

A New Approach on the Design and Optimization of Brushless Doubly-Fed Reluctance Machines

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Abstract

The Brushless Doubly-Fed Reluctance Machine (BDFRM) is being considered as a viable generator alternative to be used in wind turbines. A literature review shows that there is still a lack of researches to define a design procedure to make this machine widely used in such application. This paper aims to address this issue by considering a new BDFRM design method using a reluctance network approach and the concepts of sizing and optimization models. It also presents a case study using the proposed methodology where the torque has increased significantly whereas the iron mass has been kept to a minimum.

Variable Speed Wind Energy System

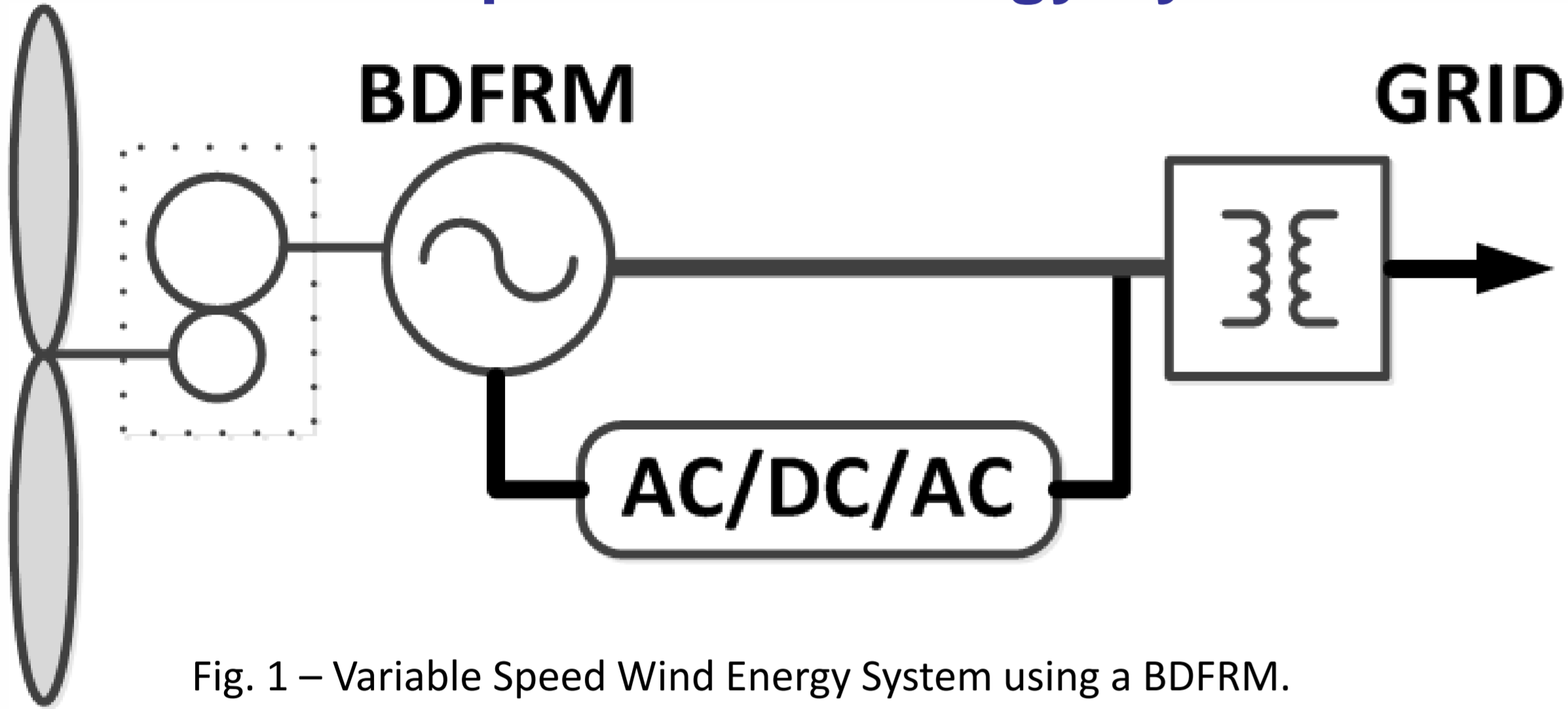


Fig. 1 – Variable Speed Wind Energy System using a BDFRM.

