# Sensorless Control of a Matrix Controlled Variable Speed Double Fed Induction Machine

STEPS

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# Contents

# Introduction to the Experimental Setup

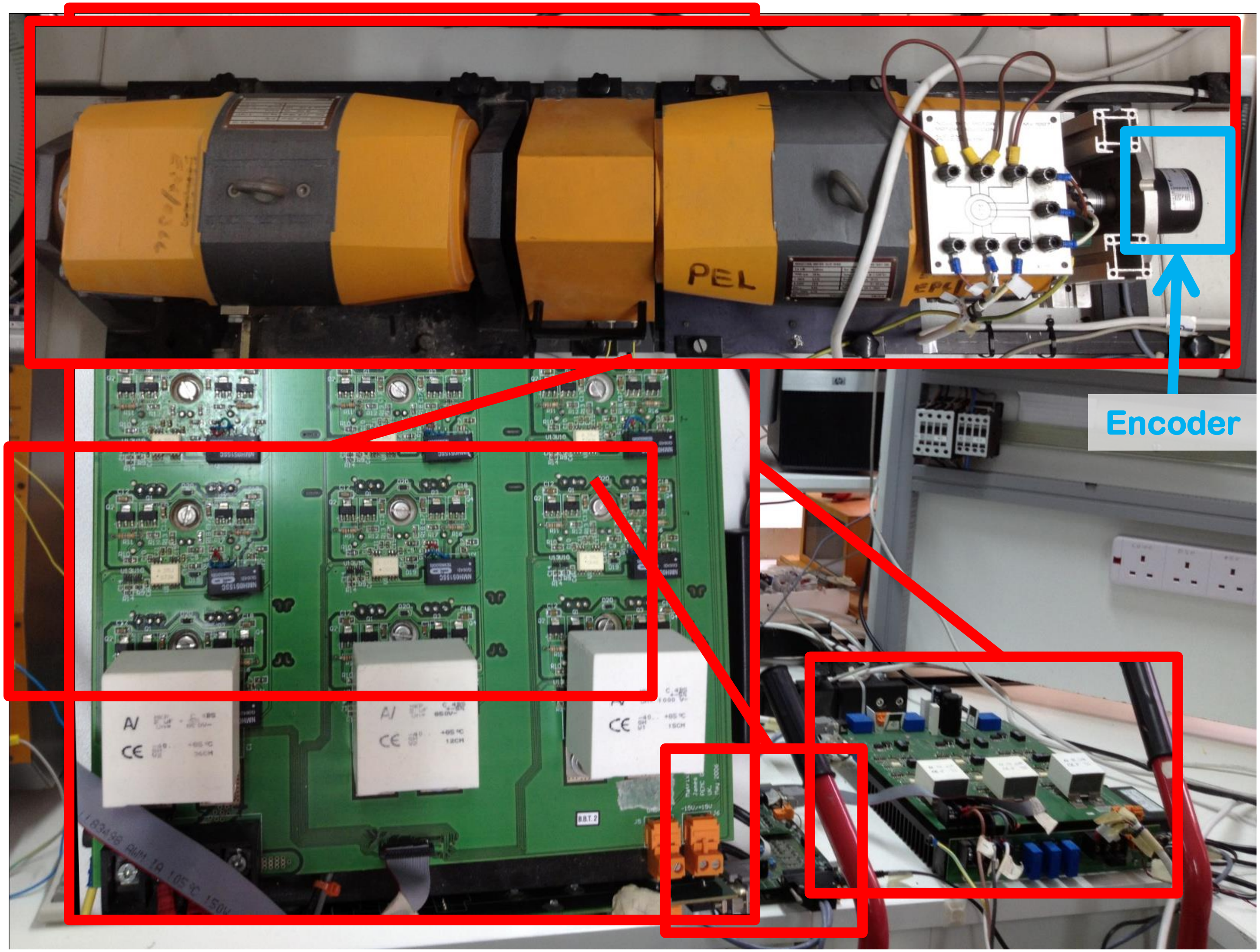



**Figure 1 – Matrix Converter with Double Fed Induction Machine Setup**

# Research Questions

- What type of sensorless techniques can be implemented on the existing experimental setup?

- To what extent do the simulation results of the system reflect the practical ones?

- How does the response of the system using sensorless techniques compare to that when a speed sensor is used?

