Institute for
Drive Systems and
Power Electronics

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Overview of IAL Software Programs for the Calculation of Electrical Drive Systems

Machine type	Synchronous machines				Induction machines		
	Electrically excited		Permanent magnet	Reluctance	three-phase		single-phase
Topic	Salient-pole rotor	Cylindrical rotor			Squirrel-cage rotor	Slip-ring rotor	Squirrel-cage rotor
Steady-state performance	SPSYN	VPSYN	PMOK		ASYN		WAMOB
	SPOK						
	SPOK-FAST						
Calculation of sudden short circuits & transient phenomena	SYNDYN				SYNDYN		
Noise	ALFRED				ALFRED / FELDER		
	AGR				AGR		
	GMA						
Operating maps	SPSYN		PMOK		ASYN		
	SPOK						
	SPOK-FAST						
Quasi steady-state start-up	SPASYN	VPASYN			ASASYN		
Powertrain	Powertrain Simulator		Powertrain Simulator		Powertrain Simulator		
Pulsation torques	ALFRED		PMOK		ALFRED		
	SPOK						
	SPOK-FAST						
Other	KAPE				WKF		
	USYM				USYM & UWELLE		
	BIEGE & TKDZ						
	SV 8 & WET & VOPI						

AGR – Analytical calculation of magnetic noise

- **Scope of calculations**
  - Analytical, steady-state
  - Vibration amplitudes at core back
  - Emitted sound pressure level
  - Eigenfrequencies of stator
  - Noise characteristics (IDEMA tool chain)
- **Machine type(s)**
  - Permanent magnet synchronous machines
  - Induction machines
  - El. excit. synchronous machines

- **Input data**
  - Geometrical data
  - Spatial harmonics in the air-gap field (e.g. calculated with ALFRED, FELDER or FEMAG)
- **Constraints**
  - Internal rotors only (external rotors optionally, on request)
  - Radial-flux machines only
  - Mode $r = 1$ not considered

ALFRED – Air-gap field analysis of faultless or damaged electrical three-phase machines

- **Scope of calculations**
  - Analytical, steady-state, eccentricities, broken bars in cage, interturn faults
  - Resulting air-gap field (permeance waves, spatial harmonics of current distribution)
  - Winding e.m.f.
  - Air-gap torque
  - Loss distribution in cage
- **Machine type(s)**
  - Induction machines
  - El. excit. synchronous machines
- **Input data**
  - Geometrical data
  - Winding data
  - Rating data (magnetic circuit)
  - Stator and exciter current, if applicable
- **Constraints**
  - Internal rotors only
  - Radial-flux machines only
  - No solid salient-pole or cylindrical rotors
  - No permanent magnet synchronous machines
  - Rough consideration of saturation

ASASYN – Asynchronous start-up of induction machines

- **Scope of calculations**
  - Analytical calculation of the quasi steady-state start-up of induction machines considering the temperature rise in the windings
  - Torque, power factor, currents and temperature rise in stator and rotor windings depending on the slip
  - Starting time, temperature rise in the rotor core
  - Temperature rise in the rotor winding in case of a stalled rotor
- **Machine type(s)**
  - Induction machines (squirrel-cage and slip-ring rotors)
- **Input data/requirements**
  - Geometrical data of the active part of stator and rotor
  - Results from ASYN calculation
  - Linear or quadratic speed dependence of the load torque consumed by the driven machine
  - Consideration of an external resistance in case of slip-ring rotors
  - Manual adjustment of the current displacement factors in the end ring

ASYN – Calculation of induction machines

- **Scope of calculations**
  - Analytical calculation of steady-state operating points
  - Single-point and map calculations
  - Symmetrical multiphase windings
  - Motor and generator mode
- **Machine type(s)**
  - Squirrel-cage rotors (with one or two cages)
  - Slip-ring rotors
  - Doubly fed induction machines
- **Input**
  - Geometrical, lamination and winding data
  - Rating data
  - Steady-state short-circuit current
- **Constraints**
  - No transient phenomena
  - Radial-flux machines only
  - No thermal prediction

BIEGE – Lateral critical speeds

- **Scope of calculations**
  - Analytical
  - Lateral critical speeds
- **Applications**
  - Shaft-bearing systems
- **Input data**
  - Geometrical data of the shaft, bearing parameters and positions
  - Point and distributed loads
- **Constraints**
  - Internal rotors only

