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XXXIII Cycle

Commissioning and Control of Sensorless Synchronous Motor Drives

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Research context and motivation

- The research focuses on design and analysis of position observers for synchronous reluctance (SyR) machines.
- Position and speed observers are sought after due to the economic incentive in eliminating sensor and cabling, increased reliability and diagnostic purposes.
- Industrial servo drives require high bandwidth controllers for fast dynamics with capability of transient overload.
- Home appliances such as washing machines demands very low speed sensorless control with least acoustic noise.
- A sensorless scheme that is independent of machine parameters and stable in all operating regions without compromising dynamic performance is a utopian challenge.
- A sensorless drive must posses the capability of flux-maps identification at the hard constraints such as standstill without mechanical rotor locking.

Addressed research questions/problems

The work hitherto performed aims to provide an incremental contribution upon the exiting techniques in the field of electrical drives.

1. **Sensorless Control of SyR Machine –** Mechanical encoderless operation is beneficial for reasons of reliability and cost. The standard technique adopted for low/zero speeds region is high frequency signal injection approach which, however, has shortcomings such as acoustic noise, voltage constraints and bandwidth limitations; hence an injectionless technique is desirable. Stability analysis of fundamental wave excitation-based scheme is necessary to demark the region of operation.
2. **Sensorless Self-Commissioning –** SyR machine exhibits high non-linear magnetic properties. Accurate identification is critical as position observers are susceptible to errors in magnetic parameters. A sensorless identification with precision is desired.

Novel contributions

1. **Sensorless Control of SyR Machine – i)** a projection vector framework is developed for position and speed error estimation; **ii)** position error signal is immune to resistance and inverter voltage errors on MTPA trajectory; **iii)** resistance observer is designed for accurate flux and torque estimation; **iv)** switching ripples based injectionless MPC scheme is developed for zero/low speeds position estimation.
2. **Sensorless Self-Commissioning –** A rotor self-locking mechanism is developed to ensure stability and systematic exploration in identifying the magnetic characteristics.

Future work

1. **Sensorless Control of SyR Machine– i)** to develop high bandwidth position observers by exploiting the speed error information; **ii)** to investigate techniques for stable sensorless operation without foreknowledge of flux-maps.
2. **Sensorless Self-Commissioning – i)** to simplify signal processing to support standalone plug & play systems; **ii)** to extend applicability to PM machines.

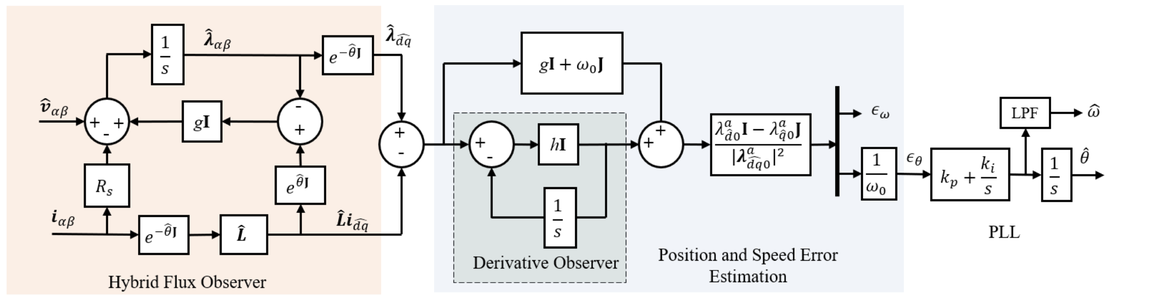
Submitted and published works

1. A. Varatharajan, P. Pescetto, G. Pellegrino, "Sensorless synchronous reluctance motor drives: A projection vector framework sans periodic signal injection", in IEEE Transactions of Industrial Applications (in review)
2. A. Varatharajan, G. Pellegrino, "Sensorless synchronous reluctance motor drives: A general adaptive projection vector approach for position estimation", in IEEE Transactions of Industrial Applications (in review)
3. A. Varatharajan, P. Pescetto, G. Pellegrino, "Sensorless self-commissioning of synchronous reluctance machine with rotor self-locking mechanism", in IEEE Energy Conversion Congress and Expo (ECCE), Baltimore, 2019.
4. A. Varatharajan, G. Pellegrino, "Sensorless synchronous reluctance motor drives: A sensitivity analysis framework and design to achieve stator resistance immunity", in IEEE international symposium of sensorless control for electrical drives (SLED), Torino, 2019.
5. A. Varatharajan, G. Pellegrino, "Sensorless control of synchronous reluctance motor drives: Improved modeling and analysis beyond active flux", in IEEE International machines and drives conference (IEMDC), San Diego, 2019
6. A. Varatharajan, P. Pescetto, G. Pellegrino, "Iniectionless sensorless control of synchronous reluctance machine for zero to low speeds region", in IEEE international symposium of sensorless control for electrical drives, Helsinki, September 2018.
7. A. Varatharajan, P. Savio, E. Vizzaccaro, S. Abrate, G. Pellegrino, V. Curri, "Remotized control of power electronic devices exploiting a plastic optical fiber photonic bus", in International Conference on Transparent Optical Networks (ICTON), Bucharest, July 2018.
8. P. Savio, A. Varatharajan, E. Vizzaccaro, G. Franco, S. Abrate, G. Pellegrino, V. Curri, "Control of power electronics through a photonic bus: feasibility and prospects", in Journal of Sensors and Actuator Networks, 2018