# Stator Field Orientation (SFO) Vector Control

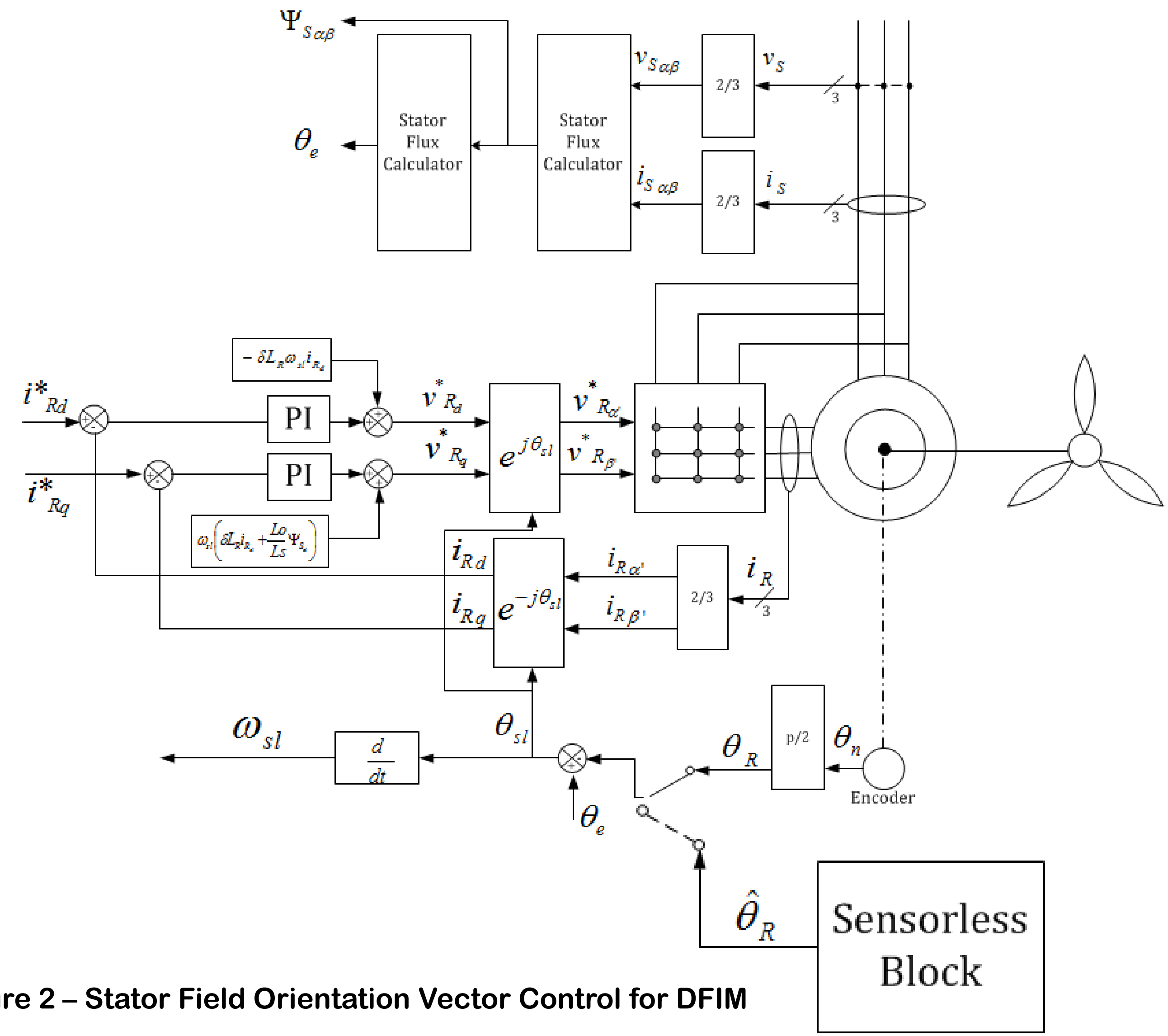



Figure 2 – Stator Field Orientation Vector Control for DFIM

# Sensorless Block:
# Model Reference Adaptive System (MRAS)

**MRAS is a model based sensorless technique which depends on two mathematical models for the stator flux:**

$\alpha\beta$ **subscript denotes stationary frame of reference**

$\alpha'\beta'$ **subscript denotes rotating frame of reference**

Stator Flux    Stator voltage    Stator Resistance    Stator current

**Voltage Model ( Reference Flux ):**

$$\psi_{S_{\alpha\beta}} = \int v_{S_{\alpha\beta}} - R_S i_{S_{\alpha\beta}} dt$$

