A Comparative Study of Synchronous Current Control Schemes Based on FCS-MPC and PI-PWM for a Two-Motor Three-Phase Drive

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***Abstract*—A two-motor drive, supplied by a five-leg inverter, is considered in this paper. The independent control of machines with full dc-bus voltage utilization is typically achieved using an existing pulsewidth modulation (PWM) technique in conjunction with field-oriented control, based on PI current control. However, model predictive control (MPC), based on a finite number of control inputs [finite-control-set MPC (FCS-MPC)], does not utilize a pulsewidth modulator. This paper introduces three FCS-MPC schemes for synchronous current control in this drive system. The first scheme uses all of the available switching states. The second and third schemes are aimed at reducing the computational burden and utilize a reduced set of voltage vectors and a duty ratio partitioning principle, respectively. Steady-state and transient performances are analyzed and compared both against each other and with respect to the field-oriented control based on PI controllers and PWM. All analyses are experimental and use the same experimental rig and test conditions. Comparison of the predictive schemes leads to the conclusion that the first two schemes have the fastest transient response. The third scheme has a much smaller current ripple while achieving perfect control decoupling between the machines and is of low computational complexity. Nevertheless, at approximately the same switching loss, the PI-PWM control yields the lowest current ripple but with slower electrical transient response.**

***Index Terms*—Multi-motor drives, predictive control, reduced-switch-count inverters, vector control.**

I. Introduction

MULTIMOTOR three-phase drives with reduced-switch-count supply have been studied in the past using various voltage source inverter (VSI) topologies. A two-motor three-phase drive can be supplied by a five-leg VSI [1].

Model predictive control (MPC) has been widely studied in conjunction with drives during the last decade, and the most frequent form is the finite-control-set MPC (FCS-MPC). Various control schemes based on FCS-MPC, including current [2], flux and torque [3], [4], speed [5], and sensorless speed [6] control, have been reported. Despite its generality, one practical problem is associated with the computational burden, which, in turn, depends on the number of inverter switching states. In the reduced-switch-count multimotor drive topology studied here, an m-motor drive requires $(2m + 1)$ inverter legs. For a two-level inverter, a total of 2^{2m+1} switching states are available. While a two-motor drive has only 32 switching states, a four-motor drive will have 512 switching states. In essence, the computational burden of the FCS-MPC increases exponentially with the number of machines.

Integration of the FCS-MPC into drives has led to the development of techniques with a reduced computational burden, at the expense of control optimality. For example, adjacent vector principle in multilevel inverters [7], restrained search technique in multiphase drives [8], and use of only adjacent switching states in multimotor drives with reduced-switch-count inverter [9] have been reported. Nevertheless, an evaluation of the control quality using full and reduced sets of switching states has never been detailed. The only work with a somewhat similar idea is [10], where a drive system with 32 VSI output voltage states has also been considered. However, the work in [10] is related to a single five-phase induction motor drive, supplied by a five-phase VSI, and the switching state number is reduced by considering voltage vector magnitudes (small, medium, and large inverter voltage vectors, which come in the sets of 10, plus two zero vector states). This is completely different from the situation elaborated here, where there are two three-phase machines supplied using an inverter with five legs (which imposes a constraint on the available output voltage vectors) and where all vectors are of the same magnitude, so that different principles of the switching state set reduction have to be used. Furthermore, the system considered here requires two predictive models since there are two machines, and therefore, the cost function used has to be associated with both motors.

This paper has two main objectives. The first one is development, evaluation, and comparison of the computational complexity and performance of three FCS-MPC schemes applied to a two-machine three-phase induction motor drive. The second one is the comparison with the rotor-flux-oriented control based on PI controllers and pulsewidth modulation (PWM; known as PI-PWM control), using PWM of [1] and [11].

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