

The Experience of Designing and Testing a 20 kW Multi Pole Permanent Magnet Generator for Wind Turbines

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1. Introduction

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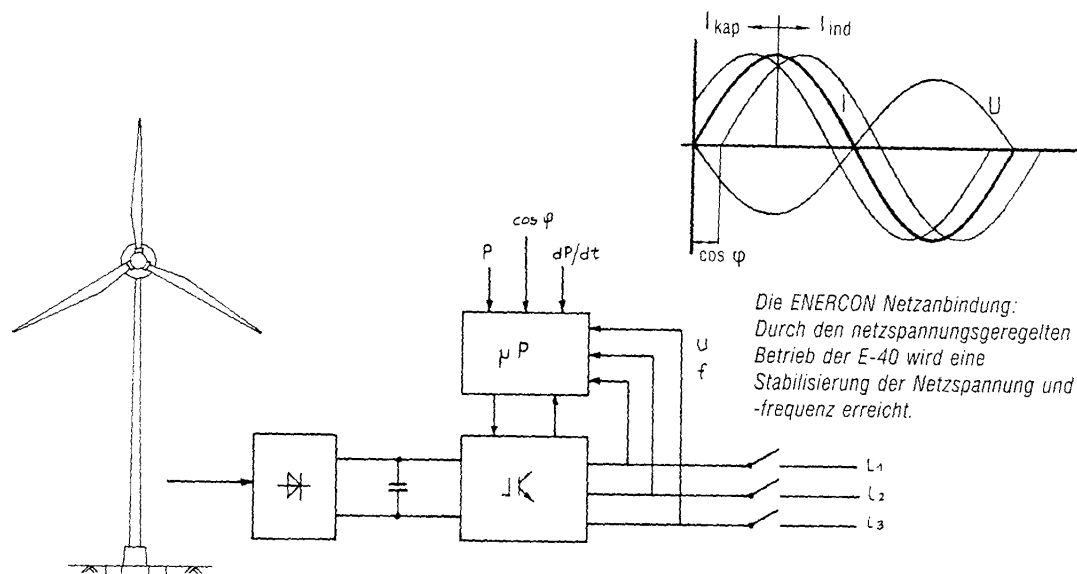


Fig. 1. Electrotechnical concept of Enercon E-40

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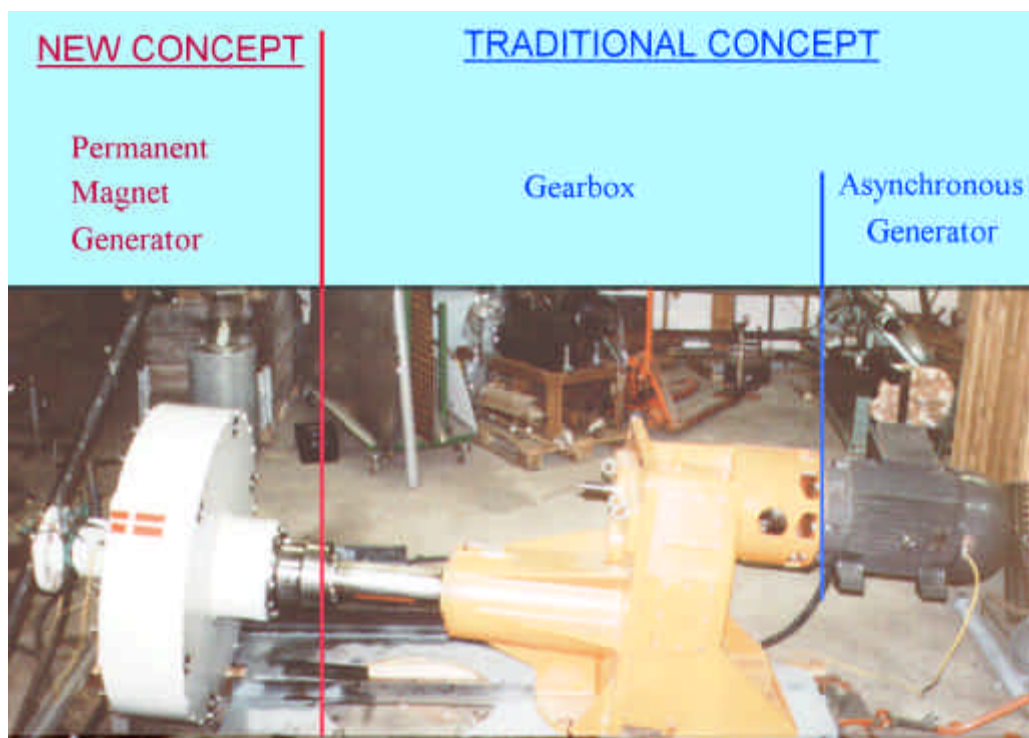


