# Space Vector Control of 5-phase PMSM supplied by 5 H-bridge VSIs

J. P. Martin, E. Semail, S. Pierfederici, A. Bouscayrol, F. Meibody-Tabar, and B. Davat

***Abstract*—The use of polyphase PMSM supplied by H-bridge VSI allows on one hand to segment the power transferred from the electrical source to the mechanical load and on the other hand to operate in degraded operating mode, with one or several non-supplied phase. Nevertheless, for an independent current control of the H-bridge VSI the magnetic coupling between each phase winding leads to high phase current ripples.**

**In this paper a global current control method of the H-bridge VSIs, based on an adapted space vector control method is proposed. The proposed method allows a considerable reduction of the current ripple rate in the case of 3-phase and 5-phase non-salient PMSM supplied by H-bridge VSIs.**

***Index Terms*-- AC motor drives, Current control, Permanent magnet motors, Electromagnetic coupling, Pulse width modulation.**

## I. INTRODUCTION

For a given power transferred from the electrical source to the mechanical load the increase of the phase number allows the use of inverters with reduced caliber switches authorizing consequently a higher switching frequency of the inverters components. A structural solution consists in using polyphase machines (fig 1) where each phase is supplied by its own H-bridge Voltage Source Inverter (VSI).

By the use of polyphase synchronous machines excited by rotor mounted permanent magnets, the segmented structure of the supply allows the system to operate in degraded mode with one or several non-supplied phases [1]. The structural properties and the modularity of the inverters make this solution attractive for embarked applications, especially for naval propulsion.

The Multi-machine Multi-converter System representation of a such system points out energy distribution and magnetic coupling of the electromechanical conversion chain (fig 2) [2]. The sources are depicted by oval forms: the equivalent electrical source (ES) and the mechanical ones (MS). The electrical coupling due to the supply by the same electrical

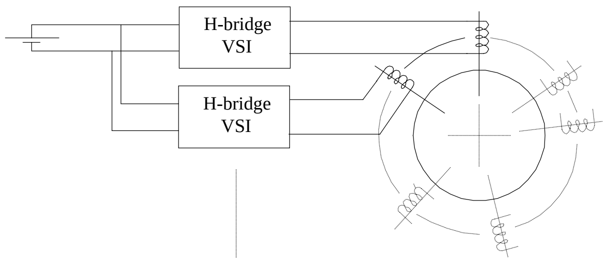


Fig. 1. Segmented supplied structure.

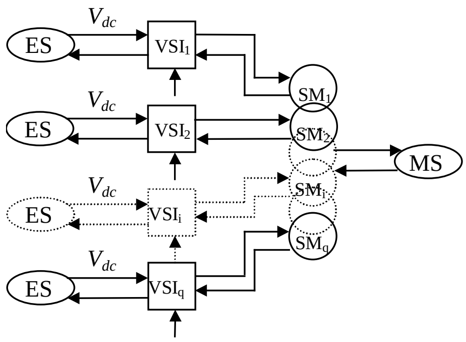


Fig. 2. MMS representation of the segmented structure.

source is neglected and the converters are supposed to be supplied by identical independent electrical sources. The electrical converters (H-bridge VSI) are represented by square forms. The odd q-phase PMSM is supposed to be equivalent to q magnetically coupled single-phase machines sharing the same rotor. q circular forms represent this machine and the intersections between them indicates the magnetic coupling.

However, the magnetic coupling between the phase windings leads to the fact that the dynamic of one phase current depends not only on its voltage value but also on the applied voltages to the other phases. So, the independent control of each phase current may lead to high current ripple rate, increasing consequently machine and converters losses.

By applying the generalized Concordia transformation ([3], [6]) to the variables of a q-phase non-salient PMSM, we show that this machine with an odd phase number is equivalent to (q+1)/2 fictitious machines without magnetic coupling: (q-1)/2 two-phase and one single-phase machines. For a machine with sinusoidal emf waveform, the machine torque depends only on the currents of one of the fictitious 2-phase machine (called main machine). The currents of the other single or 2-phase machines (called secondary machines) generate only additional

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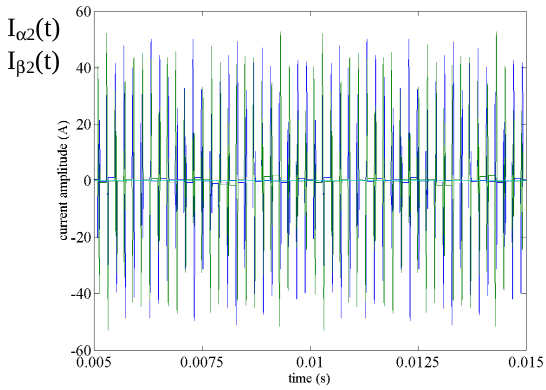


Fig. 13: Current components of the secondary fictitious machine.

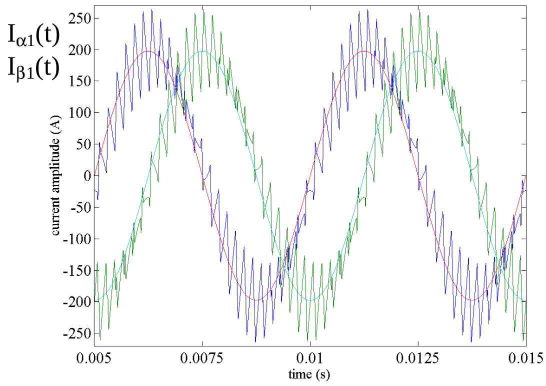


Fig. 14: Current components of the main fictitious machine.

## V. Conclusion

Thanks to the use of generalized Concordia's transformation and the diagonalisation of the machine model, it is shown that a q-phase non-salient PMSM supplied by q H-bridge VSI is equivalent to (q+1)/2 fictitious machines without magnetic coupling. Only one of these machines called main 2-phase machine generates the electromagnetic torque for a PMSM with sinusoidal emf waveform. Supplying the others leads only to supplementary losses and to high amplitude ripples in the phase current waveform due to their weak inductance

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A global current control of the q H-bridge VSIs based on the application of voltage vectors exciting weakly the homopolar and secondary fictitious machine was proposed. The application of this current control method allows a considerable reduction of the ripple rate of the phase current in the case of 3-phase and 5-phase sinusoidal PMSM supplied by H-bridge VSIs.

## VI. References

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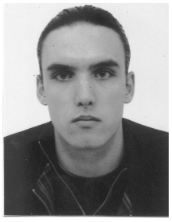
## VII. Biographies



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