FELDER – Calculation of spatial harmonics in the air-gap field of cage induction machines

- **Scope of calculations**
  - Spatial harmonics of the flux density in integer-slot windings and double-layer fractional-slot windings
  - Analytical, steady-state
  - Consideration of slotting, saturation and eccentricities
  - Consideration of harmonics in the current
  - Processing of the spatial harmonics of the flux density for input in AGR
- **Machine type(s)**
  - Cage induction machines
- **Input data**
  - Geometrical data
  - Winding data
  - Parameters of the active part
- **Constraints**
  - Internal rotors only
  - Radial-flux machines only
  - Cage IM only

GMA – Modal analysis of noise

- **Scope of calculations**
  - Emitted sound pressure level
  - Dominant frequencies
  - Vibration modes
  - Deflections at the surface along the circumference
- **Machine type(s)**
  - Permanent magnet synchronous machines
  - Induction machines
  - Electrically excited synchronous machines
  - Synchronous reluctance machines
- **Input data**
  - PLT file of *FEMAG-DC* (PMSM)
  - *FELDER* output file (IM)
  - *ALFRED* output file (ESM, IM)
  - Modal matrix of *ANSYS*
  - Node positions of *ANSYS*
- **Constraints**
  - Cylindrical cores only

KAPE – Calculation of characteristics for stationary-field machines

- **Scope of calculations**
  - Analytical, steady-state, balanced operation
  - No-load, magnetic circuit calculation
  - Equivalent circuit elements (abc and dq)
  - Partial load and rated duty
  - Losses of passive front end
  - Characteristic of field current of the primary machine depending on the excitation of the exciter machine
- **Machine type(s)**
  - Stationary-field machines
- **Input data**
  - Geometrical data
  - Winding data
- **Requirements**
  - Pole form coefficients of *PolformIdent* software
- **Constraints**
  - Radial-flux machines only

SPASYN – Quasi steady-state start-up of salient-pole synchronous machines

- **Scope of calculations**
  - Asynchronous start-up, quasi steady-state, analytical, start-up time
  - M-n characteristic considering Goerges dip and current displacement
  - Asynchronous torque, pulsation torques of double slip frequency, bar- and ring-type current distribution
  - Winding and damper bar temperatures
- **Machine type(s)**
  - Salient-pole synchronous machines with line start
- **Input data**
  - Geometrical data
  - Winding data
  - Equivalent circuit elements (e.g. from results of SPSYN calculation)
  - Thermal conductivities
  - Starting parameters: counter torque, cooling time

SPOK – Calculation of efficiency-optimized maps for salient-pole synchronous machines

- **Scope of calculations**
  - Numerical (FEM), steady-state, balanced operation
  - Single load point calculation, map calculation (efficiency-optimized)
  - Loss calculation
  - Flux linkages, torque, inductances, quantities at the terminals
- **Machine type(s)**
  - Salient-pole synchronous machines
- **Input data**
  - Machine data
  - Winding data
- **Requirements**
  - *FEMAG-DC*
- **Constraints**
  - Radial-flux machines only

SPOK-Fast – Fast calculation of optimized maps for salient-pole and cylindrical-rotor synchronous machines

- **Scope of calculations**
  - Numerical (FEM), steady-state, balanced operation
  - No-load characteristic, single load point calculation, map calculation (e.g. efficiency-optimized)
  - Loss calculation, flux linkages (FFT), torque (FFT), inductances, quantities at the terminals
  - Air-gap field (FFT)
- **Machine type(s)**
  - El. excit. synchronous machines
- **Input data**
  - Machine data
  - Winding data
  - Material data
- **Requirements**
  - *Matlab*
  - *FEMAG-DC with FESI*
- **Constraints**
  - Radial-flux machines only

SPSYN – Calculation of salient-pole synchronous machines

- **Scope of calculations**
  - Analytical, steady-state, balanced operation, fundamental perform.
  - Magnetic circuit calculation, no-load & short-circuit characteristic
  - Rating point, partial-load points, breakdown point: losses, quantities in phasor diagrams
  - Equiv. circuit elements & time constants (satur. & non-saturated)
  - THD factor (no-load)
  - M-n characteristics