Machine Modeling

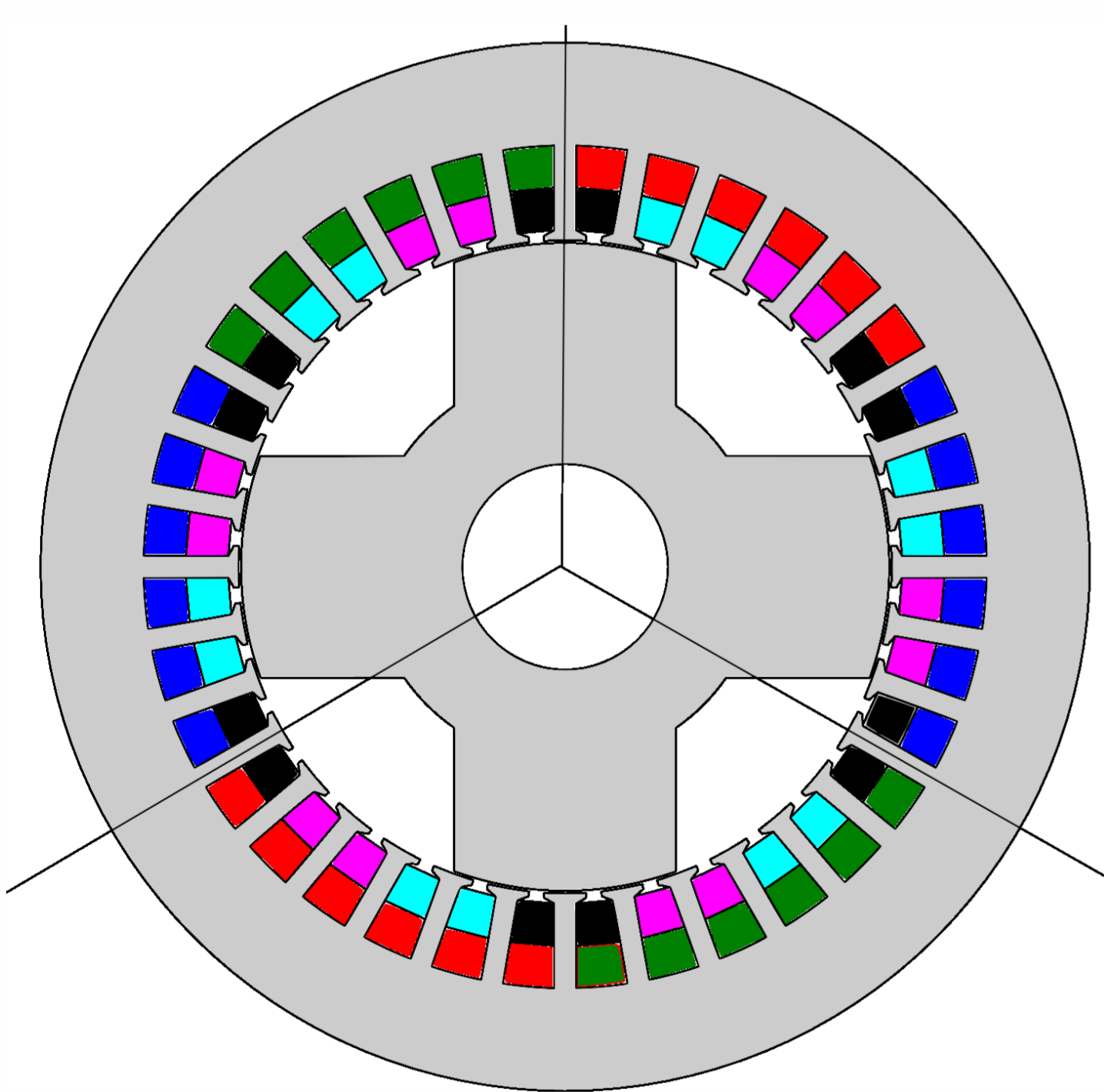


Fig. 2 – BDFRM : 2-6-4 poles.

BDFRM:

- Similar to an induction machine;
- 2 sets of three phase windings with different pole numbers;
- Reluctance Rotor: no brushes, slip rings, permanent magnets.

