Increasing the Energy Efficiency of Medium Voltage Drives

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Part I is designed as a Keynote Address, Part I and Part II combined as a Tutorial

Part I

The total losses of medium voltage power semiconductor devices are dominated by switching losses. Operating at very low switching frequency is therefore mandatory. Low switching frequency can be achieved by using multilevel inverter topologies, optimal pulsewidth modulation techniques or, at very high power, implementing series connected inverter circuits rather than series connected devices. The latter generate additional losses in their voltage balancing circuits. Parallel connected devices lead to higher currents, and consequently to higher losses.

Using these guidelines, various inverter topologies are discussed. Optimal pulsewidth modulation can be achieved by off-line optimized pulse patterns, combined with on-line optimization at transients. An alternative approach is predictive control which is presently attracting the interest of many researchers. A predictive algorithm directly generates the firing pulses of the inverter as part of a closed loop current control system, thus eliminating a pulsewidth modulator. A gate pulse is generated whenever a predefined maximum current error is exceeded. That error is computed as the difference between reference and actual current space vector. A next switching state is then determined such that maximum time elapses until the error vector exceeds its limit again. This minimizes the switching frequency and also the switching losses. A smooth transition to full-wave operation produces maximum inverter output voltage.

Part II

A further reduction of switching losses is achieved using the novel method of event-triggered, closed loop gate-charge control of medium voltage IGBTs. Other than linear control, this method overcomes various nonlinearities of the devices at microsecond response time. It uses the *gate charge* instead of the *gate voltage* of the IGBTs as the controlling variable. The IGBT is modelled as a higher order dynamic system including many nonlinear cross-coupling effects. The control strategy aims at achieving a predefined voltage gradient dU_{CE}/dt to reduce the displacement currents that tend to deteriorate winding insulation and shaft bearings of the motor. The use of harmonic filters is eliminated. Operating at a predefined current gradient dI_C/dt reduces the reverse recovery current of the diodes and hence their losses.

Both turn-on and turn-off of IGBTs is performed within only a few microseconds. Closed loop gradient control is therefore not feasible. A novel approach consists of a fast-response gate current control loop, superimposed to which is an event-triggered control system. It generates the gate current reference signal $I_G{}^*$ at calculates events and then retrieves from stored data the function $I_G(U_{CE})$ at voltage gradient control, and the function $I_G(I_C)$ at current gradient control. Reducing voltage and current gradients with conventional gate control entails increased switching losses. Against this, event-triggered gate charge control combined with optimum pulsewidth modulation leads to reducing the losses to the extent that the nominal power rating of a given drive system is tripled.

About the Speaker

Joachim Holtz graduated in 1967 and received the Ph.D. degree in 1969 from the Technical University Braunschweig, Germany.

In 1969 he became Associate Professor and, and in 1971 Full Professor and Head of the Control Engineering Laboratory, Indian Institute of Technology in Madras, India. He joined the Siemens Research Laboratories in Erlangen, Germany in 1972. From 1976 to 1998, he was Professor and Head of the Electrical Machines and Drives Laboratory, Wuppertal University, Germany. He is presently Professor Emeritus and a Consultant.

His publications include 2 invited papers in the PROCEEDINGS OF THE IEEE, 17 invited papers in IEEE Journals, and 27 single-authored IEEE Journal papers. He is the recipient of 17 Prize Paper Awards, a coauthor of seven books. He holds 33 international patents.

Dr. Holtz is the recipient of the IEEE Industrial Electronics Society Dr. Eugene Mittelmann Achievement Award, the IEEE Industrial Applications Society Outstanding Achievement Award, the IEEE Power Electronics Society William E. Newell Field Award, the IEEE Third Millennium Medal, the Anthony J. Hornfeck Service Award, and the IEEE Lamme Gold Medal. He is a Life Fellow of the IEEE.

Dr. Holtz is Past Editor-in-Chief of the IEEE Transactions on Industrial Electronics, Distinguished Lecturer of the IEEE Industrial Applications Society and of the IEEE Industrial Electronics Society.