SYNCHRONOUS DRIVES WITH FIELD ORIENTED VECTOR CONTROL AND THEIR INDUSTRIAL IMPLEMENTATION

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TASK OF THE WORK

Experimental and practical confirmation for a definitely primitive control algorithm of mass-type synchronous drives.

SPECIFICS OF MASS-TYPE HIGH-POWER CONTROLLED DRIVES

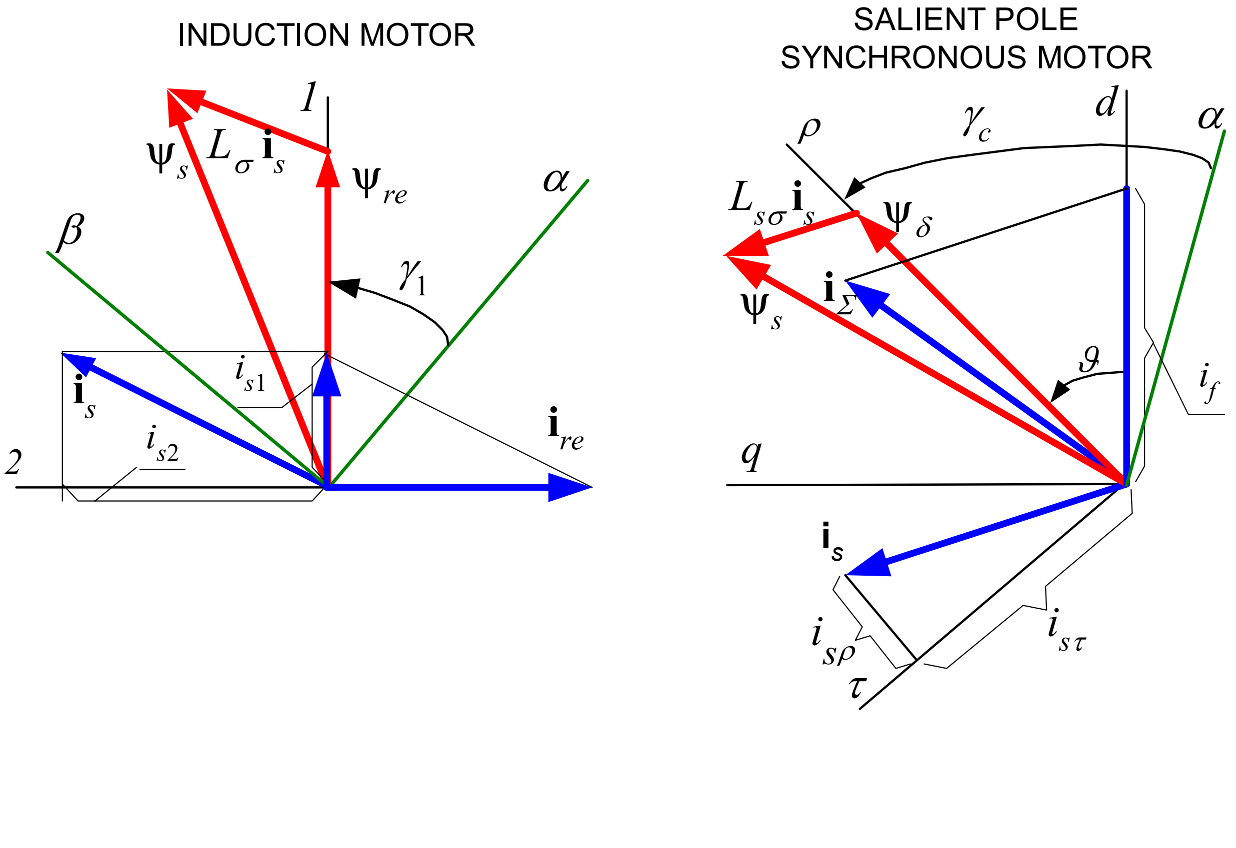
These are drives for pumps, fans, compressors, large grinding mills. The application field defines specific requirements:

1. Lower bandwidth of the speed control loop, up to 5 rad/s.
2. Lower acceleration, up to 0.5 p.u./s.
3. Relatively narrow speed control range, up to 1:5, and mainly downwards from the rated speed.
4. Very low resource in stator voltage and very low relative value of maximal excitation voltage.
5. Higher reliability.
6. Proximity of drive regimes to optimal ones in economics.
7. Operation without any encoder coupled to motor shaft.
8. Higher immunity to disturbances in power supply system.
9. Simplicity of control with possible minimum of necessary motor parameters.