Conditions for torque production:

$$\omega_{rm} = \frac{\omega_1 + \omega_2}{p_r} \text{ if } p_r = p + q$$

Torque Equations:

$$T_e = \frac{3}{2} (p + q) L_{12} I_1 I_2 \sin(\gamma + \alpha)$$

$$T_e \propto \frac{n_2 \lambda_{1AA}}{n_1 i_{1A}}$$

RelucTOOL:

- ↑ Automatically generates the network and solve equation system;
- ↑ Considers saturation effects;
- ↑ Calculates parameter sensitivity;
- ↑ Coupling to gradient-based optimization algorithms (e. g. SQP).

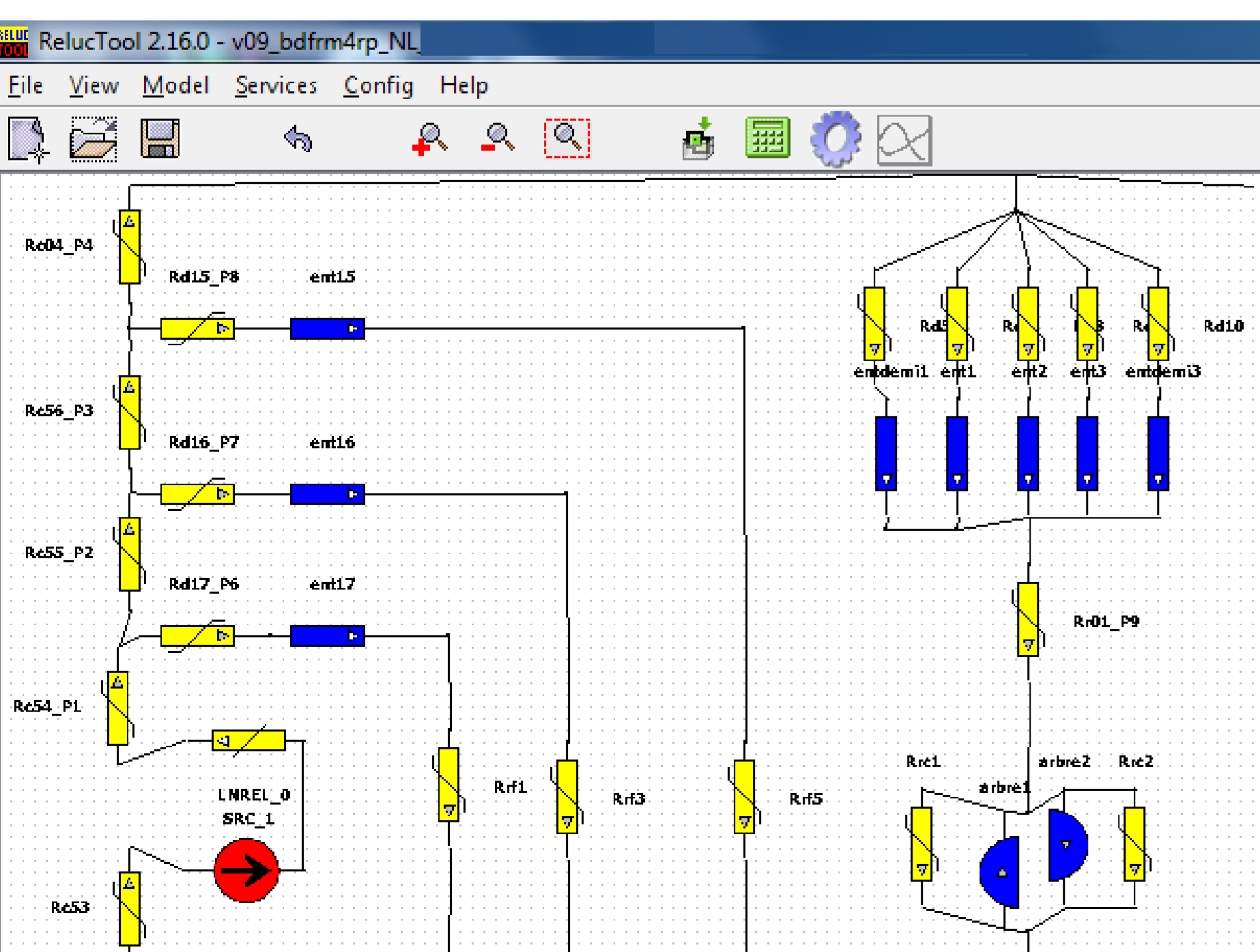


Fig. 3 – Reluctance Network Model (RelucTOOL).