Adopted methodologies

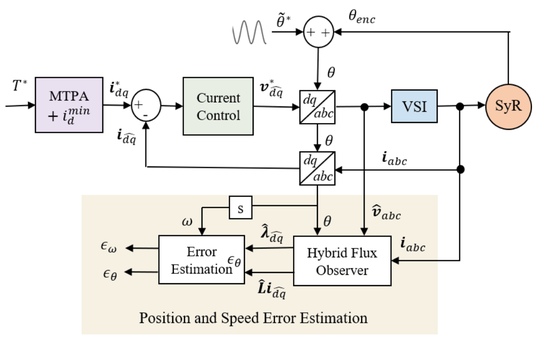
1. Projection Vector Framework for Position and Speed Error Estimation

- Instability regions of active flux-based position observer is illustrated
- A novel Adaptive Projection Vector matrix for Position and Speed error estimation (**APPS**) is developed

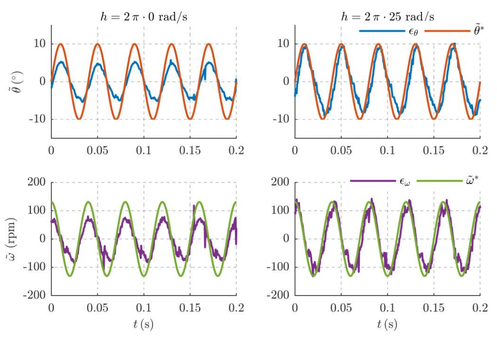


Block diagram of flux and position observer in APPS scheme

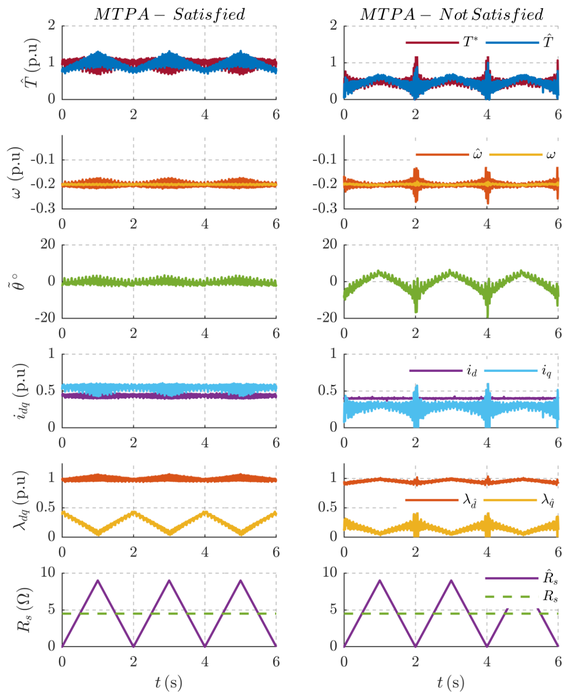
- Resistance immunity feature of APP projection vector on MTPA trajectory is demonstrated; a supplementary resistance observer is designed for accurate flux and torque estimation.
- Switching ripple-based position error estimation in FCS-MPC for zero/low speeds region in developed and fused to APP scheme.



Angle perturbation to validate APPS position and speed error estimation



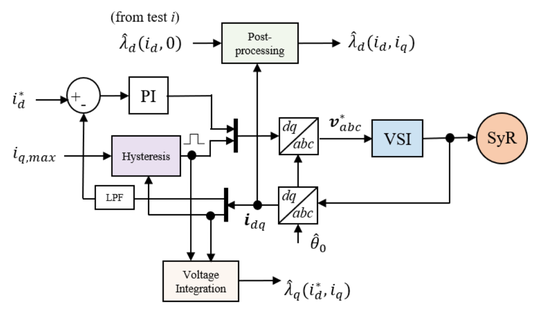
Perturbation analysis at 25 Hz



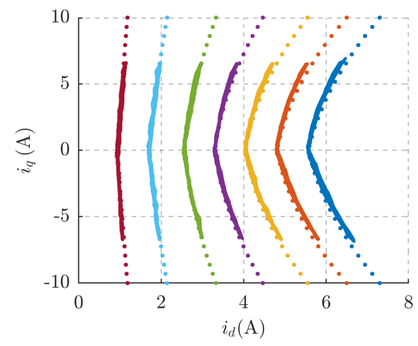
Resistance immunity of APPS on MTPA trajectory

2. Sensorless Self-Commissioning with Rotor Self-Locking Mechanism

- New technique for systematic exploration of *dq* current plane for flux-maps identification.
- Incresed stability and region of exploration



Block diagram of sensorless self-commissioning



Current trajectories traced during test

List of attended classes

- 02LWHRV – Communication (15/2/2018, 5 hours)
- 01PJMRV – Etica informatica (14/3/2018, 20 hours)
- 01SGRRV – Magnetic materials for electrical energy (18/1/2018, 20 hours)
- 01RGBRV – Optimization methods for engineering problems (13/6/2018, 30 hours)
- 08IXTRV – Project Management (19/3/2018, 5 hours)
- 01RISRV – Public Speaking (19/3/2018, 5 hours)
- 02RHORV – The new Internet Society (13/3/2018, 6 hours)
- 01SHCRV – Unsupervised neural networks (9/4/2018, 30 hours)
- 01ROERV – Sensorless control of electric machines (21/1/2019, 25 hours)
- 01NDLRV – Lingua italiana I livello
- 01LCPRV – Experimental modeling (4/2/2019, 33 hours)

POLITECNICO DI TORINO

PEIC Power Electronics Innovation Center

PhD program in
Electrical, Electronics and Communications Engineering