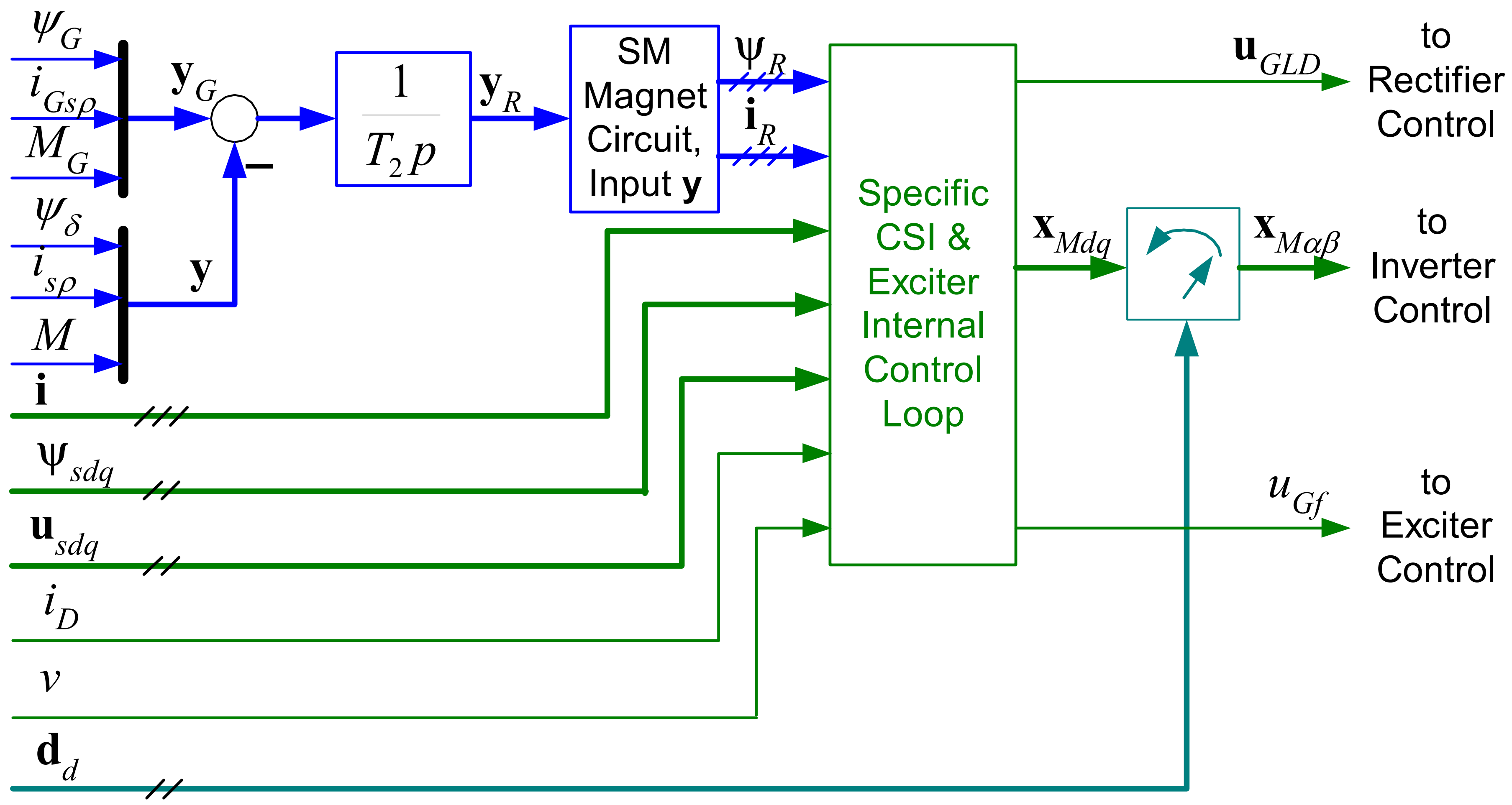
ROTOR ORIENTED CONTROL FOR SYNCHRONOUS DRIVES

Field oriented control, commonly used for drives with induction motor, looses main advantage applied for synchronous motor: change of torque current component simultaneously changes flux.