Optimization Model

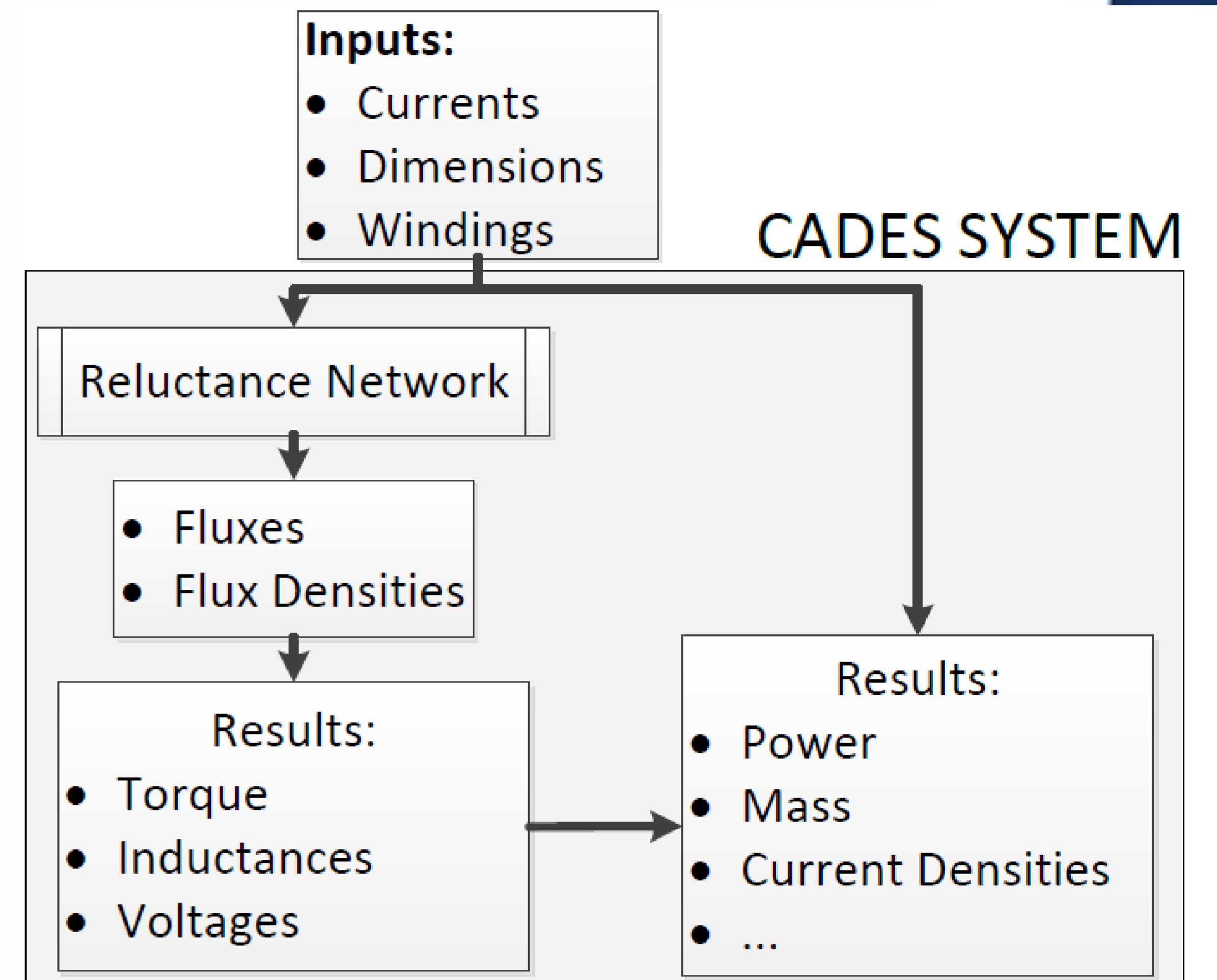


Fig. 4 - Optimization model implemented in CADES.

