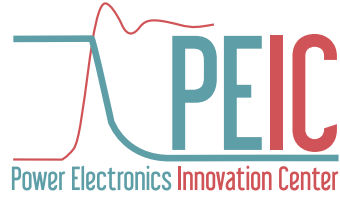




**Politecnico
di Torino**

Department of Energy
"G. Ferraris"



**UNIVERSITÀ
DEGLI STUDI
DI PADOVA**

GalFer Contest: DataSet Creation and EM Analysis

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- Geometric Model: from Parameters to FEA Model
- Non-linear Magnetic FEA
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Introduction

The objectives of this first part are:

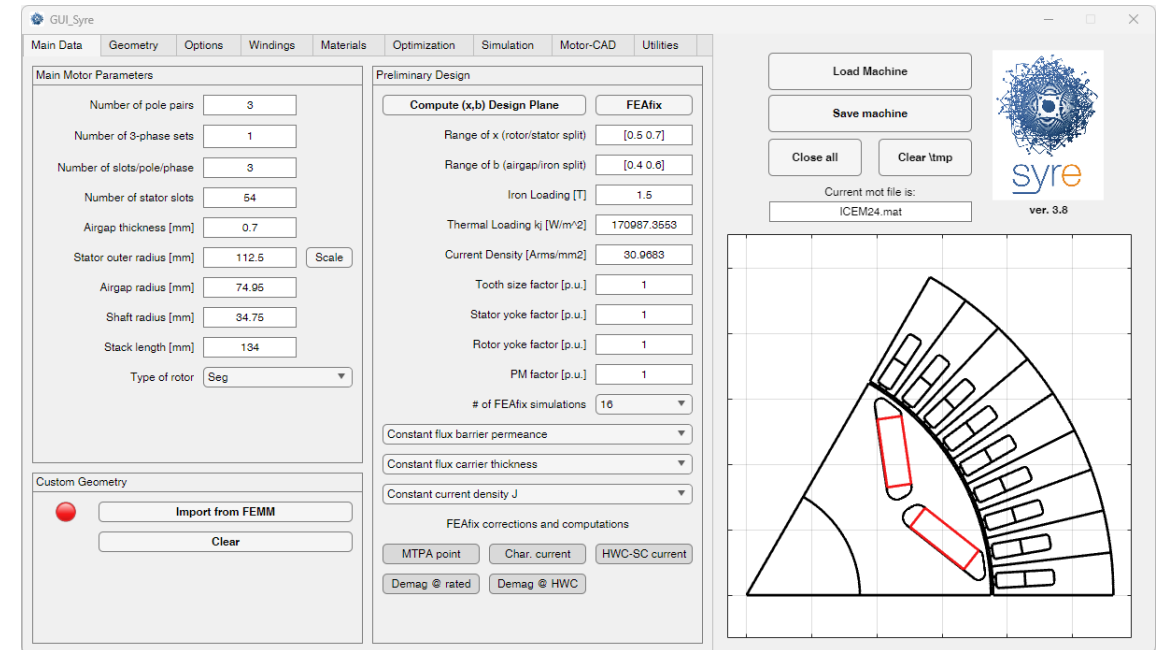
- Presents the geometric parametrization adopted
- Introduce the computation workflow and environment
- Show how the selected electromagnetic metrics are computed

The dataset is built and computed using SyR-e, available on [GitHub](#) and integrated with specific functions

Computation Environment: SyR-e

SyR-e is an open-source environment, developed for design and analysis of different kind of synchronous machines

- Originally created for SyRM optimization
- In the years, it evolves, adding other machines (PM-SyRM, SPMSM, IPMSM, ...) and preliminary design procedures
- It embeds specific procedures for flux maps manipulation and elaboration and the link with eDrive models (Simulink/SimScape, PLECS, ...)
- It is based on [FEMM](#) for the EM FEA simulations
- Available on [GitHub](#) e [Matlab File Exchange](#)
- Used for the dataset creation for GalFer Contest, embedding specific functions from the contributors



Computation Environment: SyR-e

The screenshot displays the GUI_Syre software interface, which is used for motor optimization. The interface is divided into several sections:

- Main Data:** Includes tabs for Main Data, Stator, Rotor, Options, Materials, Optimization, Simulation, Motor-CAD, and Utilities.
- Optimization options:** Contains settings for the surrogate model dataset (Sobol), current overload (1 p.u.), number of generations (0), and population size (1024). It also has checkboxes for Mechanical Stress Control and Constant current, and an Optimize button.
- Time stepping raw (evolution):** Includes Rotor angular excursion (60) and # of rotor positions (30).
- Time stepping fine (Pareto re-evaluation):** Includes Rotor angular excursion (60) and # of rotor positions (20).
- Objectives and Penalization Limits:** A table of optimization objectives and their limits:

