Fault Detection of PMSMs using IMM Strategy

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Why Permanent Magnet Synchronous Motors (PMSM)?
- Efficiency: PMSM > IM
- Power to Mass Density: PMSM > IM
- Reduced operating temperature
- Can extract features artificially or automatically
- Applicable for almost all kinds of faults

Different Faults In PMSMs
- Mechanical Faults
  1) Bearing Faults
  2) Eccentricity Fault
- Electrical Faults
  1) Inter-turn Short-Circuit
  2) Phase to Phase/Ground short circuit
  3) Phase Open Circuit
- Magnetic Faults
  1) Demagnetization Fault

Fault Detection Methods in PMSMs
- Data-Driven Methods (AI)
- Model-Based Method
- Signal Processing Methods

Model of PMSM with Inter-Turn Short Circuit (ITSC) fault
Phase and fault currents for different numbers of short-circuited turns and different short-circuit resistors

IMM Strategy For Fault Detection
- Extract several models for healthy and faulty conditions
- Select appropriate filters (Kalman or SVSF) for extracted models
- Calculate the probability that the system is in a particular model at a given time, based on measurements
- Estimate the system’s mode based on the mode probability computed
- States of the system are estimated using the filter associated with the estimated mode.

Mode Probabilities of Models

Estimation and real values of the R_f

Simulation Results
Three models for fault detection are considered. One for the electric motor in healthy condition and two for faulty conditions with different fault severity. Process or real system has a fault with different severity and switches between different fault severity conditions at sample times equal to 200, 1500, 2500, and 3500. Corresponding Extended Kalman Filter (EKF) is designed and used for each one of these models. As presented in the following figures, Interactive Multiple Model (IMM) is able to detect the fault occurrence in a reasonable number of time steps.

The results of the IMM-Kalman filtering need to be compared with IMM-Smooth-Variable Structure Filter (SVSF) since that method is more robust to uncertainty in the models. Also, all results need to be evaluated using a real PMSM setup which provides access to the middle point of the winding and enables emulating ITSC fault by using an external resistor.