Fig. 2.: Multi pole generator with permanent magnets (PMG)

2. The choice of magnetic circuit materials

2.1 The choice of magnets

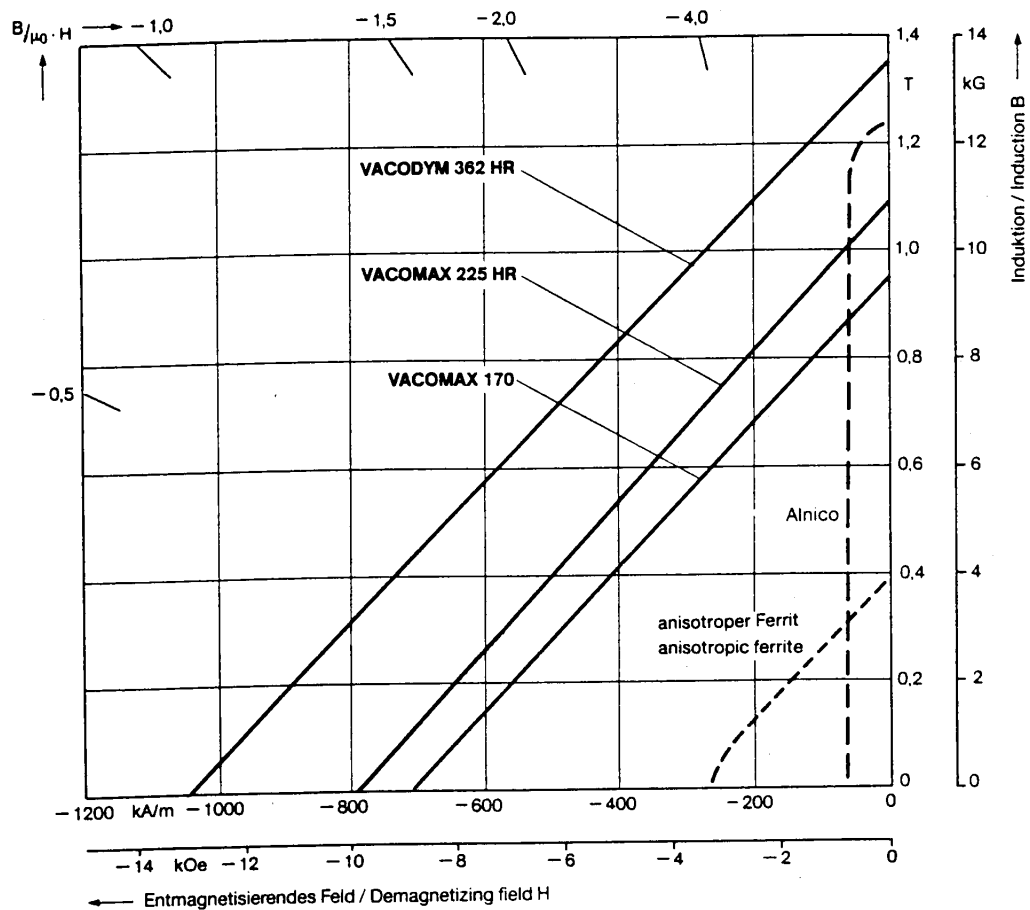


Fig. 3: Characteristics of magnets, provided by VACuumschmelze GmbH.

