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State of the art of Multiport Electrical Machines and Magnetic Gears with respect to Wind Power Generation Application

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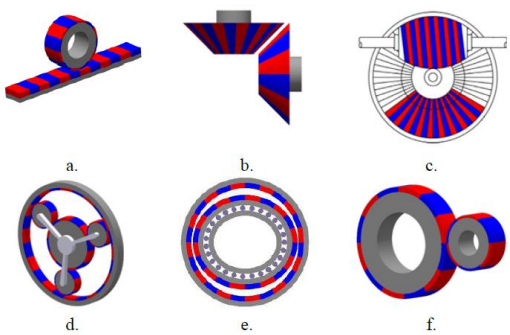
Abstract. This paper presents a state of the art of multiportmachines and magnetic gears designed for power generation applications. A multiport machine consists mainly of an electrical machine wo which a magnetic gear is integrated. Thus, one can get a device with more than two shafts, capable to operate at different levels of torque and speed. The main structures found in the literature, their operation, speed increase capability, materials, advantages and disadvantages are depicted in this review-type paper.

Magnetic Gears Topologies

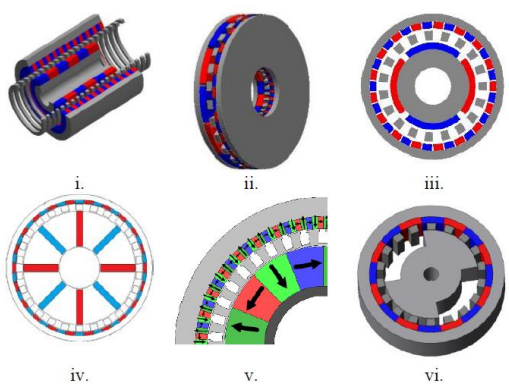
- The presence of the magnets reduces the metallic physical contact with contactless magnetic interaction. Based on working principle, the MG can be divided in:

1. Non-Modulating MG - consist in two magnetic wheels, with PMs on their surfaces. The operating principle is based on interaction between the PMs from one wheel, interacting with the PMs from the other wheel, creating a driving force which is applied on the driven wheel.



a) rack & pinion, b) bevel type, c) worm type, d) planetary type, e) harmonic gear, f) spur type

2. Modulated MGs – has two moving parts and one static part. On the surface of the moving parts the PMs are attached, having a different number of magnetic poles. The static part is made of iron pole pairs and is placed between the moving parts. This static part is also called flux modulator, the reason of the MGs group name



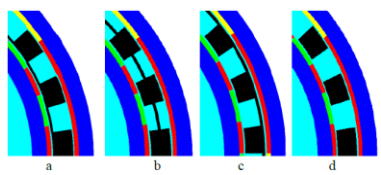
i. linear, ii. Axial, iii. Concentric, iv. Spoke type, v. Halbach array type, vi. Reluctance type

Principle of operating

A. Gear ratio - directly related to the number of PM pole pieces and iron pole pieces

$$G_r = -\frac{\omega_{out}}{\omega_{in}} = \frac{p_{in}}{p_{out}}$$

B. Iron pole-pieces design – responsible of torque transmission and influences the iron losses

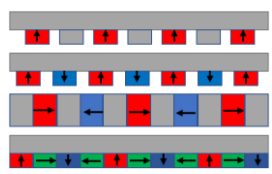


Iron pole-pieces bridges: a. bottom, b. middle, c. up, d. without bridges

C. Cogging torque factor – gives a specific poles-pieces configuration for smooth mechanical characteristics

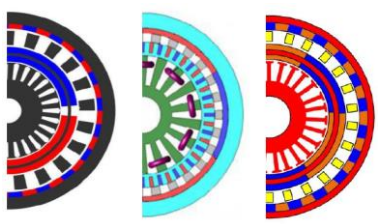
$$k_r = \frac{(2 \cdot p_{in} \cdot n_s)}{LCM(2 \cdot p_{in} \cdot n_s)}$$

D. Rotor's design aspects – for higher effieciency



Different arrangements of the PMs and their orientation: leakage pole, surface-mounted, flux concentration, Halbach array

Magnetically Geared Machines



Advantages:

- lack of lubrication, reduced maintenance, reduced noise production and isolation between their moving parts
- Two levels of speed and torque
- Reduced mass and volume
- Increasing speed without increasing the supplying frequency

Conclusions: Mechanical gears are used in several application in industry domain but their drawbacks, like often maintenance and performance limitation are significant. For example, in wind power industry, gearbox needs on many occasions maintenance interventions, which lead to interruptions in electric power generations. A solution is required to overcome this shortcoming and one possible solution is the used of magnetic gears (MGs). The magnetic configuration has the advantages of lower maintenance, torque transfer without physical contact and it offers the possibility of physically decoupling the input shaft with respect to the output shaft. The industrial interest has increased regarding the use of MGs lately, thus a review on the possible solutions to be used, even the ones with multiport options, has motivated this study. Beside the renewable energy domain, such solutions are useful for the automotive industry.

The current development of MGs has been presented in this paper, with special attention paid to the concentric configurations, but also for variants containing an outer rotor electrical machine with integrated magnetic gear. Till present, there are various applications using MGs because of their advantages, but the subject of losses is still under investigation. A lot of work is still needed for more practical validation in order to widely evaluate the suitability of the MGs or multiport electrical machines and their place in industry. The most important drawbacks of such variants are the complexity and the cost of the PMs, mainly. But the other emphasized advantages make the MG or the multiport machine a desired candidate for electric power generation applications.

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