Objective	Limit
Torque [Nm]	-0.1
Torque ripple (pp) [Nm]	10000
Power factor	-0.001
No load flux [Vs]	0
PM mass [kg]	10000
Copper mass [kg]	10000
- Variables and Bounds:** A table of design variables and their bounds:

Variable	Bound
Airgap radius [mm]	[60 78]
1st barrier pos. [p.u.]	[0.65 0.85]
Radial ribs [mm]	[0 0]
Tooth width [mm]	[3.8 6.3]
Barriers positions [p.u.]	[0.17 0.5]
Tangential ribs [mm]	[0 0]
Tooth lenght [mm]	[15 22.5]
Barrier width [p.u.]	[0.3 0.7]
Fillet Rad ribs in [mm]	[0.4 0.8]
Stator slot open [p.u.]	[0.1 0.4]
Barrier offset [p.u.]	[-0.75 0.75]
Fillet Rad ribs out [mm]	[0.4 0.8]
Tooth tan. depth [mm]	[0.8 1.2]
Barriers shrink [p.u.]	[0 0]
Fillet Tan ribs in [mm]	[0.4 0.8]
Airgap thickness [mm]	[0.4 0.8]
Barrier shift [mm]	[-4 6]
Fillet Tan ribs out [mm]	[0.4 0.8]
Theta FBS [mech °]	[0 15]
PM dimension [p.u.]	[0 1]
PM shape factor [p.u.]	[10 89]
Gamma [°]	[30 60]
PM remanence [T]	[0.3 0.38]
- Buttons:** Load Machine, Save machine, Close all, and Clear tmp.
- Current mot file is:** GalFer01_20240709.mat
- Logo and Version:** syre ver. 3.8
- Diagram:** A schematic diagram of a motor stator/rotor assembly, showing the arrangement of slots and poles. Two red rectangular regions are highlighted on the rotor, indicating areas of interest or optimization focus.



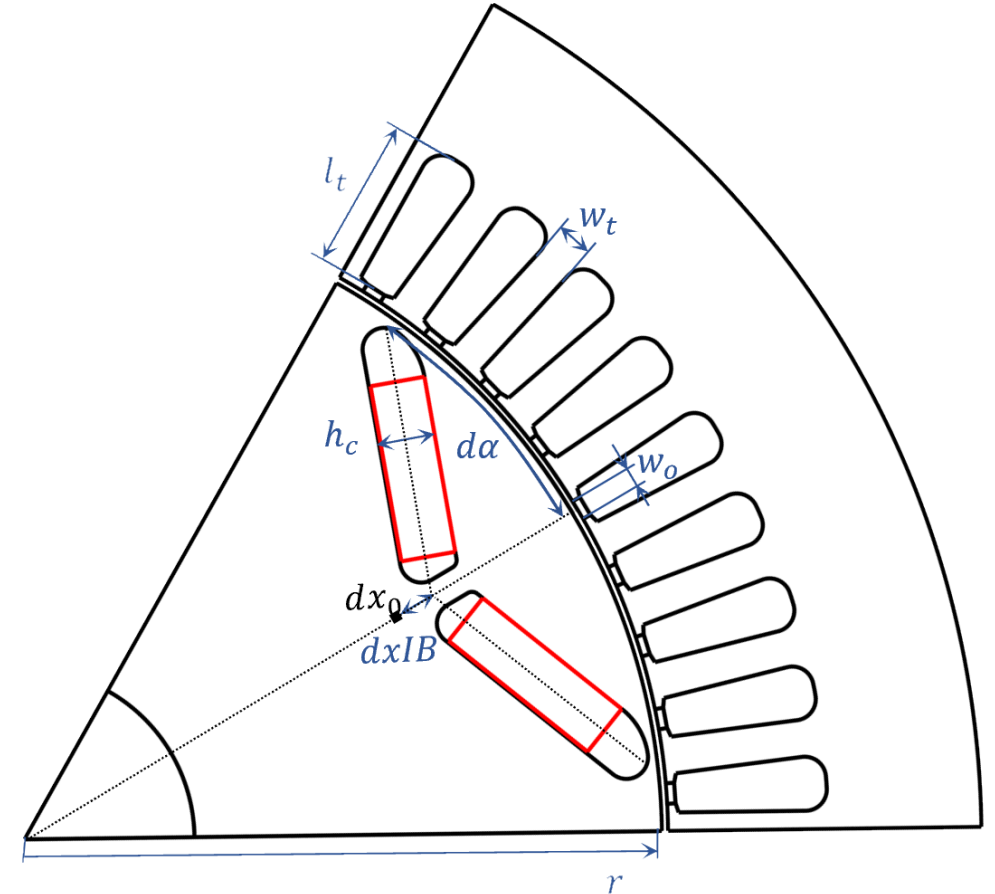
Parametrized Geometric Model

SyR-e exploit geometric parametrization, primarily for the optimization problem.

