Manufacturing tolerances influence on permanent magnet synchronous generator (PMSG) performance

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Abstract

A permanent magnet synchronous generator (PMSG) based wind turbine has been designed and manufactured to be installed in an educational area within **SWIP project** (“New innovative solutions, components and tools for the integration of wind energy in urban and peri-urban areas”) .

During the design stage, several finite element studies have been performed to evaluate the PMSG behavior and calculate parameters such as no-load voltage, generated power, or cogging torque analysis among others. During this stage dimensions are “ideal” and no machine deformations are considered. However, when the real prototype is manufactured, dimensions may differ due to manufacturing tolerances, and the results obtained in the design stage can get away from those measured in the prototype. Therefore, before PMSG manufacturing stage, a previous analysis must be done considering the influence of these manufacturing tolerances and the eccentricity on the different parameters.

This study allows to identify possible differences between the PMSG behavior expected from design stage simulation studies and measurements obtained in the test bench and later when the generator is installed in the wind turbine.

Objectives

This study aims to evaluate the effects of manufacturing tolerances and the eccentricity in the behavior of the PMSG designed within the SWIP project. In order to evaluate this influence, ripple power and cogging torque are analyzed evaluated by using a finite element software (FLUX 2D).

The influence will be evaluated and corrective actions may be taken into account before the manufacturing stage.

Methods

Fig.1 establishes the flowchart applied before the PMSG prototype is manufactured. Once the PMSG is designed, the manufacturing tolerances influences are evaluated. These tolerances values depending on the manufacturing process and the assembly process and are shown in Table 1 and 2.

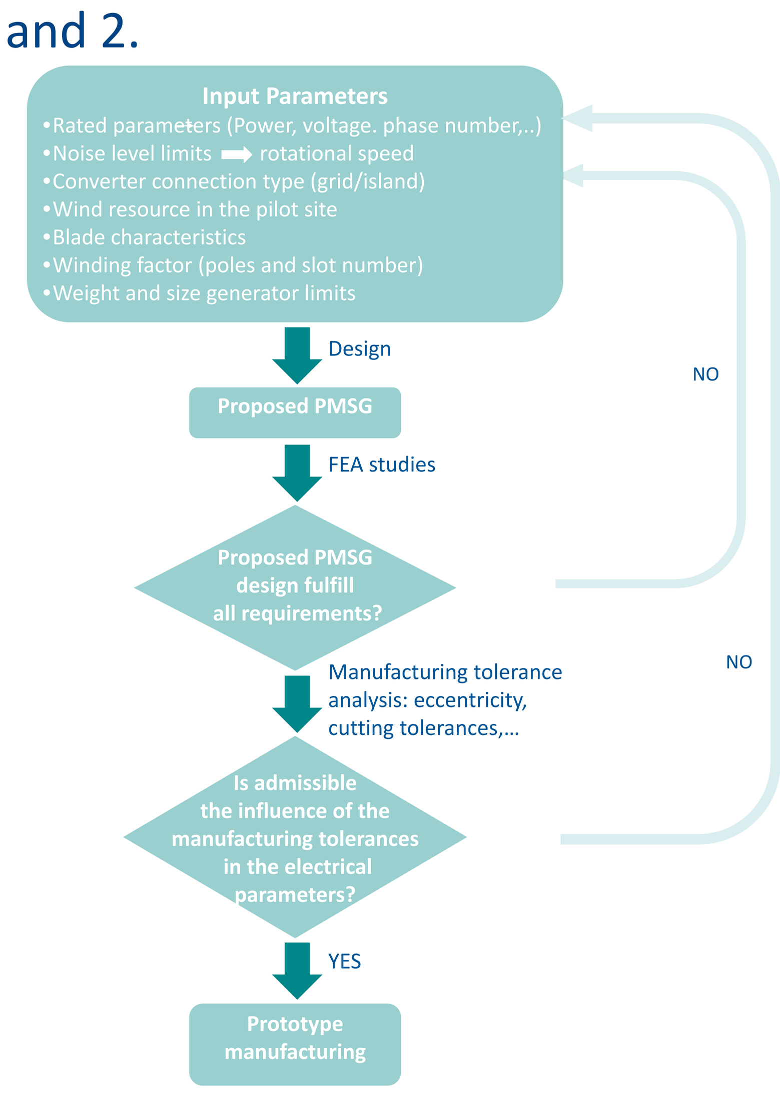


Fig. 1 Flowchart of PMSG design process.

Table. 1. Cutting process tolerance values of stator/rotor.

Cutting process	Tolerances
Laser cutting	±0.1 mm
Waterjet Cutting	±0.1 mm
Single Notching	±0.01 mm
Punching	±0.01 mm

Table. 2. Manufacturing process tolerance values of PM.

Manufacturing process	Tolerances
Magnetization angle (β)	±4º
Remanence magnetization (Br)	±0.02 T
Dimensional tolerances	±0.02 mm

Experimental setup

The generator analyzed is a radial flux PMSG with surface mounted magnets, inner rotor and fractional slot winding.