**Current Model ( Estimated Flux ):**

Estimated rotor frequency

Estimated Stator Flux

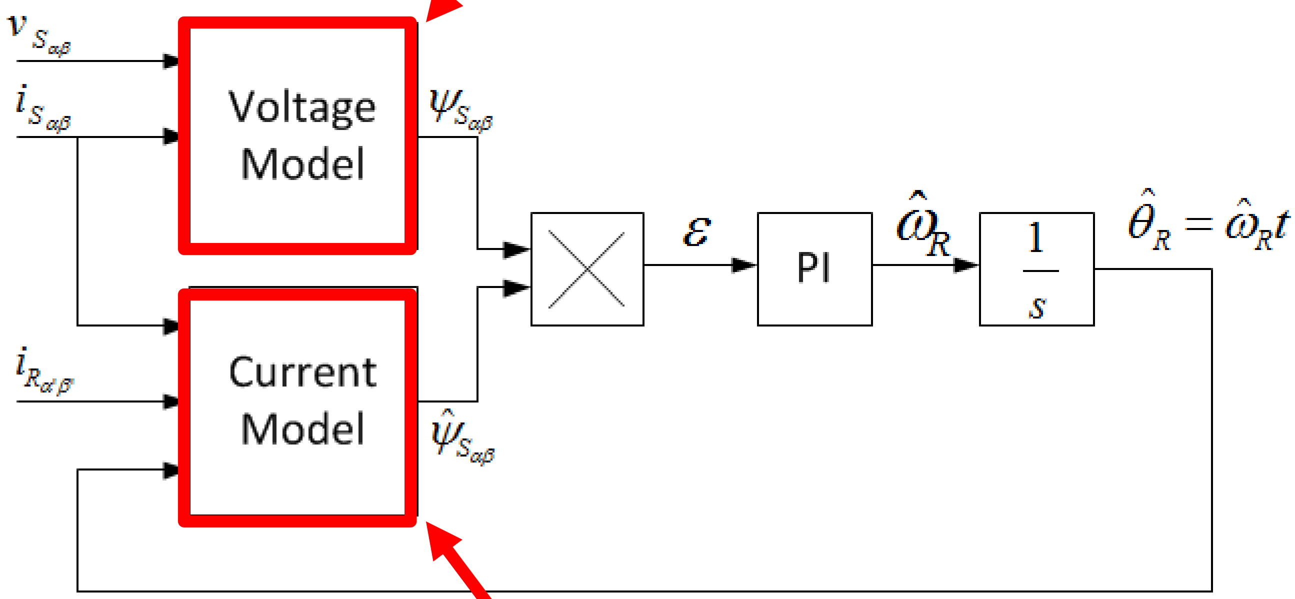
$$\hat{\psi}_{S_{\alpha\beta}} = L_S i_{S_{\alpha\beta}} + L_O i_{R\alpha'\beta'} e^{j\hat{\omega}_R t}$$

Stator Inductance    Mutual Inductance    Rotor current

Stator current

# Sensorless Block:
# Model Reference Adaptive System (MRAS)

$$\psi_{S_{\alpha\beta}} = \int v_{S_{\alpha\beta}} - R_S i_{S_{\alpha\beta}} dt$$




$$\hat{\psi}_{S_{\alpha\beta}} = L_S i_{S_{\alpha\beta}} + L_O i_{R_{\alpha'\beta'}} e^{j\hat{\omega}_R t}$$

