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TUNING OF SPEED PI IN FCSMPC OF MULTI-PHASE DRIVES USING PARETO

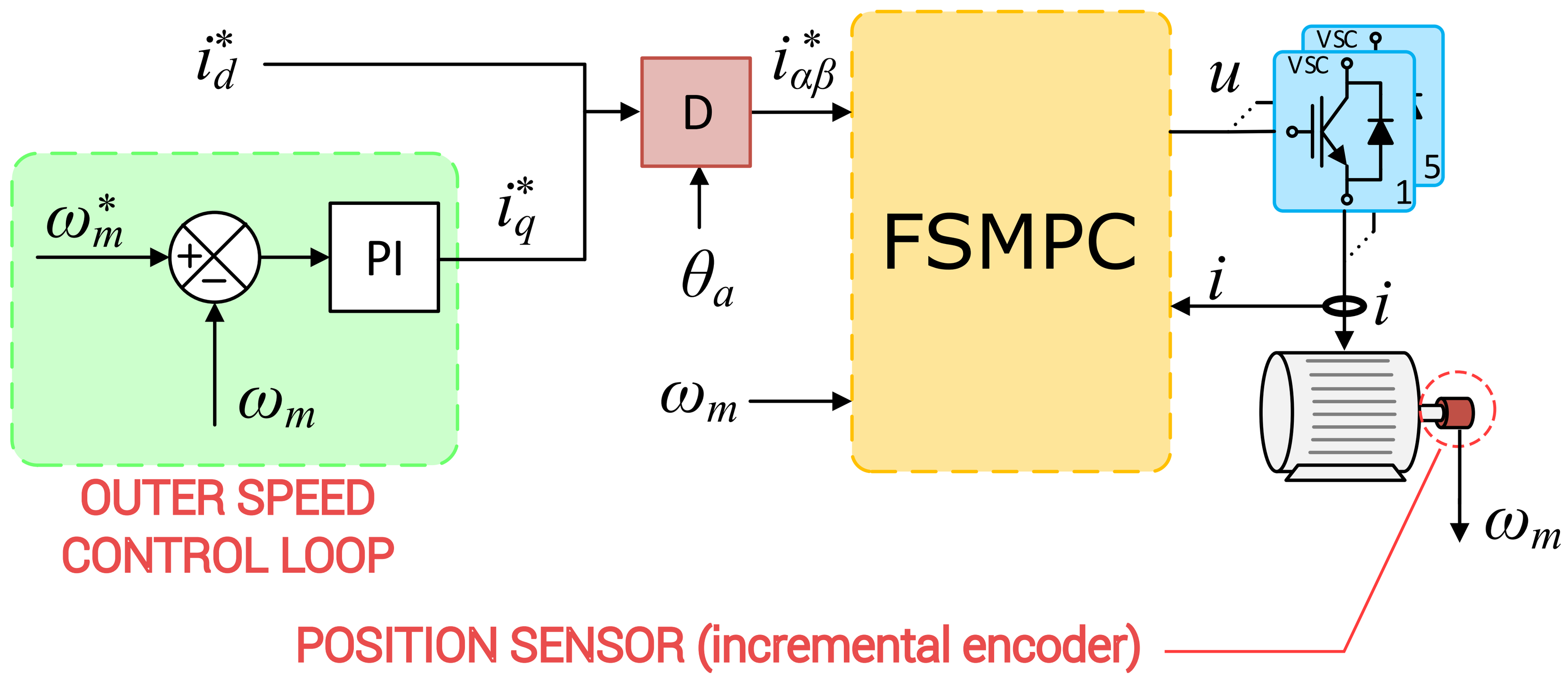
F. Barrero[a], M. G. Satué[b], M. Perales[a]