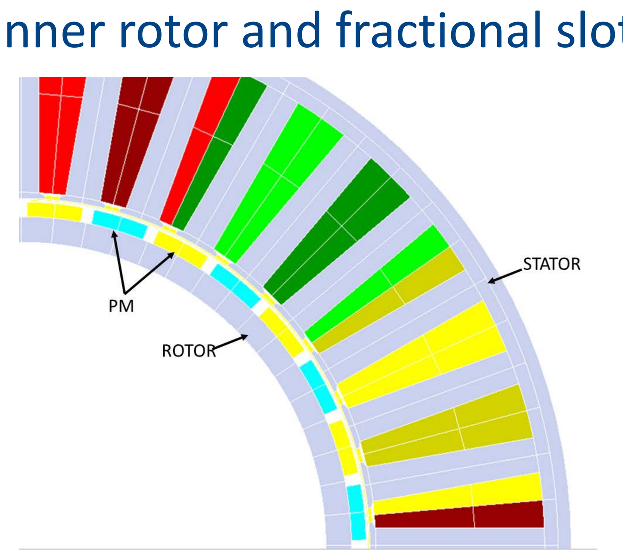


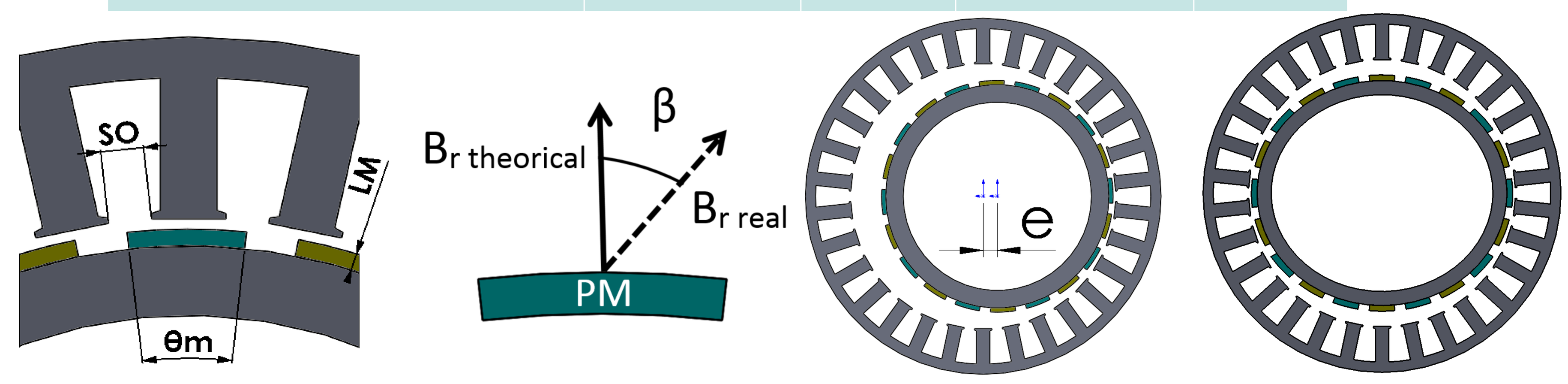
Fig. 2 2D Finite element model PMSG.

Table. 3. PMSG characteristics.

	Values	Units
Rated voltage	400	V
Rotational speed	120	r.p.m.
Phase number	3	
Slot number	36	
Pole number	32	

Table. 3. Tolerances analyzed during the study.

	Minimum value	Rated value	Maximum value	Units
Slot opening (SO)	SO-0.1	SO	SO+0.1	mm
Magnet length (LM)	LM-0.2	LM	LM+0.2	mm
Magnet angle (θ_m)	θ_m-0.3	θ_m	θ_m+0.3	º
Magnetization angle (β)	β-4	β	β+4	º
Remanence magnetization (Br)	B_r-0.02	B_r	B_r+0.02	T
Static Eccentricity (e)	25 %gap	0	50% gap	mm
Dynamic Eccentricity		0	0,1	mm



a) b) c)

Fig. 3 Graphic representation of the tolerances under study. a) Dimensional and magnetic tolerances; b) Static eccentricity; c) Dynamic eccentricity.

Results

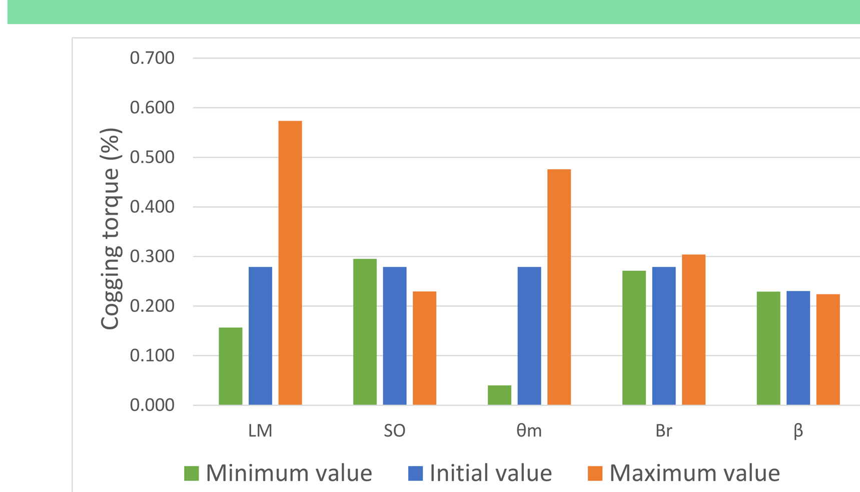


Fig.4 Manufacturing tolerance influence in Cogging torque (%).