**Figure 3 – MRAS Observer**

# Sensorless Block: Simulation Results

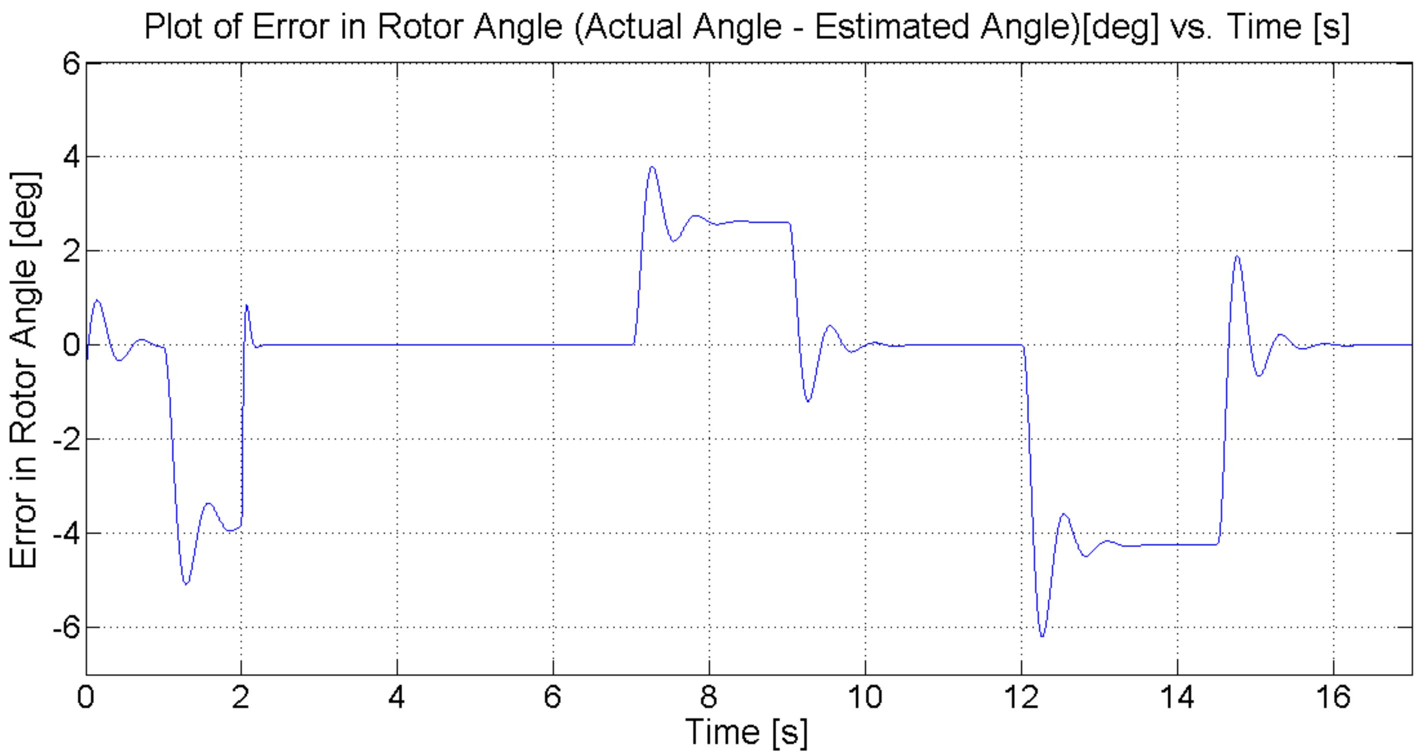
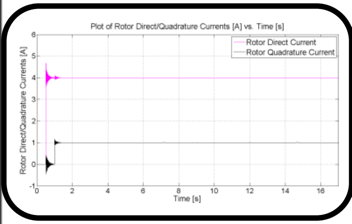
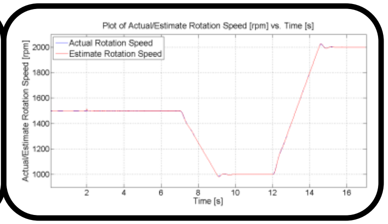
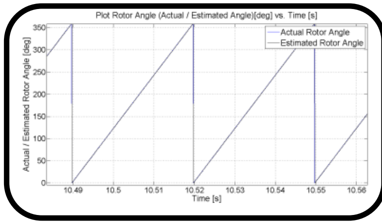
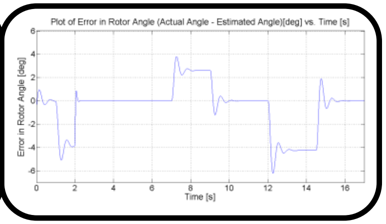



**Figure 7– Plot of Error in Rotor Angles [deg] vs. Time [s]**









# Stator Voltage Model

The voltage model analyzed previously is:

$$\psi_{S_{\alpha\beta}} = \int v_{S_{\alpha\beta}} - R_S i_{S_{\alpha\beta}} dt$$

In order to use a pure integrator no dc offsets must exist in the stator voltage and current measurements.