Results

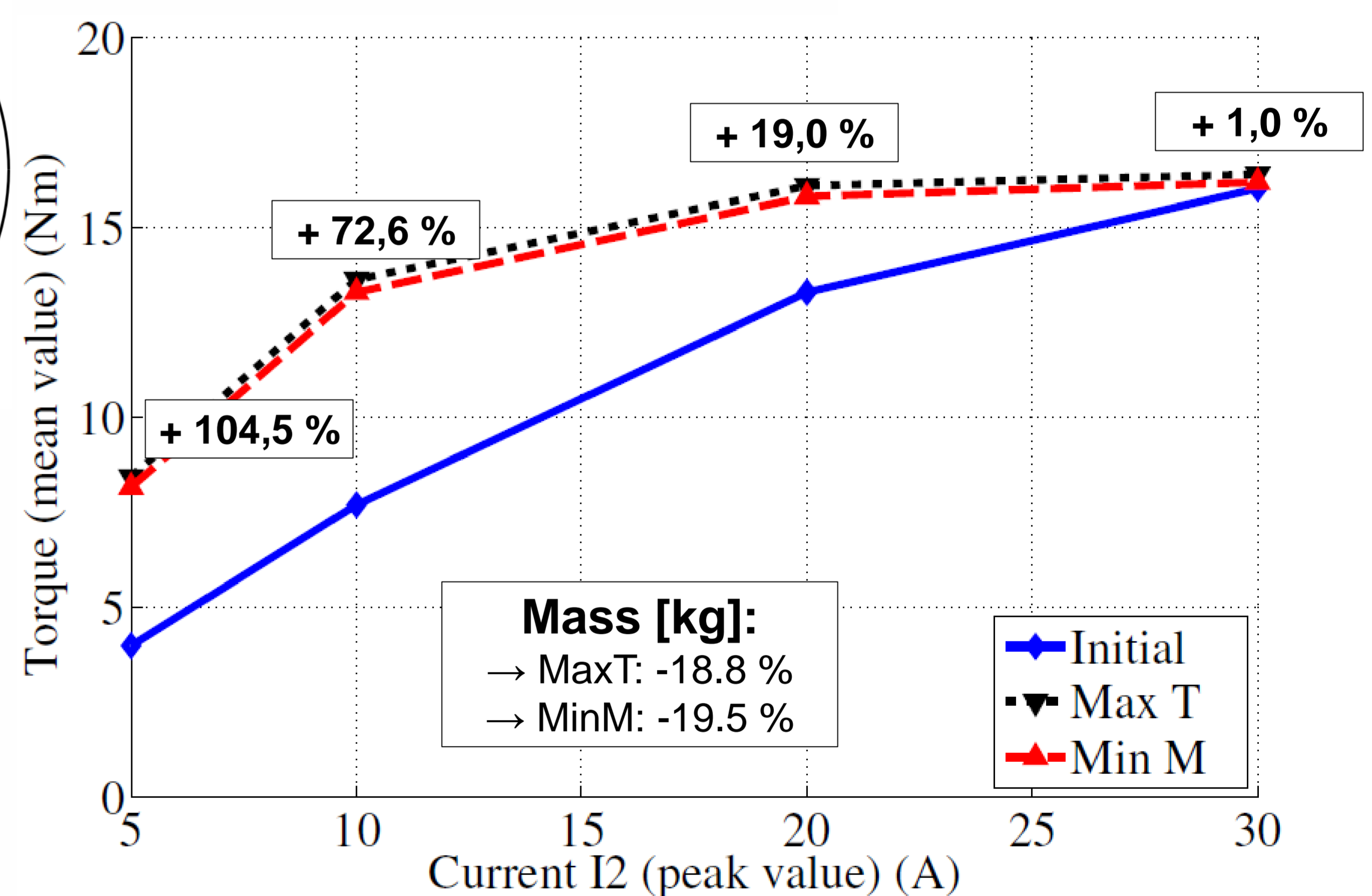


Fig. 5 – Torque as a function of secondary current for different designs.

Conclusions

- New BDFRM design method focusing on its electromagnetic structure optimization using a Reluctance Network approach;
- Design methodology contributes to reach the objective of making the BDFRM widely used;
- Example which maximizes the torque whereas keeping the mass to a minimum illustrates the interesting possibilities on using this procedure.

Further Work

- Development of a dynamic Reluctance Network (multi-static);
- Highly accurate model (compared to FEA) that allows to take into account in the optimization model constraints like voltage harmonics and torque ripple;
- Model uses an external function developed in JAVA and it has a built-in Jacobian calculation procedure that can be applied directly to a deterministic optimization algorithm such as SQP.
- Results to be presented at the OIPE 2014 conference.

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