VECTOR DIAGRAMS FOR STEADY-STATE REGIMES

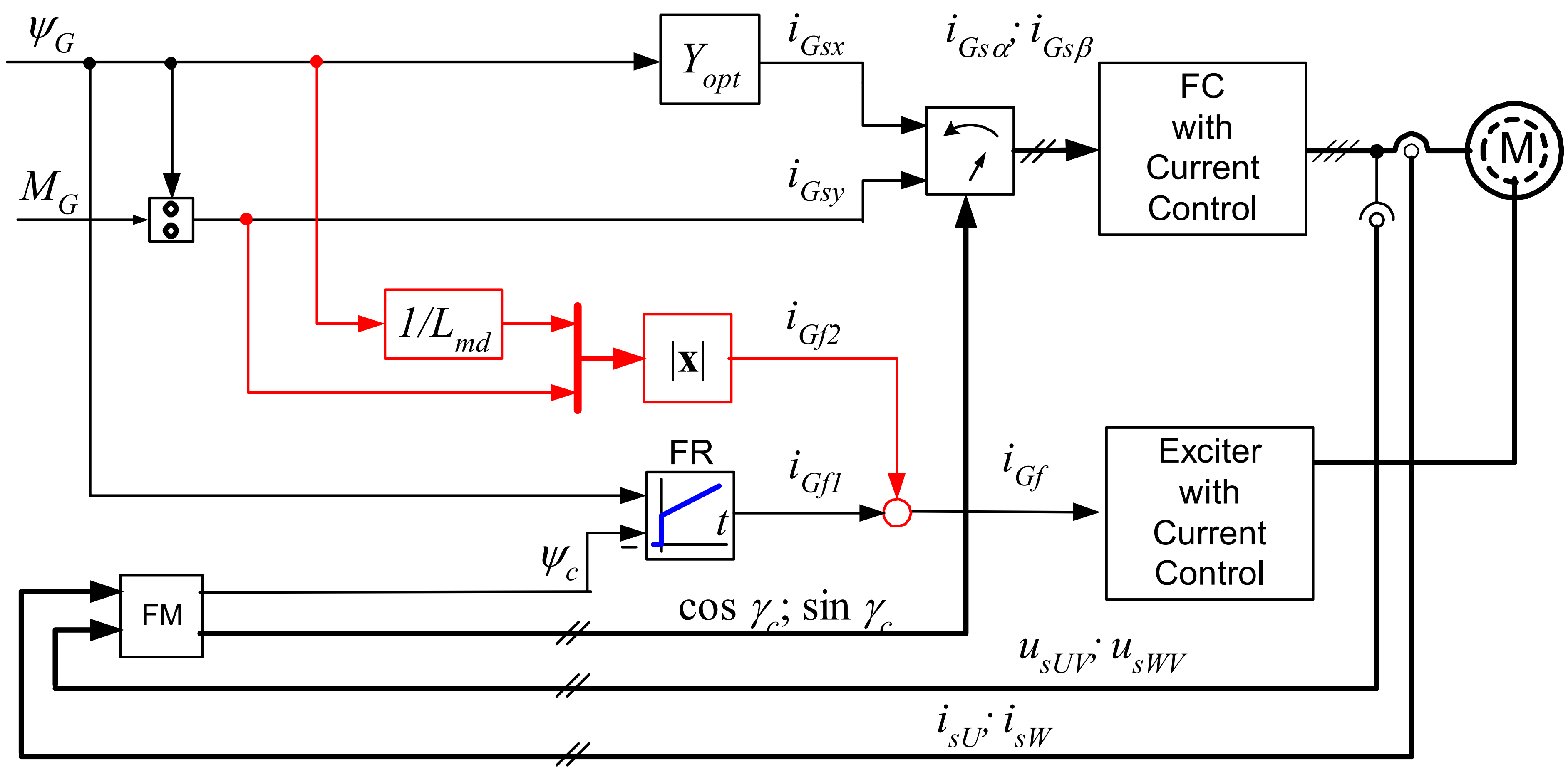


Rotor oriented control is most suitable for synchronous drives.



PROPOSED CONTROL ALGORITHM OF FIELD ORIENTED CONTROL

New algorithm of field oriented control for synchronous drives is developed for maximal unification with algorithm for asynchronous drives.



Differences:

- **Feed-forward into reference for excitation current**.
- **Orientation on vector of main flux**