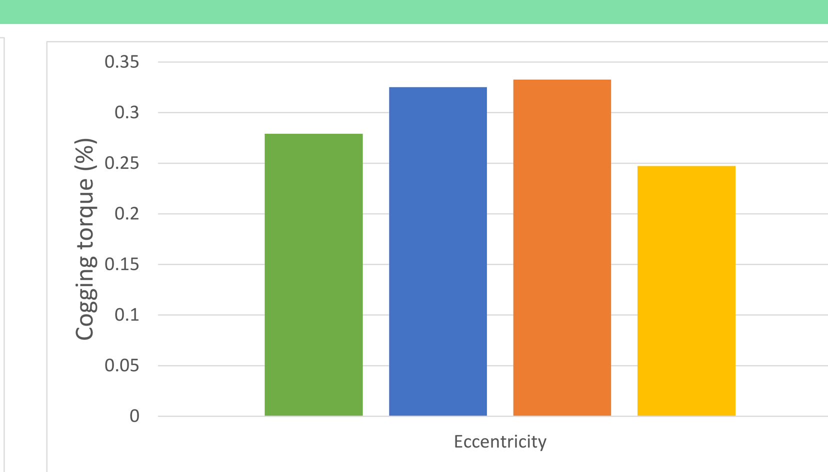


Fig.5 Eccentricity influence in Cogging torque (%).

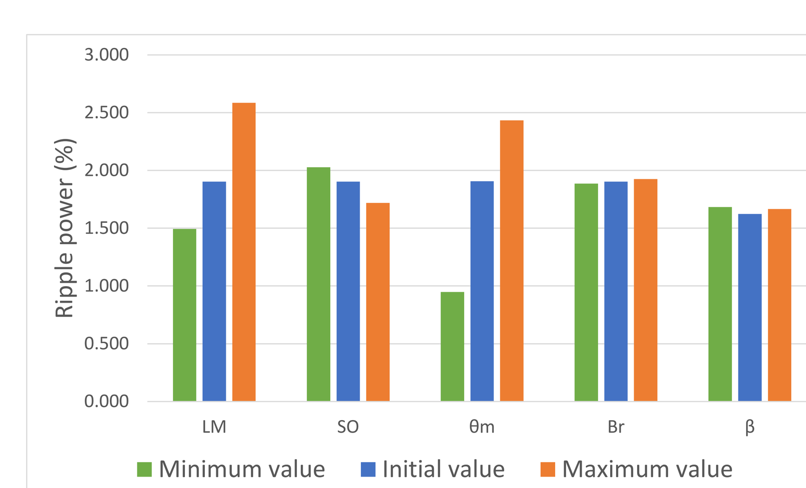


Fig.6 Manufacturing tolerance influence in Ripple power (%).

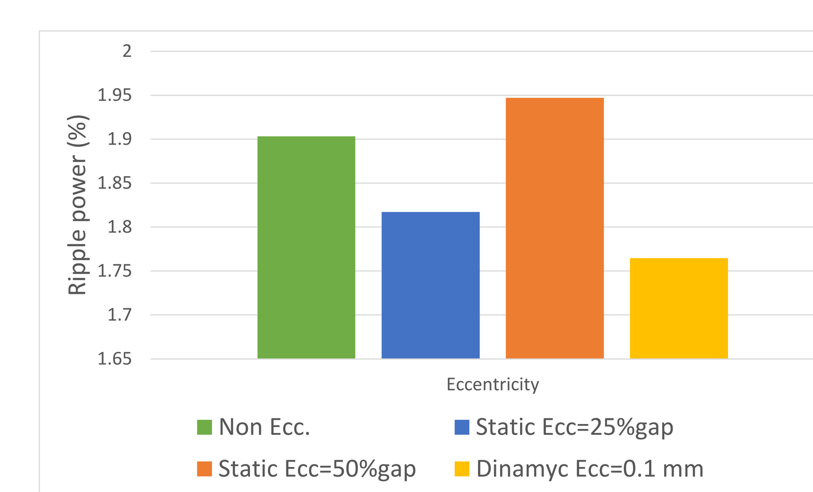


Fig.7 Eccentricity influence in Ripple power (%).

Conclusions

- Manufacturing tolerances affect PMSG behavior and should be taking into account during the design stage.
- Length magnet and magnet angle tolerances have an important influence in cogging torque and ripple power.
- Static eccentricity influence in the cogging torque and ripple power is higher than the dynamic eccentricity.
- Cogging torque and power ripple are barely affected by the magnetization angle.
- Manufacturing tolerances have higher influence in cogging torque and ripple power variation than static and dynamic eccentricity.

References

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