MAGNET TYPE	PRICE ,DKK/cm ³	RICE, DKK/g
Nd-Fe-B		
SmCo ₅ ; Sm ₂ Co ₁₇		
Ferrites		
AlNiCo		

*) For the last two years the price for rare earth magnets has been going down due to developing of new technologies for their production. According to figures, given by Risø National Laboratory, Denmark [4], the price for Nd-Fe-B in 1995 was around 0,6 DKK/g.

Tab. 1: Specific prices for different types of magnets

MAGNET TYPE	VOLUME, cm ³	PRICE, DKK
Nd-Fe-B		
SmCo ₅ ; Sm ₂ Co ₁₇		
Ferrites		
AlNiCo		

*) The material is chosen for prototype of the PMG -20 kW. The total price for magnetic system has been estimated on the basis of market price for Nd-Fe-B (around 0,6 DKK/g).

Tab. 2: Volumes and prices for different magnets

2.2 The choice of electrical steel

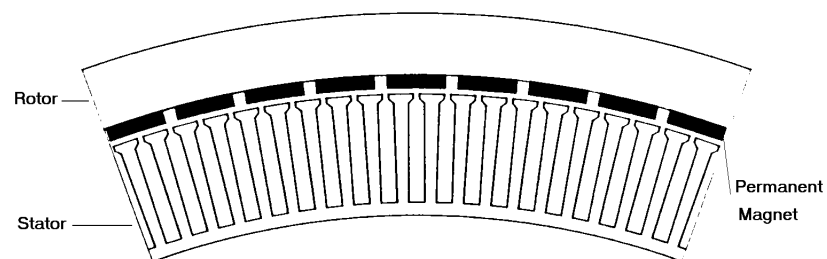


Fig. 4: A proposed design of PMG - 20 kW magnetic circuit

3. Requirements for the winding

3.1 Stator winding

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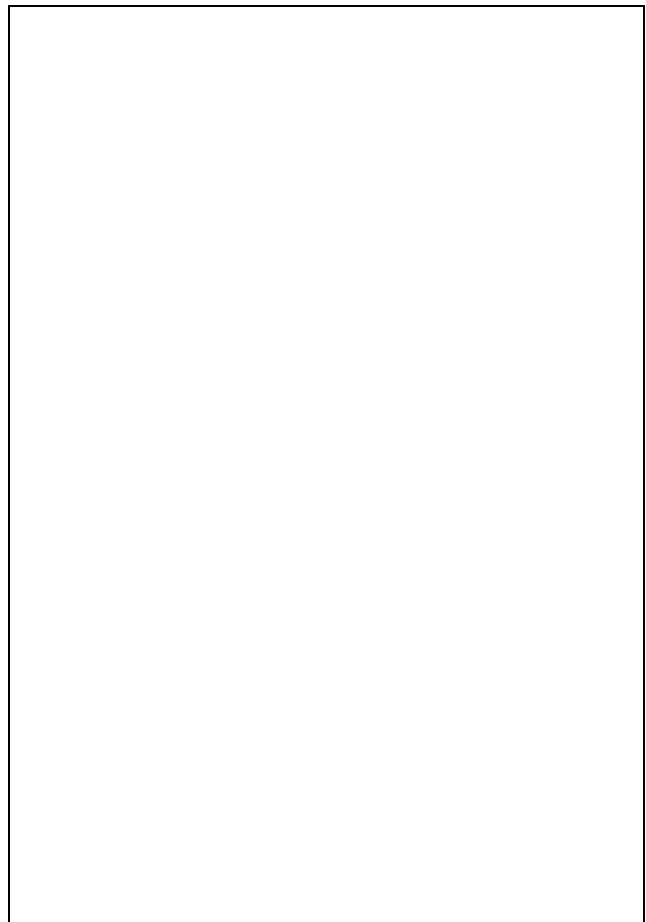
3.2 Damper winding