- **Machine type(s)**
  - Salient-pole synchronous machines

- **Input data**
  - Geometrical data
  - Winding data
  - Rating data
  - Operating limits

- **Constraints**
  - Internal rotors only

SYNDYN – Transient phenomena in electrically excited synchronous machines and induction machines

- **Scope of calculations**
  - Torsional critical speeds
  - Transient phenomena: synchronization, break in power supply, phase-to-phase & three-phase faults, start-up, braking, load consumption & load rejection
  - Magnetizing saturation considered
  - Current displacement in the cage
  - Modelling of shafting as multibody system with max. 19 masses
- **Machine type(s)**
  - El. excited synchronous machines
  - Induction machines
- **Input data**
  - Equivalent circuit elements, no-load characteristic
  - Mechanical data as multibody system
  - Initial state
  - Line/converter voltage, field voltage, counter torque
- **Constraints**
  - Fundamental behaviour,
  - Operation at stiff system, no controllers
  - Constant equiv. circuit param. within one calculat.

SV 8 – Current displacement in rectangular conductors

- **Scope of calculations**
  - Analytical, steady-state
  - Current displacement in and leakage coefficients of symmetrical integer-slot and fractional-slot windings
  - Coils of equal coil pitch and concentric coils
  - Rectangular conductors
- **Machine type(s)**
  - All machine types with form-wound coils
- **Input data**
  - Machine data
  - Winding data
    - Winding diagram
    - Conductor dimensions
- **Constraints**
  - Rough approximation of leakage flux in conductors near the air gap

PMOK – Calculation of efficiency-optimized characteristics for permanent magnet synchronous machines

- **Scope of calculations**
  - Numerical (FEM), steady-state, balanced operation
  - Single load point calculation, map calculation (η-optimized, MTPA, FOC)
  - Flux linkages, torque, inductances, quantities at the terminals, losses
  - Coupling with powertrain simulator
- **Machine type(s)**
  - PM synchronous machines
- **Input data**
  - Geometrical data
    - Autom. model preparation
    - Surface-mounted magnets
    - Buried magnets
  - Machine data
  - Winding data
- **Requirements**
  - *FEMAG-DC*
- **Constraints**
  - Radial-flux machines only

PS – Powertrain simulator

- **Scope of calculations**
  - Driving cycle simulation of electric vehicles
  - Energy consumption
  - Temperature pattern of motor components
  - Simulation of power semiconductors
  - Optional simulation with battery systems and boost converters
  - Single load point calculation
- **Machine type(s)**
  - Induction machines
  - permanent magnet and electrically excited synchronous machines
- **Input data**
  - Geometrical and winding data of the machine
- **Requirements**
  - Characteristics from other software programs:
    - PMOK, SPOK, SPOK-FAST, SPSYN, ASYN
- **Constraints**
  - Only internal rotors considered by thermal models so far

VPSYN – Calculation of synchronous machines with cylindrical rotor

- **Type of calculations**
  - Analytical, steady-state, balanced operation, fundamental perform.
  - Magnetic circuit calculation, no-load & short-circuit characteristic
  - Rating point, partial-load points, breakdown point: losses, quantities in phasor diagrams
  - Equiv. circuit elements & time constants (satur. & non-saturated)
  - THD factor (no-load)
  - M-n characteristics
- **Machine type(s)**
  - Synchronous machines with cylindrical rotor
- **Input data**
  - Geometrical data
  - Winding data
  - Rating data
  - Operating limits
- **Constraints**
  - Internal rotors only
  - Radial-flux machines only

TKDZ – Torsional critical speeds

- **Scope of calculations**
  - Analytical
  - Torsional critical speeds
- **Machine type(s)**
  - All shaft-bearing systems
- **Input data**
  - Geometrical data of the shaft
  - Point loads
- **Constraints**
  - Internal rotors only (rotating around direct axis)

USYM – Performance in case of asymmetrical stator winding

- **Scope of calculations**
  - Analytical, steady-state, unbalanced operation (missing coils in stator winding)
  - Current distribution in single stator branches
  - Partial load and rated duty
- **Machine type(s)**
  - Electrically excited synchronous machines
  - Induction machines
- **Input data**
  - Geometrical data
  - Winding data
  - Rating data
  - Magnetic circuit data, e.g. from SPSYN, VPSYN or ASYN
- **Constraints**
  - Internal rotors only
  - Radial-flux machines only
  - No solid salient-pole or cylindrical rotors

