### Introduction

- Scalar V-Type Volts/hertz (V/Hz) control has a simple structure and is easily implemented.
- Vector 1-Type Field Oriented Control (FOC) yields good dynamics and accuracy.
- The proposed sensorless control strategy merges the simplicity of the conventional scalar control with the improvements in the torque delivery capability at low speed and steady state speed precision, both typical features of FOC control.
- The control algorithm is derived from the conventional FOC equations by successive approximations. Voltage references are calculated instead of derived by the current regulators (V-Type control).

### Sensorless proposed V-Type Foc Control

![Diagram of Sensorless proposed V-Type Foc Control](image)

Control equations in the reference frame synchronised to the rotor flux:

\[ a_d = R_s i_d + \frac{L_s}{L_r} \lambda_q \]

\[ a_q = R_s i_q - \frac{L_s}{L_r} \lambda_d + \frac{L_{sq}}{L_r} \lambda_d \]

\[ a_q'' = a_q'' + a_{iq} + \frac{L_{sq}}{L_r} \lambda_{dref} \]

The slip angular frequency is obtained by the estimated flux linkages and the filtered quadrature current.

### Migration from I-Type to V-Type Control

**I-TYPE INDIRECT FOC DRIVE:**
- The separation between torque and flux producing components of the stator currents gives excellent dynamic performances.
- Precise motor speed measurement is required.
- The voltage references are delivered by two PID current regulators.

**V-TYPE SENSORLESS FOC DRIVE:**
- Elimination of the speed measurement, which compromises the mechanical robustness. The actual speed is approximated by the given speed reference.
- The current loops are substituted by the IM voltage balance equations, for a given (known) set of motor parameters. The derivative terms are omitted.
- The control preserves the vector-orientation features. It correctly manages the voltage vector in all working conditions, assuring superior performance.
- The quadrature current component needs to be filtered to guarantee stability.

### Stability Analysis

The stability depends on the constant time \( T_f \) of the low pass filter in the quadrature current measurements:

- Low values of \( T_f \) leads to instability.
- High values of \( T_f \) slow down the system dynamics.
- A trade-off has to be accepted.
- It has been found that the system sensivity to \( T_f \) is rather low. The tuning of \( T_f \) is quite simple.

### Experimental Results: \( T_f \) Tuning

- Measurements on IM2. Speed response to a load torque step variation of 60% of the rated torque at \( \omega_{nref} = 18 \times \omega_n \).
- Best tuning: \( T_f = 90 \text{ ms} \), obtained by a trial and error procedure.

### Experimental Results / Conclusions

- Measurements on IM2. Speed response to a load torque step variation of 60% of the rated torque with best tuning for \( \omega_{nref} = 18 \times \omega_n \).
- Null steady state speed error and fast transient. It has been experienced that the higher speed, the larger the \( T_f \) range for stability.

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