PREVIOUS ANALYSIS AND SIMULATION RESULTS

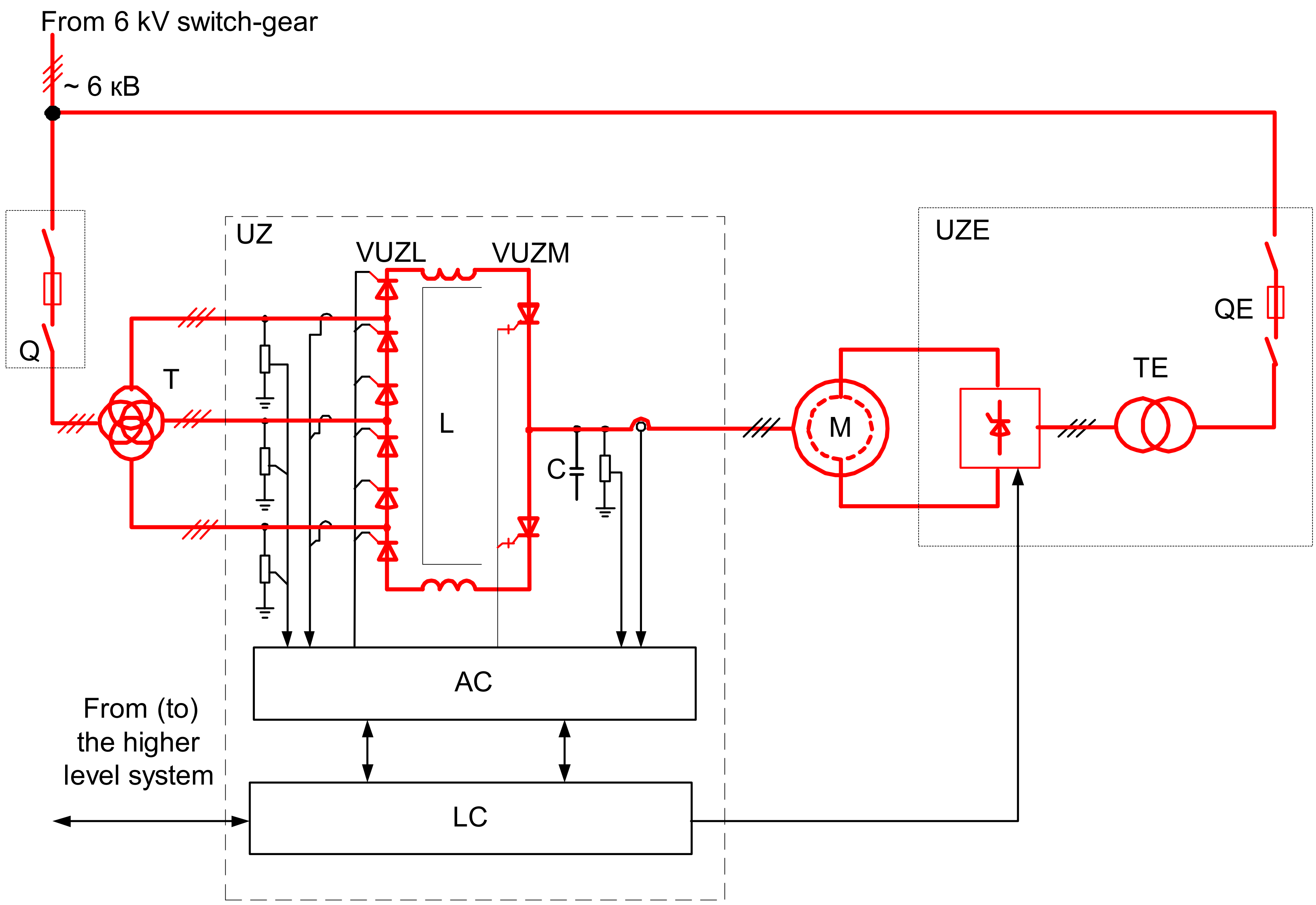
Proposed algorithm has evident disadvantages.

But **it satisfies requirements to mass-type high-power controlled drives** (limited requirements).

INDUSTRIAL IMPLEMENTATION

Proposed control algorithm is implemented in **two mine fan drives, 3.15 MW, 500 rpm, 6 kV each**. Preliminary tests were performed at the virtual test bench including real control device and computer model of the drive power part, operating in a real time mode. And **tests on operating drives are performed** while start-up. Drives are in operation since April 2008.

Composition



Each drive includes:

1. The **synchronous motor *M*, brush-type excitation**; **3.15 MW, 500 rpm, 6 kV**.
2. The converting-regulating device (CRD) PowerFlex 7000 by Rockwell Automation. The CRD includes **frequency converter on the base of CSI with PWM**.

The programmed parameters of drive control defining quick-responsibility:

Maximal modulation frequency is $f_{M.\max}$ **= 260 Hz**.

Bandwidth of the control loop for DC current is Ω_i **= 300 rad/s**; high quick-responsibility is useful for immunity to fast changes of supply voltages.