Considering stator voltage offsets:

$$\psi_{S_{\alpha\beta}} = \int (v_{S_{\alpha\beta}} + v_{Sof_{\alpha\beta}}) - R_S i_{S_{\alpha\beta}} dt$$

$$\psi_{S_{\alpha\beta}} = \psi_{Si_{\alpha\beta}} + \psi_{Sof_{\alpha\beta}}$$

Where:

$\psi_{Si_{\alpha\beta}}$ Ideal stator flux without offsets

$\psi_{Sof_{\alpha\beta}}$ Stator flux offset component due to voltage offset

# Stator Voltage Model
# Band-pass filter approximation

- Second order band-pass filter can be used to approximate Integrator.

- Signals at the input of band-pass are at 314.159 rad/s (50 Hz)

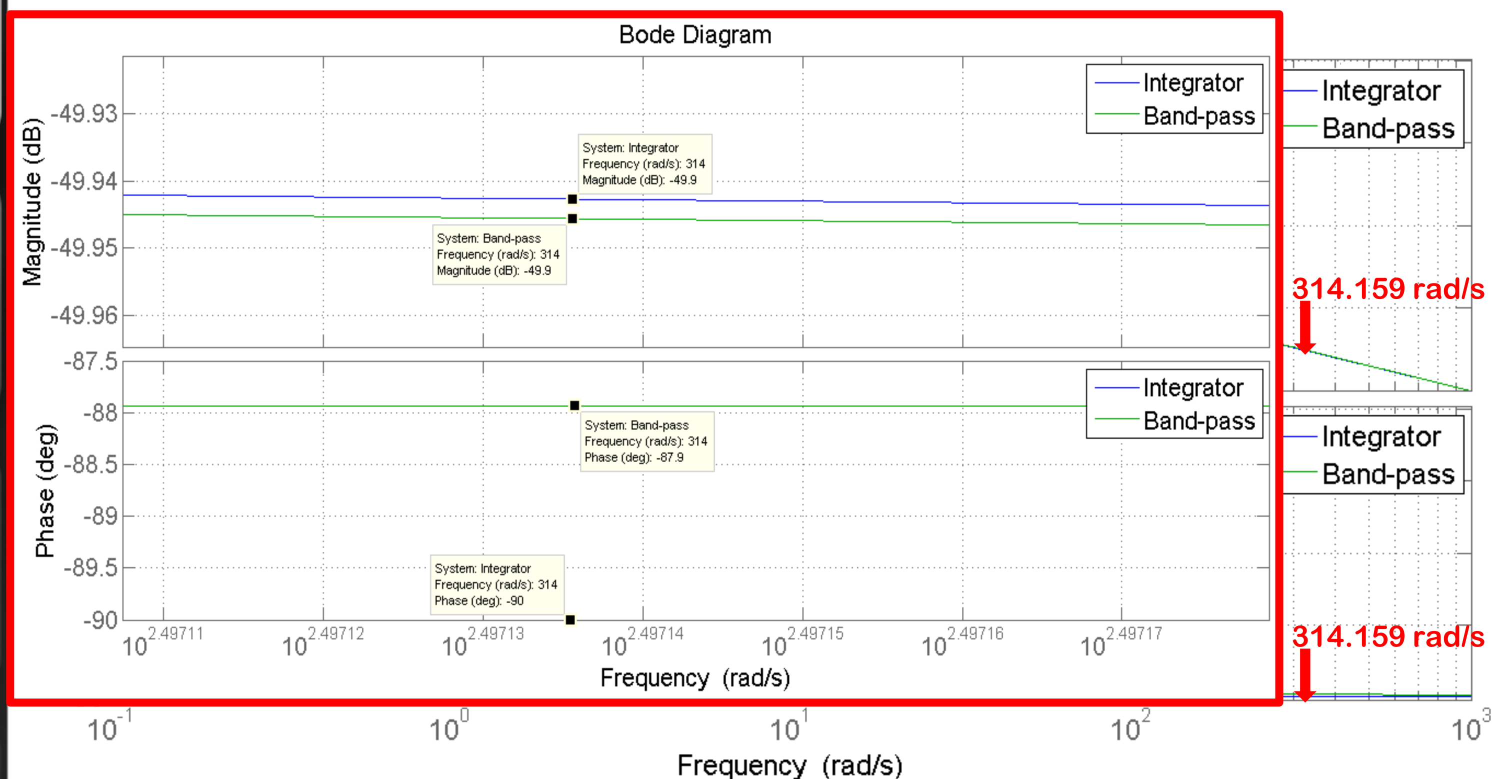



**Figure 8– Bode of Plot for Integrator / Band-pass**

# Stator Voltage Model: Simulation Results

**Simulations in Simulink© were repeated with the voltage model using the band-pass filter for the following conditions:**