The parametrization is adopted also for the GalFer Contest dataset definition

The geometric variables, selected for the contest, are:

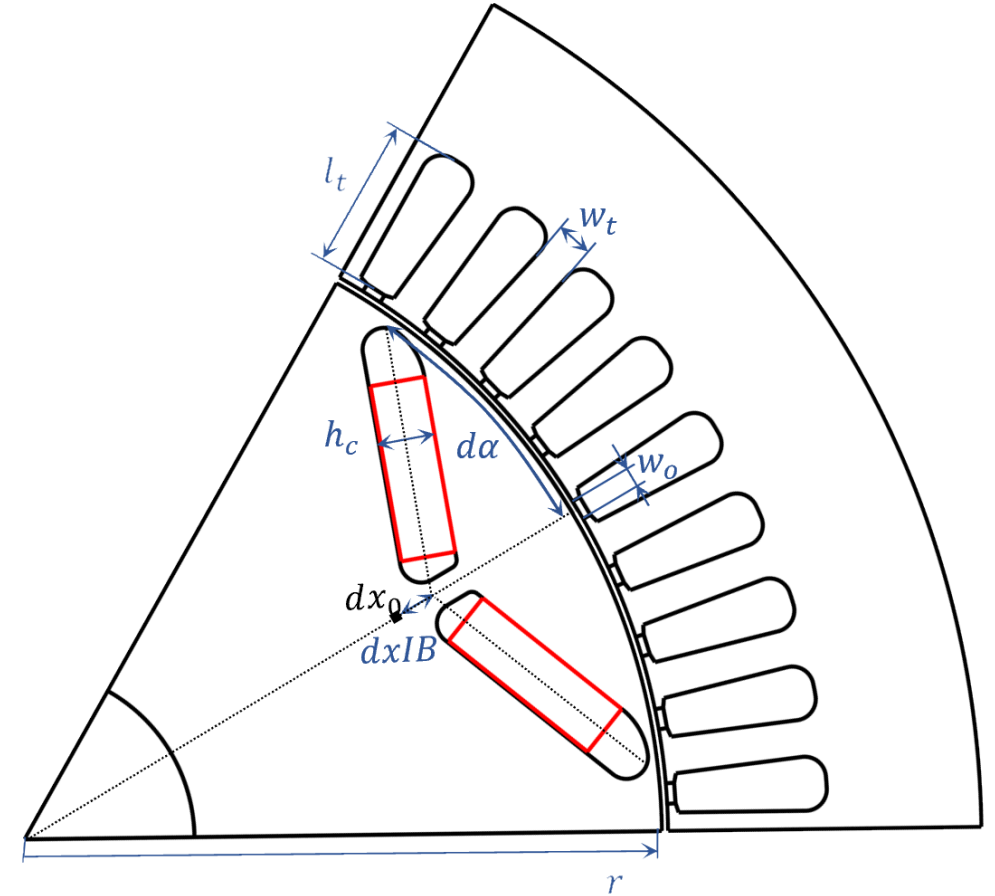
- Rotor radius r
- Pole span angle $d\alpha$
- PM thickness h_c
- Barrier shift dx_{IB}
- Stator tooth length l_t
- Stator tooth width w_t
- Stator slot opening w_o



Parametrized Geometric Model

Some geometric quantities are constant in the database:

- Stator outer radius
- Stack length
- Number of poles
- Number of slots
- Type of rotor (V-type)
- Materials
- Winding pattern
- Slot filling factor
- (Number of turns)



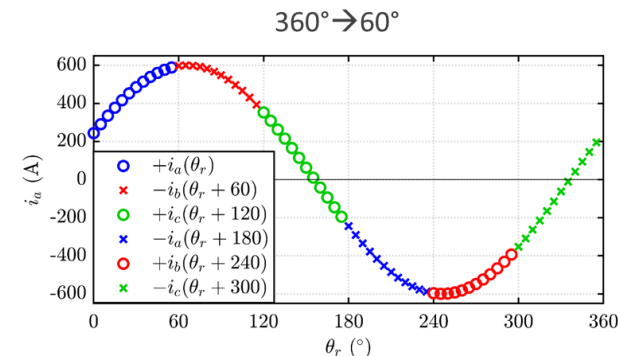
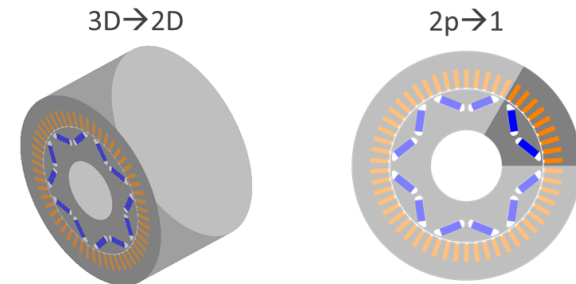
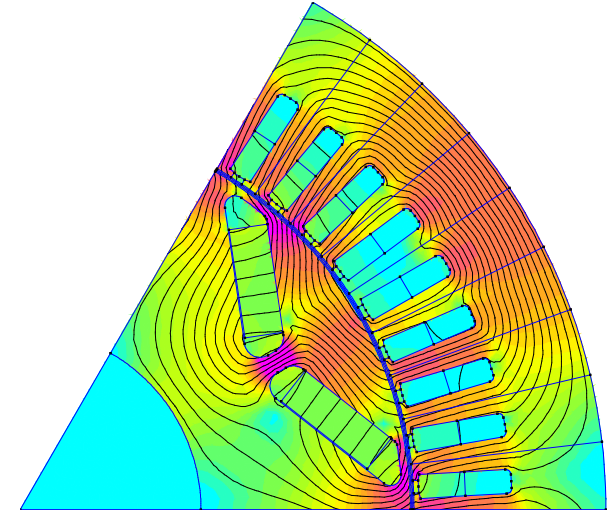
FEA Model and Simulations