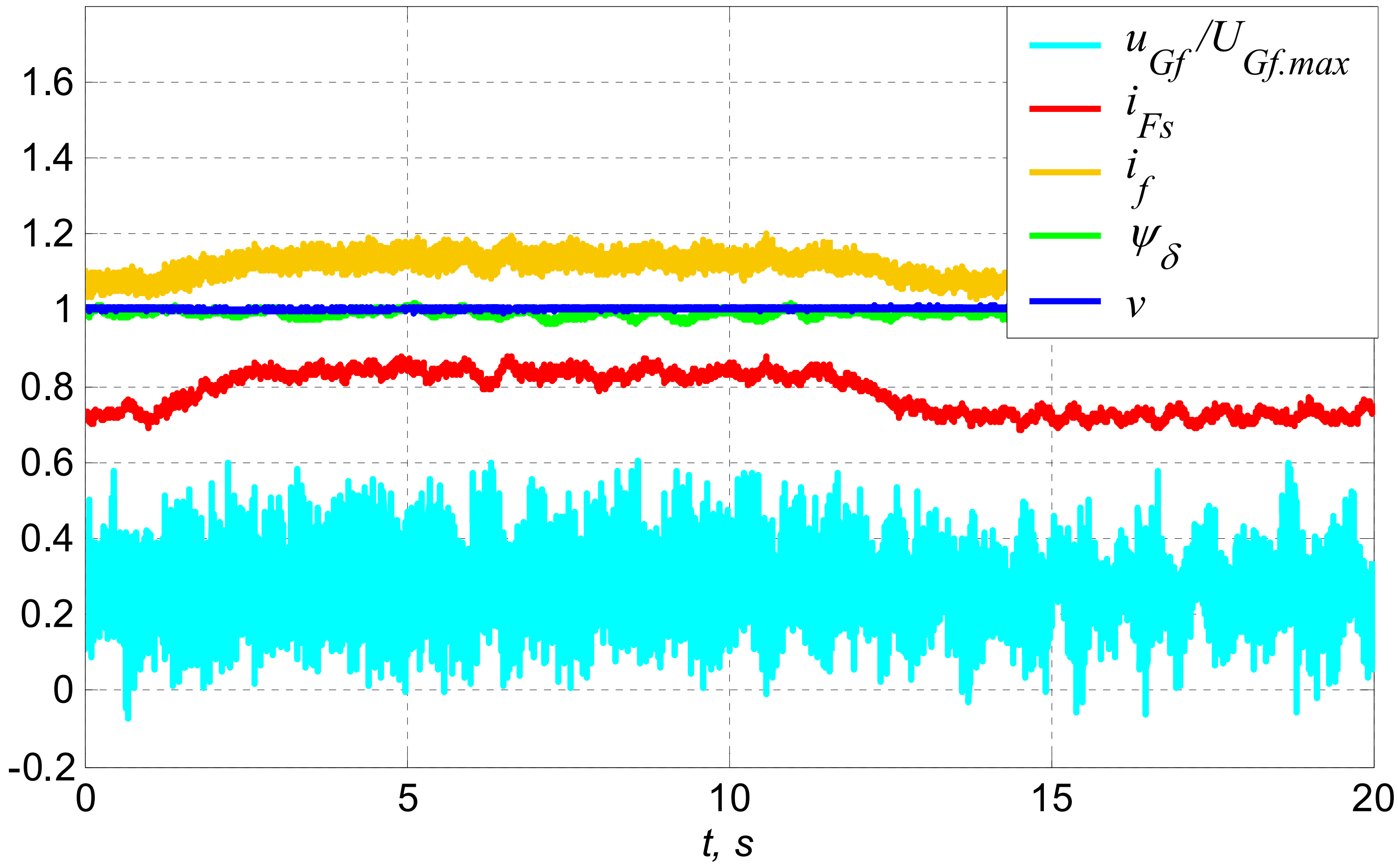
Bandwidth of the control loop for the excitation current (with open stator circuit) is Ω_{if} **= 10 rad/s**; this for the flux control is Ω_ψ **= 2 rad/s**.

Bandwidth of the speed control loop is Ω_v **= 0.3 rad/s**. With relatively low bandwidth, quality factor of speed control $K_{Rv} = T_j\Omega_v = 9$ is relatively high one because of very high inertia.

Simulation at the virtual test bench

Registered variables: u_{Gf} – command for excitation voltage; i_{Fs} – stator current (vector module), process is filtered (T_F = 0.02 s); i_f – excitation current; ψ_δ – main flux; v –velocity.