[a] Departamento de Ingeniería Electrónica

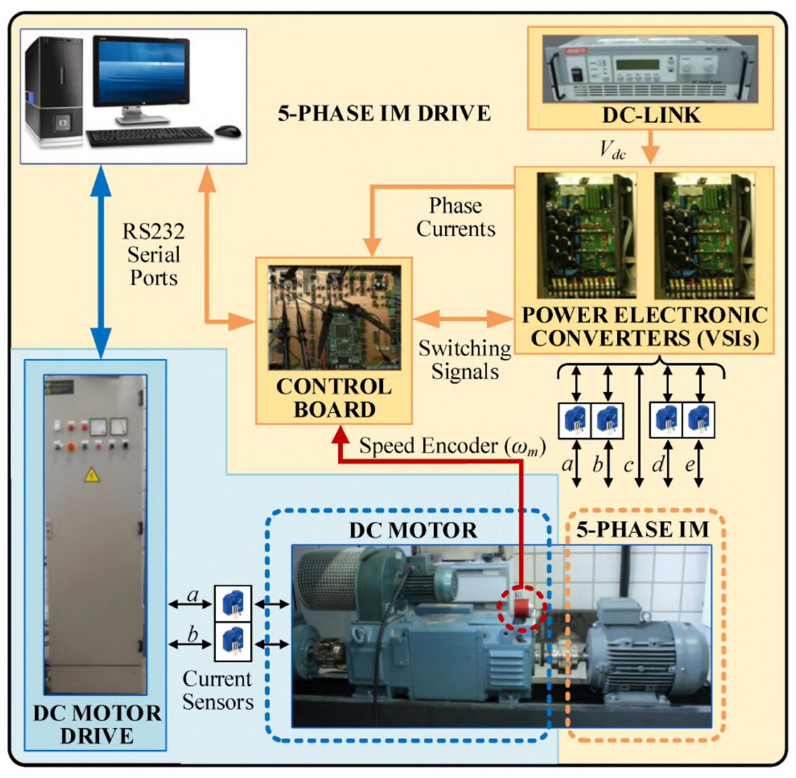
[b] Departamento de Ingeniería de Sistemas y Automática

Context

Control of drives is often done using an outer speed loop and an inner current loop. The outer loop is mostly performed by a PI controller. Its tuning is not trivial. In this paper a Pareto analysis is proposed to reveal tradeoffs between figures of merit. A finite-state predictive method is used for the inner loop (current control). The analysis is done experimentally, thus including all sorts of non-idealities not appearing in commonly found models. The importance of the result lies in showing that arbitrary performance enhancements are not possible in a general case.



Laboratory setup



- five-phase motor
- five-phase VSI constructed from two three-phase SEMIKRON SKS 22F modules
- 300V DC power supply is used in the DC-link
- MSK28335 board housing a TMS320F28335 DSP
- Hall effect sensors (LH25-NP)
- DC motor is used sharing the same shaft as the IM to provide an opposing torque load

