A Fault-Tolerant Two-Motor Drive With FCS-MP-Based Flux and Torque Control

Chee-Shen Lim, *Member, IEEE*, Emil Levi, *Fellow, IEEE*, Martin Jones, Nasrudin Abd Rahim, *Senior Member, IEEE*, and Wooi-Ping Hew, *Member, IEEE*

***Abstract*—Independently controlled multimotor drives are typically realized by using a common dc link and independent sets of three-phase inverters and motors. In the case of an open-circuit fault in an inverter leg, one motor becomes single phase. To enable continued controllable operation by eliminating single phasing, the supply for the motor phase with the faulted inverter leg can be paralleled to a healthy leg of another inverter using hardware reconfiguration. Hence, the two motors are now supplied from a five-leg inverter, which has inherent voltage and current limitations. Theoretically, violating the voltage limit leads to inverter overmodulation and large torque oscillations. It is shown here that the finite-control-set model predictive control, designed to control the machines' stator flux and torque, can consider the inherent voltage limit dynamically in the control loop. Apart from preserving the independent control of the two machines, the additional constraint consideration significantly widens the operating speed ranges of the machines. In particular, it is shown that, whenever the voltage limit is entered, the controller reduces the stator flux level automatically, without requiring external flux reference change. The obtained performance is illustrated using experimental results and is also compared to the conventional two-motor field-oriented control scheme. The control concept is thus fully experimentally verified.**

***Index Terms*—Field weakening, flux and torque control, model predictive control, open-circuit fault, two-motor drive.**

I. Introduction

MULTIMOTOR three-phase drives use typically a common dc link and separate three-phase inverters to realize independent motor control. In the case of an open-circuit fault in one of the inverter legs, a possible solution for fault-tolerant operation is to use a switch to connect the motor phase that has lost the supply to a healthy inverter leg of another motor. The concept is illustrated in Fig. 1 for a two-motor drive, where, after the open circuiting of the phase c of the second motor, the supply for this phase is connected in parallel to the phase c supply of the first motor.

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C.-S. Lim was with the Power Energy Dedicated Advanced Centre, Wisma R&D, University of Malaya, 59990 Kuala Lumpur, Malaysia, and the School of Engineering, Technology and Maritime Operations, Liverpool John Moores University, Liverpool, L3 3AF, U.K. (e-mail: limcheeshen@gmail.com).

E. Levi and M. Jones are with the School of Engineering, Technology, and Maritime Operations, Liverpool John Moores University, Liverpool, L3 3AF, U.K. (e-mail: e.levi@ljmu.ac.uk; m.jones2@ljmu.ac.uk).

N. A. Rahim and W.-P. Hew are with the Power Energy Dedicated Advanced Centre, Wisma R&D, University of Malaya, 59990 Kuala Lumpur, Malaysia (e-mail: nasrudind@um.edu.my; wphew@um.edu.my).

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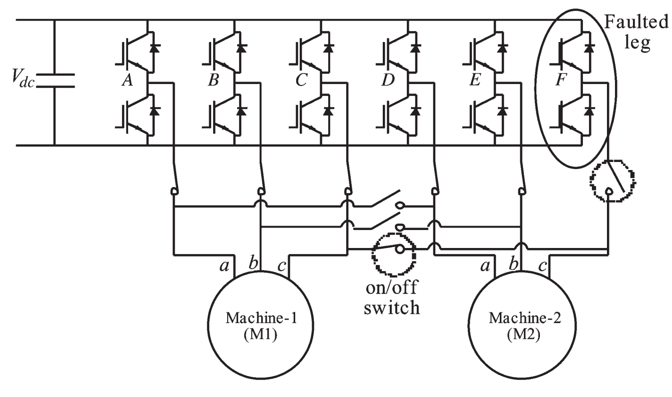

Fig. 1. Reconfiguration of the electrical connections of the two-motor system through appropriate on/off switches after a fault in one inverter leg.

The resulting inverter topology in Fig. 1 is a five-leg inverter supplied two-motor drive, which has been considered extensively in the past as one of the reduced-switch-count topologies for multimotor drive systems [1]–[3]. The five-leg configuration provides a similar fault-tolerant property as the addition of a redundant inverter leg, studied in [4], except that the control here is more involved due to the sharing of an inverter leg between the machines. It is important to emphasize that all phases are energized here after the fault, in contrast to the configuration in [5], and hence, a higher and smoother torque can be obtained.

In postfault operation, the shared inverter leg topology in Fig. 1 leads to a limited dc-bus voltage availability, as well as the potentially (depending on the loading) higher current flow in the shared inverter leg [3]. The full utilization of the available dc-bus voltage in an m-motor drive supplied by a $(2m+1)$-leg voltage-source inverter is possible using the suitable pulse width modulation (PWM) techniques developed in [2] and [3]. Since the dc-bus voltage is set to the value that corresponds to a single-motor drive, even with the full dc-bus voltage utilization, there is a limit on the achievable operating speeds, which in simple terms means that the sum of the frequencies of any two machines cannot exceed the rated supply frequency.

MPC has been introduced into the drives area in the last decade, and the most frequent form is the finite-control-set model predictive control (FCS-MPC). Using FCS-MPC, various machine control schemes have been studied, including flux and torque control [6], [7], and speed [8] control. FCS-MPC has been also recently applied in the two-motor drive system supplied by a five-leg inverter [9], where synchronous current control has been investigated.