Processes while load steps

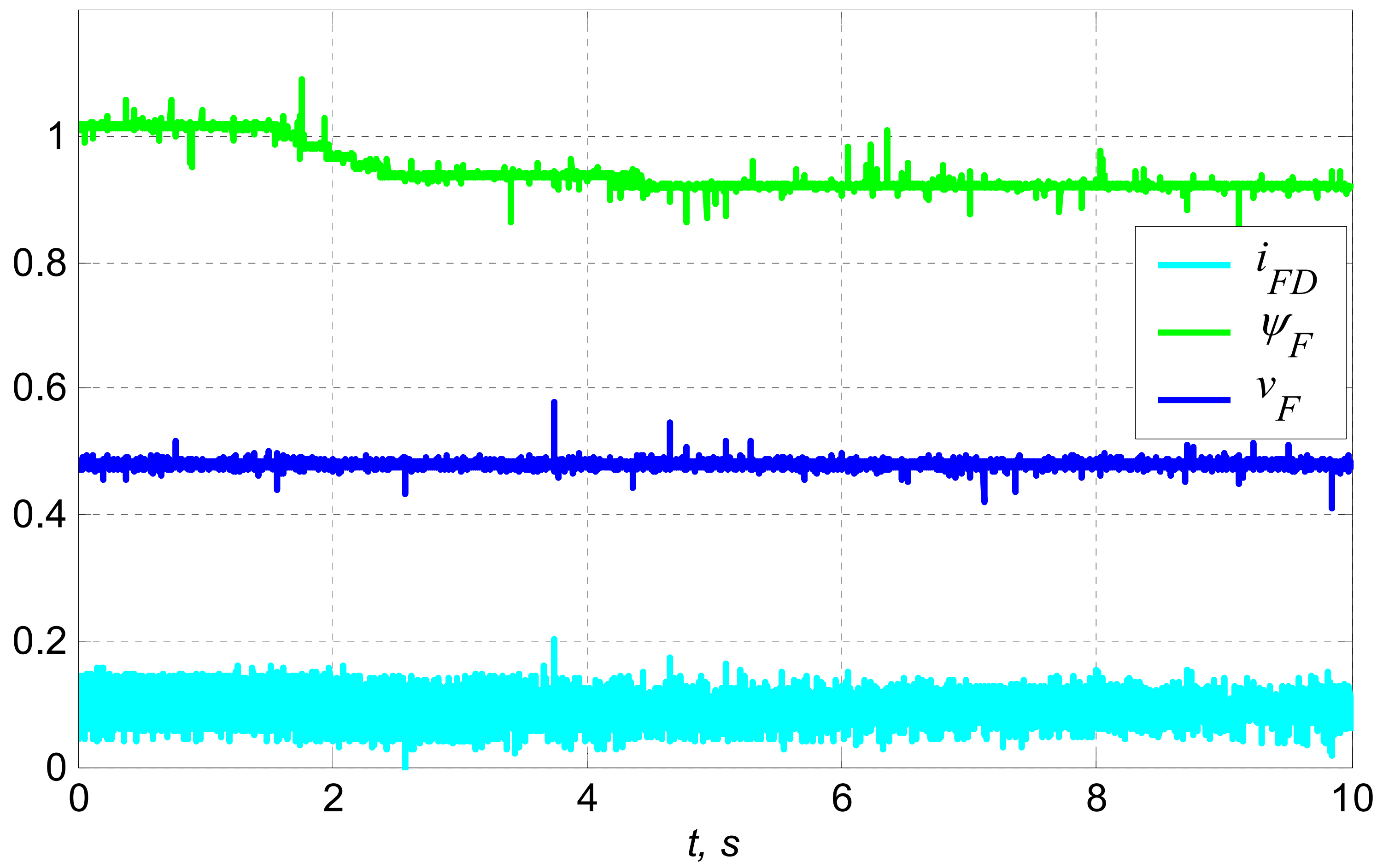


Suitable operation is confirmed with practically autonomous regulation of flux and torque.