Performance indices

$$\Gamma = (PO, Q_T, RT)$$

rise time: $$RT = \underset{t\geq 0}{\arg\min}(\omega^*(t) - \omega(t))$$

torque ripple: $$Q_T = \sqrt{\frac{1}{N}\sum_{k=1}^{N}(T^*(k) - T(k))^2}$$

percentage overshoot: $$PO = 100\frac{\max(\omega - \omega^*)}{\omega^*}$$

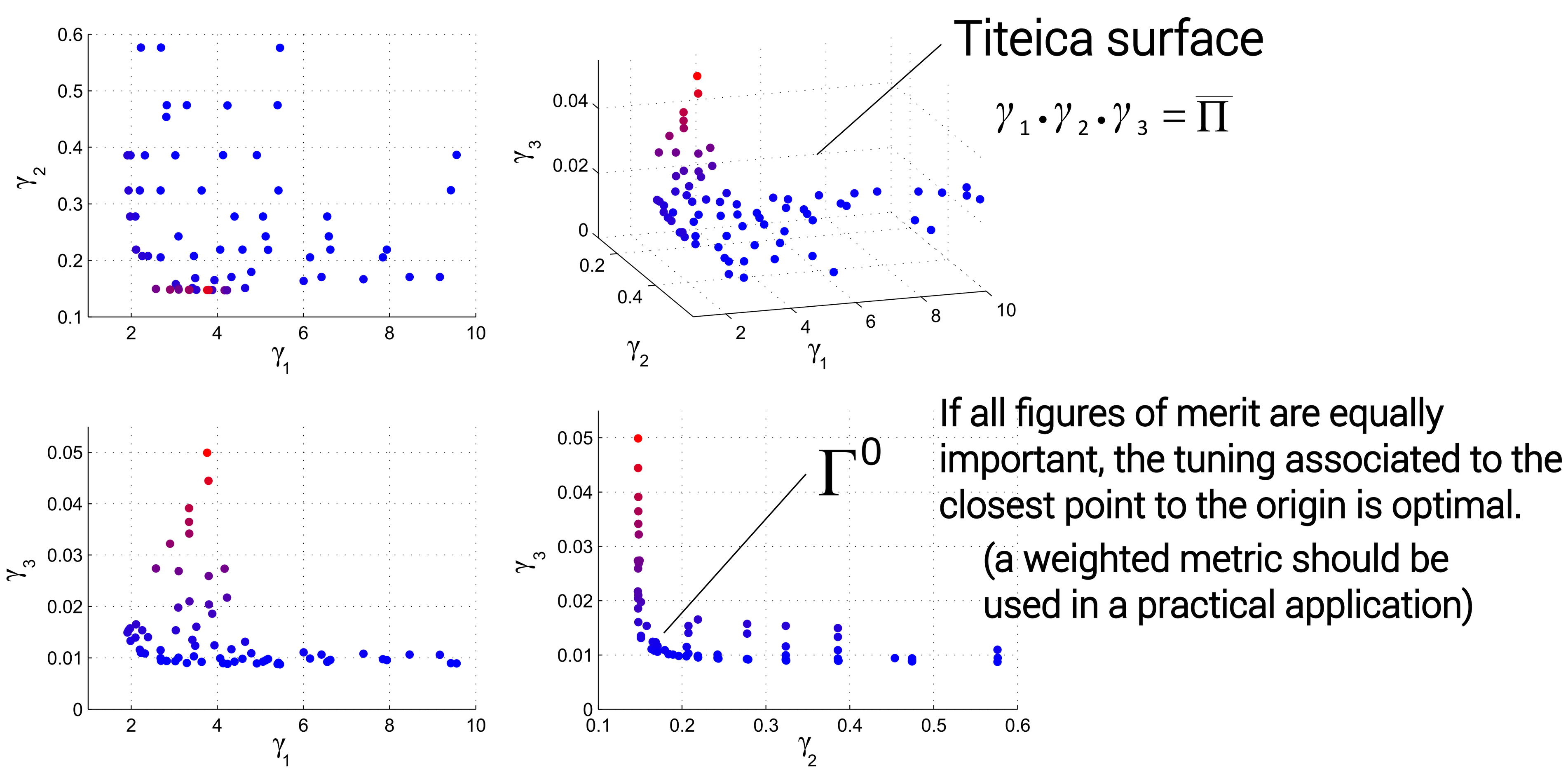
The performance indices can be obtained experimentally from a step test.

Experimental results

A set of step tests are performed on the 5-phase IM to obtain the performance indices for various combinations of the PI parameters (k_p,k_i).

A process of elimination is used to exclude the triples that are not Pareto-optimal.

By PI tuning alone it is imposible to enhance all figures of merit simultaneaously.



Pareto surface for operating point ω^* = 500 (rpm)

Influence of the operating regime

Optimal tuning is different for each operating point:

ω^*	$k_p^0 \cdot 10^3$	$k_i^0 \cdot 10^5$	$\gamma_1{}^0$	$\gamma_2{}^0$	$\gamma_3{}^0$	Π
500	65	100	3.3	0.17	0.0120	0.0148
375	42	107	5.3	0.17	0.0103	0.0114
250	120	80	7.1	0.11	0.0123	0.0123
125	130	60	12.9	0.09	0.0101	0.0224

Possibilities to improve control performance in a operation range:

- Scheduling solutions
- **Average best tunings for each operating point:**

ω^*	Tuning	$\gamma_1{}^0$	$\gamma_2{}^0$	$\gamma_3{}^0$
500	T1	3.92	0.177	0.0281
500	T2	3.98	0.168	0.0283
375	T1	5.25	0.152	0.0290
375	T2	5.34	0.141	0.0295
250	T1	7.37	0.131	0.0289
250	T2	7.34	0.119	0.0293
125	T1	13.77	0.128	0.0277
125	T2	13.83	0.109	0.0284

T1: PI parameters of optimal tuning for 500 rpm

T2: averaged optimal PI parameters of variuos speed regimes

The results are not so different for T1 and T2, and the degradation with respect to the optimal case might be acceptable in many applications. This provides support for the usual engineering practice used for tuning. However, for high-end applications, the results of this paper show that PI tuning has limits and that something else is needed to provide high performance at all operating points.

Conclusions

Assessment of controllers is presented in many works by means of a few cases. The results of this paper show that such a procedure is insufficient because two important issues are kept in the dark. First, the trade-offs between figures of merit and second, the relationship between optimal tuning and operating regimes. Without a complete Pareto analysis covering all operating regimes, the conclusions are necessarily baseless.

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