**Ird* = 4 A at 0.5 s**
**Irq* = 1 A at 1 s**
**MRAS estimate used at 3 s**

**Shaft speed = 1500 rpm at 0 s**
**MRAS started at 2 s**

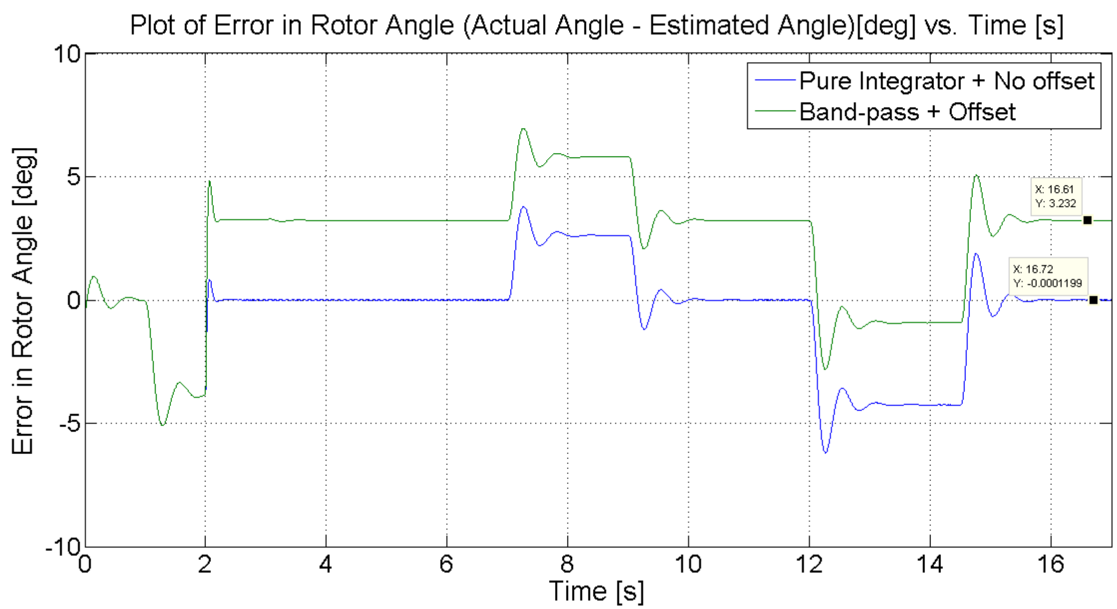
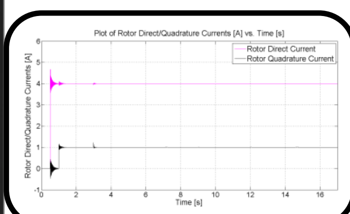
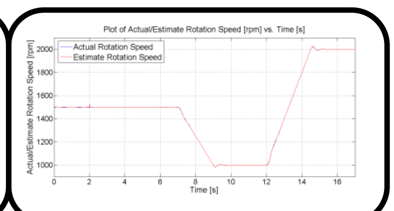
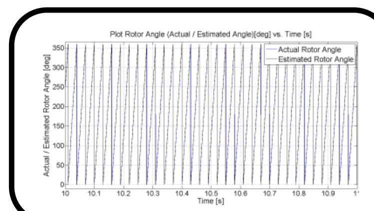
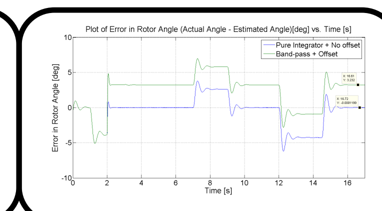