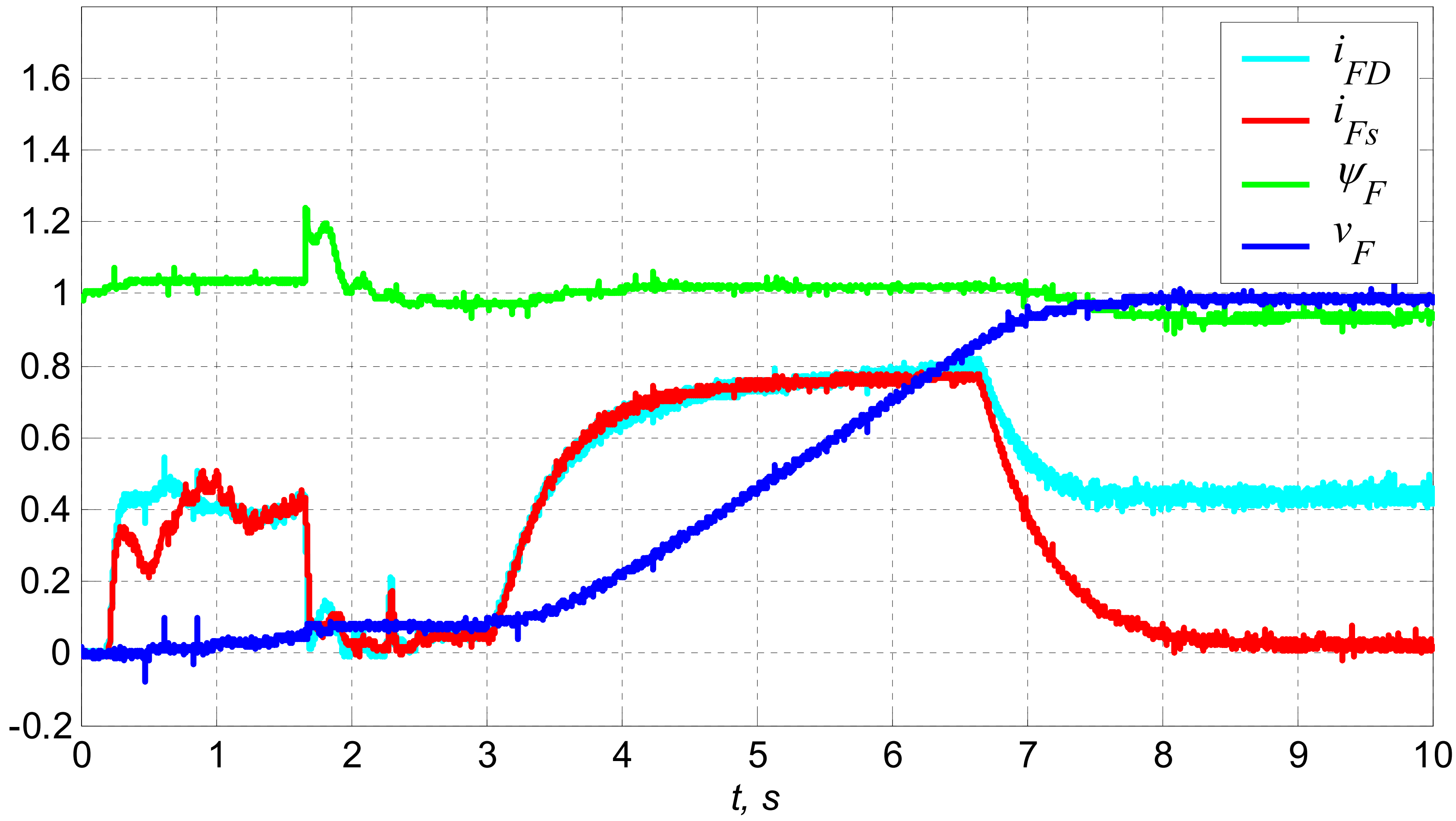
Tests while start-up

Registered variables: i_{FD} – feedback signal of the DC link current; ψ_F – feedback signal of the flux; v_F – feedback signal of the velocity, i_{Fs} – stator current (vector module), process is filtered (T_F = 0.02 s); M_F – electromagnetic torque, process is filtered (T_F = 0.02 s), i_f – excitation current.