UWELLE – Calculation of shaft voltages

- **Scope of calculations**
  - Analytical calculation of shaft voltages caused by imperfections and unbalances in the magnetic circuit
  - Consideration of damper windings
  - Influence of rotor skewing
  - Consideration of non-linear magnetizing curve
  - Different types and distributions of imperfections in the stator yoke
  - Frequency-dependent analysis of resulting (damped) shaft voltages sorted by cause
- **Machine type(s)**
  - Cage induction machines

- **Input/requirements**
  - Geometrical and winding data of the active part of stator and rotor
  - Operating point data and corresponding magnetic voltages
- **Constraints**
  - Imperfections in stator possible only
  - Cage rotors only

VOPI – Voltage on Power Interfaces

- **Scope of calculations**
  - Calculation of motor terminal voltage in accordance with IEC 61800-8
  - Calculation depending on
    - voltage source (grid)
    - rectifier and converter
    - filter
    - cable parameters
    - motor performance
  - Either calculation or manual entry of cable parameters possible
- **Machine type(s)**
  - Converter-fed machines
- **Input/requirements**
  - Grid voltage and type
  - Fundamental frequency
  - B6C/B2C/active rectifier
  - 2-,3-, multilevel converters
  - Filter type: none, dU/dt, sinusoidal filter, output reactor, HF common-mode filter
  - Cable parameters: Capacitance and inductance per unit length / alternative: type and geometrical cable dimensions
  - Motor performance

VPASYN – Quasi steady-state start-up of synchronous machines with cylindrical rotor

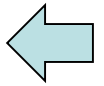
- **Scope of calculations**
  - Asynchronous start-up, quasi steady-state, analytical
  - M-n characteristic considering the Goerges dip
  - Asynchronous torque, pulsation torques
  - Bar- and ring-type current distribution
  - Winding and damper bar temperatures
  - Start-up time
  - Consideration of current displacement

- **Machine type(s)**
  - Cylindrical-rotor synchronous machines with line start

- **Input data**
  - Geometrical data
  - Equivalent circuit elements (result of VPSYN calculation)
  - Thermal data
  - Start-up data: counter torque, cooling time

WAMOB – AC induction machines in consideration of spatial harmonics

- **Scope of calculations**
  - Speed-torque characteristic considering the positive- and negative-sequence harmonics
  - Power consumption and power output
  - Phase and line current
  - Capacitor voltage
- **Machine type(s)**
  - Cage induction machines with two- and three-phase stator windings for AC operation
  - Steinmetz star and delta connection
- **Input data**
  - Winding data
    - symmetrical
    - quasi symmetrical
    - arbitrarily asymmetrical
  - Geometrical machine data
  - Rating data
- **Constraints**
  - Cage rotors only
  - Internal rotors only



WET – Winding design tool

- **Scope of calculations**
  - Design/analysis of multiphase integer-slot and fractional-slot windings
  - Analytical calculation of all winding factors, differential leakage and symmetrical components of e.m.f.
  - Visualization of the Goerges polygon and the resulting distribution of the ampere turns (including FFT)
  - Symmetrical and (given) asymmetrical windings
- **Machine type(s)**
  - Induction and synchronous machines
- **Input/requirements**
  - Winding design/analysis
    - number of phases
    - number of pole pairs
    - number of slots
    - number of layers
    - coil pitch for double-layer windings
  - Analysis of asym. windings
    - Specific. of winding diagram
    - Entry of number of turns, if required
- **Constraints**
  - Max. two winding layers

WKF – Forces in the winding overhang and end-turn bracing

- **Scope of calculations**
  - Analytical calculation of forces in the winding overhang
  - Recommendations for end-turn bracings
  - Phase-to-phase and three-phase faults
  - Start-up
  - Form-wound coils with resin-rich or VPI insulations
- **Machine type(s)**
  - Induction machines
  - El. excit. synchronous machines (optional, on request)
- **Input data**
  - Geometrical coil data
  - Winding data
  - Rating data
  - Steady-state short-circuit current
- **Constraints**
  - Internal rotors only
  - Radial-flux machines only
  - No round-wire windings