necessary to model and simulate the global electrical power chain in the first development phases [3]. In this paper, we talk about the distribution of the EM constraint over the whole power chain. We also present here two complementary modelling approaches: behavioural and predictive with their drawbacks and...
advantages. Frequency and time domain [4] model are compared in terms of limitation and frequency range validity of noise spectrum. Technological bricks identified as levers of optimisation, such as input filters components or innovative power harnesses, are also introduced. Constraints distribution over the whole power train chain Due to certification constraints, the electrical system has to meet requirements of standard DO160 in terms of conducted (currents flowing in each phases and common mode currents) and radiated RF emission (electrical field). To fulfil the standard and solve impediments already listed the power chain shown on Fig. 1 is modelled. An optimisation is possible if constraints are distributed on the components of the system and not only on the EMC filters. There is a trade off between the attenuation of the filter, the RLGC parameters of the power harness, the transfer surface impedance of the shielding and the CM impedance of the actuator. LISN Va Vb Vc HEATSINK HEATSINK Ibcre Icbmo Imo Fig. 1: Synopsis of a power chain Time domain and frequency approach The time domain modeling is used for predictive approach on the constraints levels and to have an accurate reference (validity must be increased to have predictive frequency models derivated). The time domain modeling is done with circuital software able to simulate non linear component like diode, IGBT, etc. Fig. 2: Simulation synoptic The frequency domain modeling is used for a behavior approach allowing to do optimization at an operating point and avoiding convergence issues when using numerous converters simultaneously on a network. The frequency domain modeling is suitable to represent parameter variation with frequency like resistance and inductance of cable due to skin effect. As shown on Fig. 2, we first start by time domain modeling, select a worst case operating point and do a frequency approach optimization. Technological bricks Filter To reduce the conducted EM emission of the power chain, the inverter is composed of at least an input EM filter. Researches on the input filter are always opportunity of reduction of weight and volume as it can represent the third of the inverter. Here, a new structure of the magnetic core leads to a decrease of 20% of the volume. Fig. 3: Input inductive filter Power harness Because of the airplane topology, the converters and the actuators are not always side mounted. Therefore, they are linked with more or less long power harnesses. Overvoltage can occur due to quick variation of the voltage (dv/dt) and harness can be a major contributor the CM current flowing though the stray capacitance. Then, it is interesting to master the primary parameters of the harness (i.e., RLGC). Fig. 4: Innovative electrical power harness The harness shown on Fig. 4 has a lower per unit length CM capacitance (divided by 8) compared to classical shielded power cables. This leads to a decrease of the CM current. As the conducted RF emission due to the CM is reduced, we can design lighter shielding and EM filters. Conclusions Extensive predictive modeling has been done in time domain on power chain components: bus bar, layout, electrical harnesses, power switch (noise source) and actuator (non predictive). In frequency domain black box model should be useful for exchanges between manufacturers and system suppliers and EM filter design. Optimization parameters have been identified like CM impedance of harnesses and actuator, primary parameters of harnesses and EM filter. Innovative component of the power chain has been developed in order to optimize the weight and volume of the system. References 1 S. Chen, T. A. Lipo: Source Of Induction Motor Bearing Currents Caused by PWM Inverters, IEEE Transactions on Energy Conversion, Vol. 11, No 1, pp. 25–32, March 1996. 2 Costa F., Gautier C., Revol B., Genoulaz J., Démoulin B., "Modeling of the Near-Field Electromagnetic Radiation of Power Cables in Automotives or Aeronautics", Power Electronics, IEEE Transactions on, vol. 28, n. 10, pp. 4580-4593, March 2013. 3 Genoulaz J., Jettanasen C., Costa F., Vollaire C., "Modelling of Common Mode Conducted Noise Emissions in PWM Inverter – Fed AC Motor Drive Systems", Proceedings of the 12th European Conference on Power Electronics and Applications, EPE 2007, Aalborg, Denmark, September 2-5, 2007, paper 398. 4 Marlier C., Videt A., Idir N., Moussa H., Meuret, R., "Hybrid time-frequency EMI noise sources modelling method", Proceedings of the 15th European Conference on Power Electronics and Applications, EPE 2013, Lille, France, September 2-6, 2013.

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