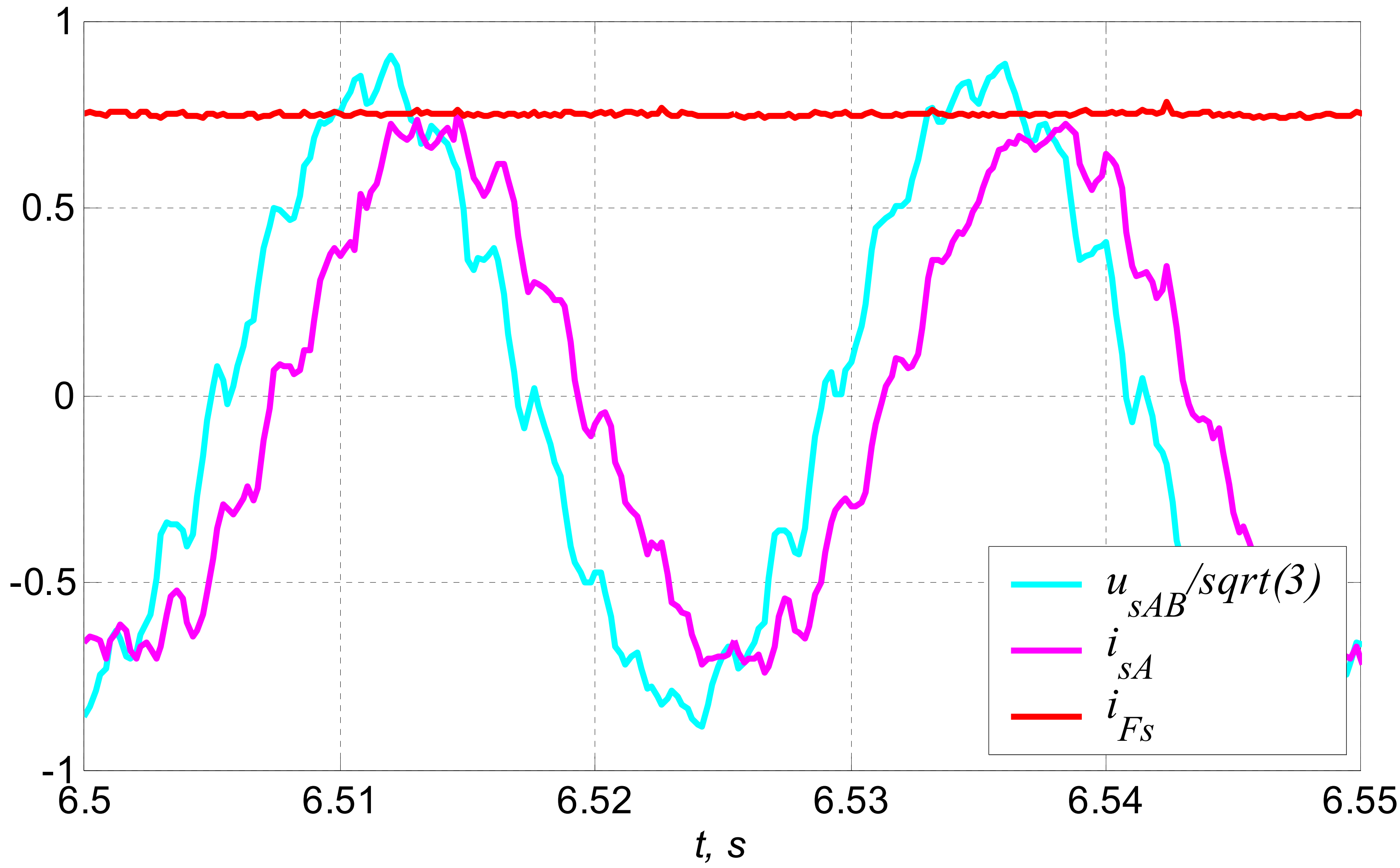
Tests without fan, step of flux command



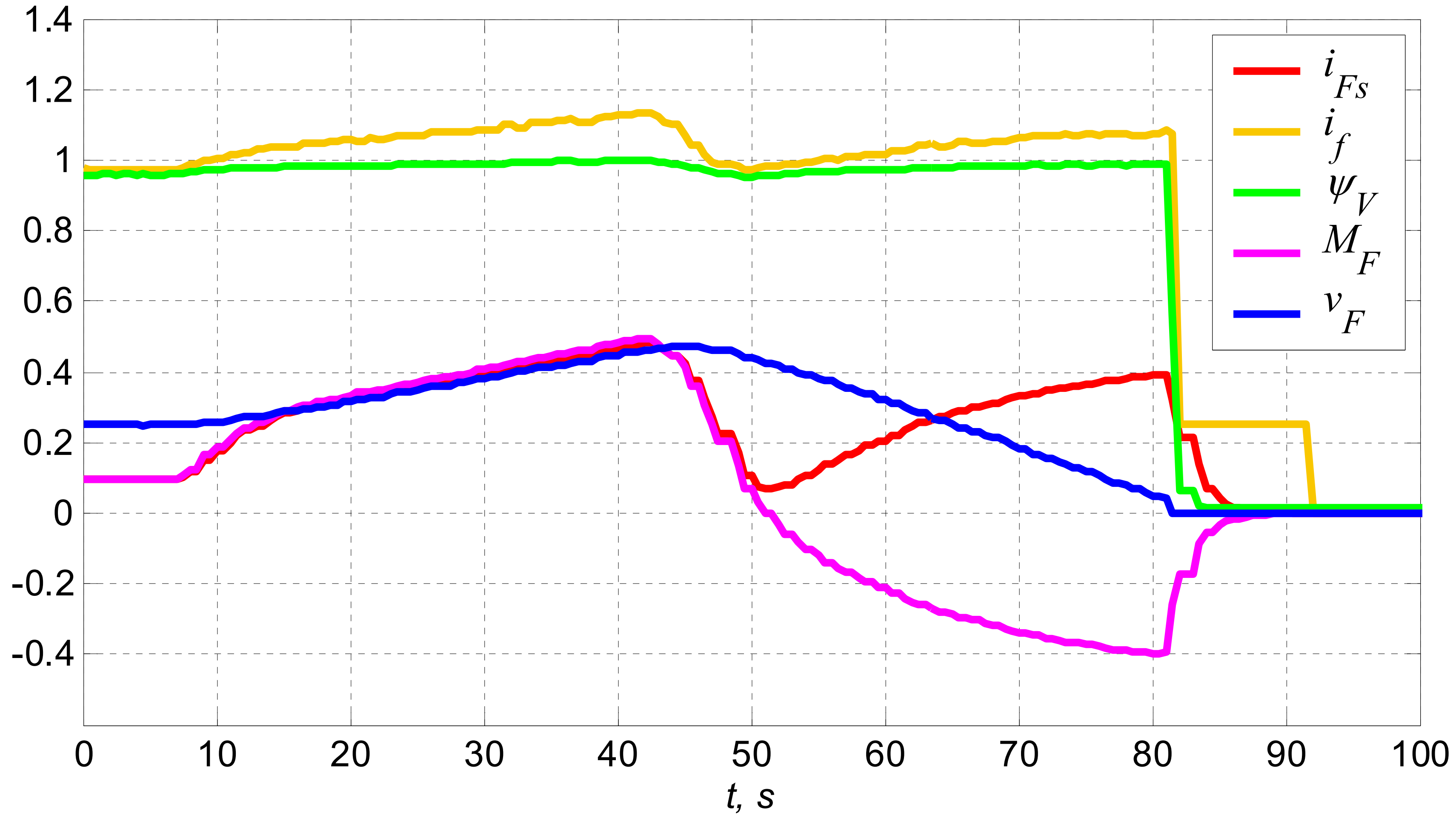
Tests without fan, dynamical loading



Stator voltage and current while start with higher acceleration



Tests with fan, acceleration followed by braking



CONCLUSIONS

1. **The mine fan drives have passed tests while start-up successfully. And they continue successful operation.**
2. **Drives are tested with torques, close to expected torque in the future. Static and dynamical characteristics of the drives correspond to desired characteristics. They satisfy all the requirements of the application.**
3. **Tests confirmed proper operation of newly developed algorithm for excitation control.**