Failure Prognosis for Permanent Magnet AC Drives Based on Wavelet Analysis

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- **Objectives**
  - Detection of non-catastrophic faults in Permanent Magnet AC machines which lead to reduced life and eventually failure
  - Stator Faults
  - Insulation failures
  - Resistance changes

- **Discrete Wavelet Transform (DWT)**
  - Wavelets have finite energy concentrated around a point which helps to localize irregularities in a signal
  - Can give a sparse representation of a fault
  - Can choose different basis functions (mother wavelets) to achieve the best results for a specific application
  - Coefficients can be realized using a filter bank
  - FIR filter coefficients \( h_i \) and \( h_j \) based on the scaling and wavelet functions

- **Undecimated Discrete Wavelet Transform (UDWT)**
  - Shift-invariant representation of the DWT
  - Realized using the "Algortihme à Trous", which omits downsampling and inserts zeros between filter coefficients at each successive scale

- **Linear Discriminant Analysis**
  \( D_k(x) = x_1a_{q1} + x_2a_{q2} + \ldots + x_Na_{qN} + a_{q+k} \quad k = 1,2,\ldots,K \)
  - Categorization of \( x_i \) into \( j \)
  - Iterative training procedure for the weighting coefficients makes adjustments to \( a_j \) and \( a_i \) following an initial guess, where
  \[ D_j(x) = \max_{a_j, a_i} |D_j(x)||D_k(x)| \]
  - \( a_j(i+1) = a_j(i) + \alpha_j \)
  - \( a_i(i+1) = a_i(i) - \alpha_i \)
  - and \( \alpha \) is a gain constant

- **Faults Explored**
  - Series Resistance (5 and 10ms)
    - Intermittent increased series contact resistance
    - A normally closed switch and a resistance in parallel are added in series with one of the motor phases
  - Turn-to-Phase Short (5 and 10ms)
    - Insulation failure in the stator windings of the motor
    - A normally open switch is added between a winding and its corresponding phase

- **Analysis Methods**
  - Field oriented currents are used since the fundamental electrical frequency is not present
  - UDWT applied to measured q-axis current
  - Daubechies D4 wavelet used
  - Decomposition performed for 6 scales
  - Inception and clearing of faults are identified separately
  - Detection Algorithm
    - A threshold is applied to the weighted energy of the UDWT at each time instant
    - Threshold is set to 40% greater than the largest observed on healthy motors
  - Classification Algorithm

- **Experimental Setup**

- **Typical Results**

- **Algorithm Performance**

- **Conclusions**
  - Detection and classification of machine faults which manifest themselves in the stator current is achieved
  - Data from an exhaustive set of operating conditions is necessary to develop a robust algorithm

- **Linear discriminant analysis applied to the 64 samples beginning 8 samples prior to where detection occurred**