FEMM is adopted for ElectroMagnetic FEA

- 2D Static Time Step FEA Simulation
- Simulation of 60 elt degrees rotation, 30 rotor position

FEA settings:

- Geometric model is created through SyR-e parametrization and workflow
- Current amplitude is defined starting from the **thermal loading** (i.e. loss in peak conditions)
- **Current angle** in dq reference is part of the variables



FEA Model and Simulations

Results from FEMM:

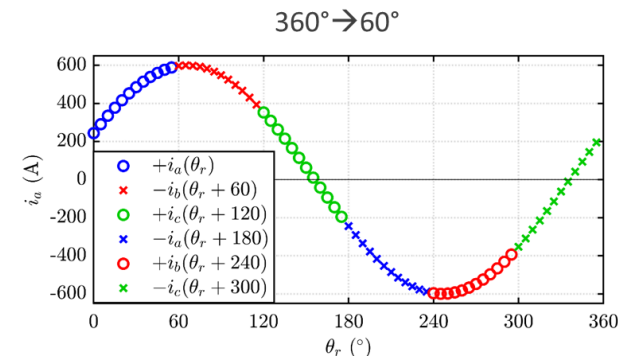
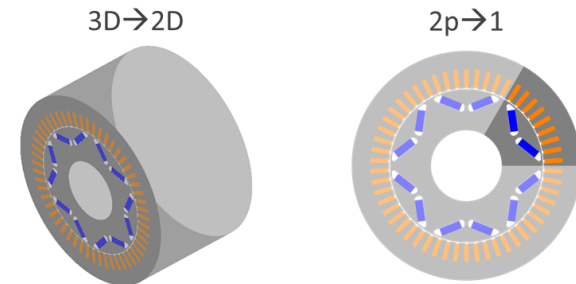
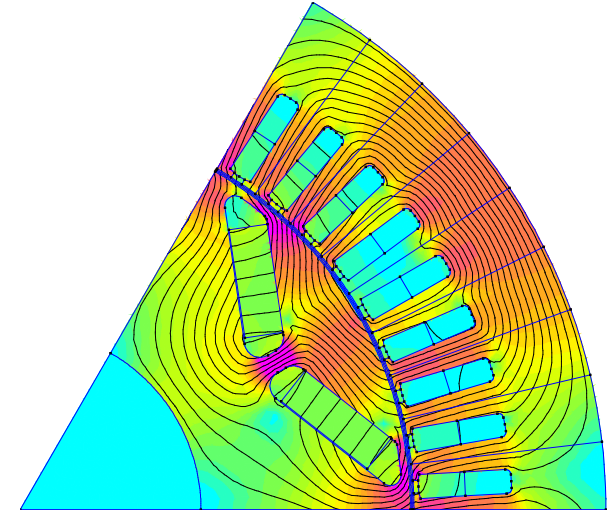
- Flux linkages (phase and dq waveform)
- Torque waveform

Then, electromagnetic output are computed and included in the dataset:

- Average torque
- Peak-to-peak torque ripple
- Power factor (from dq quantities, R_s neglected)

Furthermore, geometric output are computed, as cost metric:

- Copper mass (windings)
- PM mass



Computation Workflow in SyR-e

SyR-e optimization workflow is modified and expanded for the dataset creation:

- Latin hypercube or **Sobol** sampling
- Structural simulations are implemented in the dataset workflow simulation (was developed just as stand-alone simulation)
- Thermal simulations are implemented (UniPD code)

NB: FEMM mesh is adopted for all the physics

- EM: natively FEMM
- Structural: 2D, PDE toolbox, same mesh
- Thermal: 3D, extruded mesh, starting from FEMM