**Figure 12 – Plot of Error in Rotor Angle with Band-pass filter [degrees] vs. Time [s]**

# Practical MRAS Results

**Practical Results obtained by applying MRAS on experimental set-up with the following conditions:**

**Ird* = 3.5 A** **Initial Shaft speed = 1500 rpm**

**Irq* = 1 A**

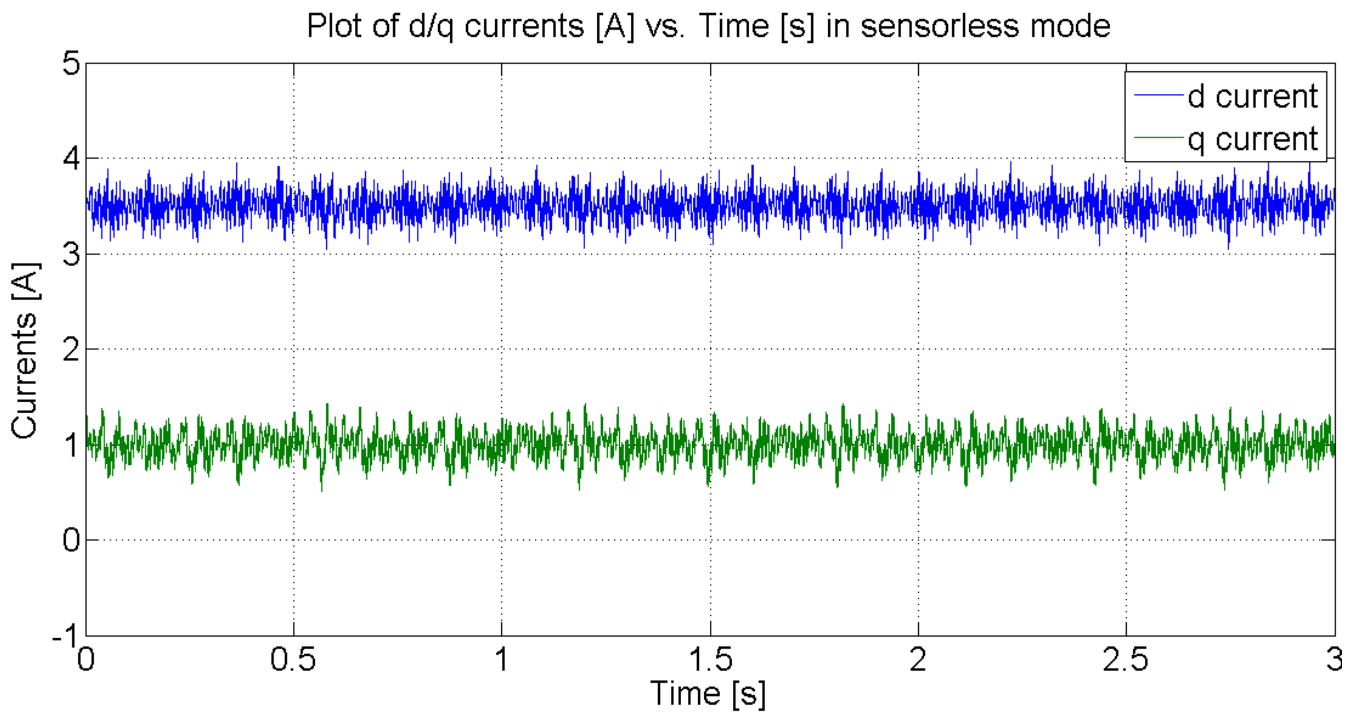
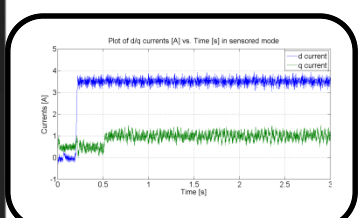
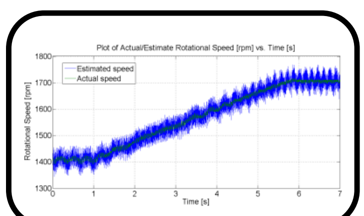
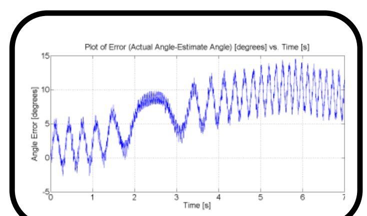
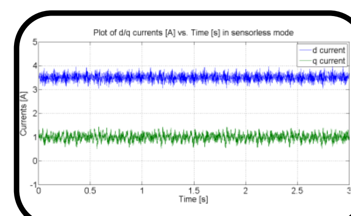



**Figure 16 – Plot of d/q currents [A] vs. Time [s]**

## Further Work

- Introduction of inductances in series with rotor windings to reduce harmonics.

- Analysis of low frequency harmonic in practical estimated angle error.

- Improved stator voltage models to eliminate dc offsets measurements without steady state error.

End of Presentation

Questions