Tutorial

Title: Pulse Width Modulated Voltage Issues in Motor Drive Systems

Author:

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Primary audience and secondary audience being targeted:

All electrical and electronic engineers
Undergraduate and postgraduate students

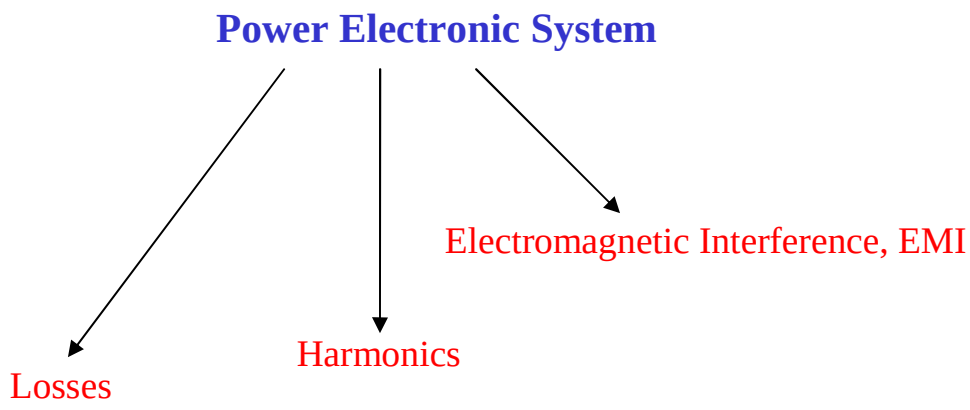
Tutorial duration:

Four hours (half-day)

Description of the tutorial:

The purpose of this tutorial is to address common-mode and shaft voltage issues in motor drive systems. Pulsed width modulated voltage waveform generated by a DC-AC converter with variable magnitude and frequency creates voltage stress (dv/dt) and common mode voltage. Due to capacitive coupling between different parts of an electric motor, the pulse width modulated voltage creates shaft voltage and leakage current.
Fast switching transient improves the system performance, switching losses and system efficiency but a main drawback is the electromagnetic interference due to fast transient and parasitic components within the systems.
In order to reduce switching losses during power conversion, the semiconductor devices have been forced to turn on and off as fast as possible which are known to be substantial sources of electromagnetic noise. These electromagnetic emissions significantly cause additional costs. Therefore the electromagnetic compatibility of power electronic applications has become an engineering discipline with enormous economic importance.

This tutorial also presents a new approach to optimize size, cost and losses of a motor drive system by taking into account EMI issue as a main problem at the first development stage of a power electronic system. This is a challenging issue in modern power electronics, which requires engineers in mechanical, electrical, control and packaging disciplines consider it as a major problem. The purpose of this tutorial is to address fundamental concepts and principles of EMI and EMC in modern motor drive systems.



In most power electronics systems, switching losses, and thermal issues have been considered as major problems of power electronic systems and development engineers optimise the system using design tools with less attention on EMI as a main parameter. For example most of electrical energy is consumed by electric motors used in industries and home appliances; and motor drives have been widely used to minimise the energy consumption by controlling the speed of the electric motor used in different applications. Development engineers who design electric motors can optimise the electric motors if they consider EMI issues to minimise all capacitive coupling between the motor windings, stator and rotor which create significant conducted noise and shaft voltage.

Control engineers who develop software and algorithm to apply a modulation strategy consider dynamic performance of the system and total losses; different techniques and topologies with considering EMI issue can improve the system cost, size and performance.

Mechanical engineers analyse heat flow using finite element analysis in order to transfer heat generated by high power components in a system. It is a trade off between thermal and EMI issues in high power and high frequency systems where decreasing the separation between the conductors separated by insulators improves the thermal performance but increases the capacitive coupling and conducted emission noise.

These design engineers need to share their knowledge with EMC experts in order to understand better the problems and to minimise the source of noise at the development phases. This is a key point which improves the overall system performances.

This tutorial consists of the following topics:

1: Major EMI Problems in Power Electronic Systems

In this section, several problems in motor drive systems will be discussed with theoretical analysis and simulation results which describe the main EMC problems in modern power electronic systems such as motor drives and high power converters. di/dt and dv/dt effects due to fast switching transients are analysed which may generate bearing current, shaft voltage, leakage current and over voltage. High power electronic motor drive systems have significant leakage current due to high capacitive coupling between the winding and the motor frame. This leakage current has a major source of conducted emission which requires bulky and expensive passive filters. Several active EMI filters will be discussed in order to suppress the leakage current and common-mode voltage.

2: High Frequency Model of Electric Motors

Predicting the conducted emission in development phase is one of the major points to estimate cost and size of the EMI filter. A good high frequency model of a motor drive system is important to find the conducted emission noise level. This section describes several methods to model electric motors for EMI analysis.

3: Pulse Width Modulated Voltage Waveform and Common Mode Voltage

In this section, common mode voltage will be calculated in term of active and zero vectors generated by a pulse width modulated voltage. The effects of zero vectors and capacitive couplings on shaft voltage will be discussed.

4: Techniques to Reduce Common Mode Voltage in Motor Drive Systems

Several techniques will be discussed to reduce common mode voltage and shaft voltage. The side effects of these methods on quality, performance and cost of system will be addressed for different applications.