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4. Test results of PMG - 20 kW

4.1 Open circuit test and voltage diagram

$\Phi\delta$



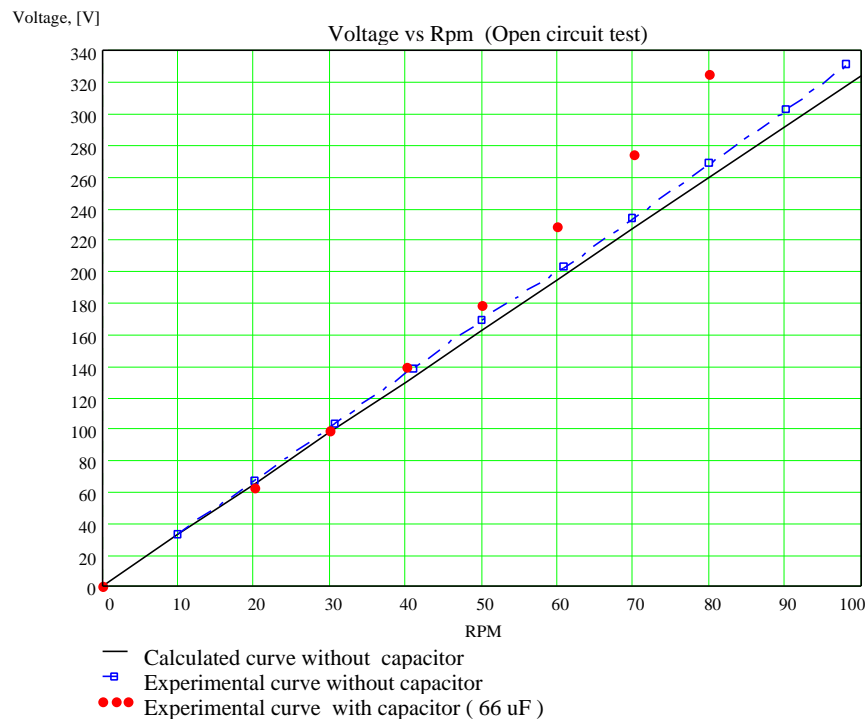
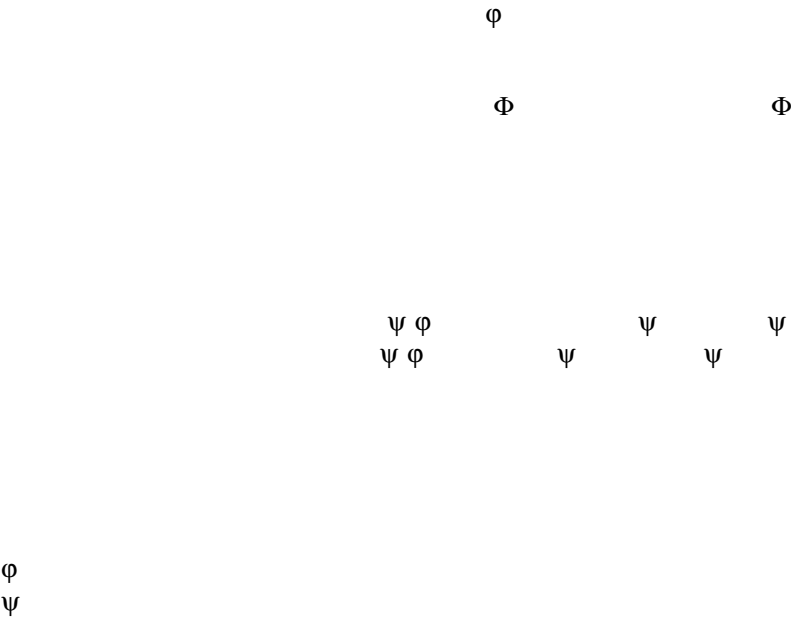


Fig 5. Calculated and experimental curves for open circuit tests

4.2 Output characteristics of the PMG - 20 kW



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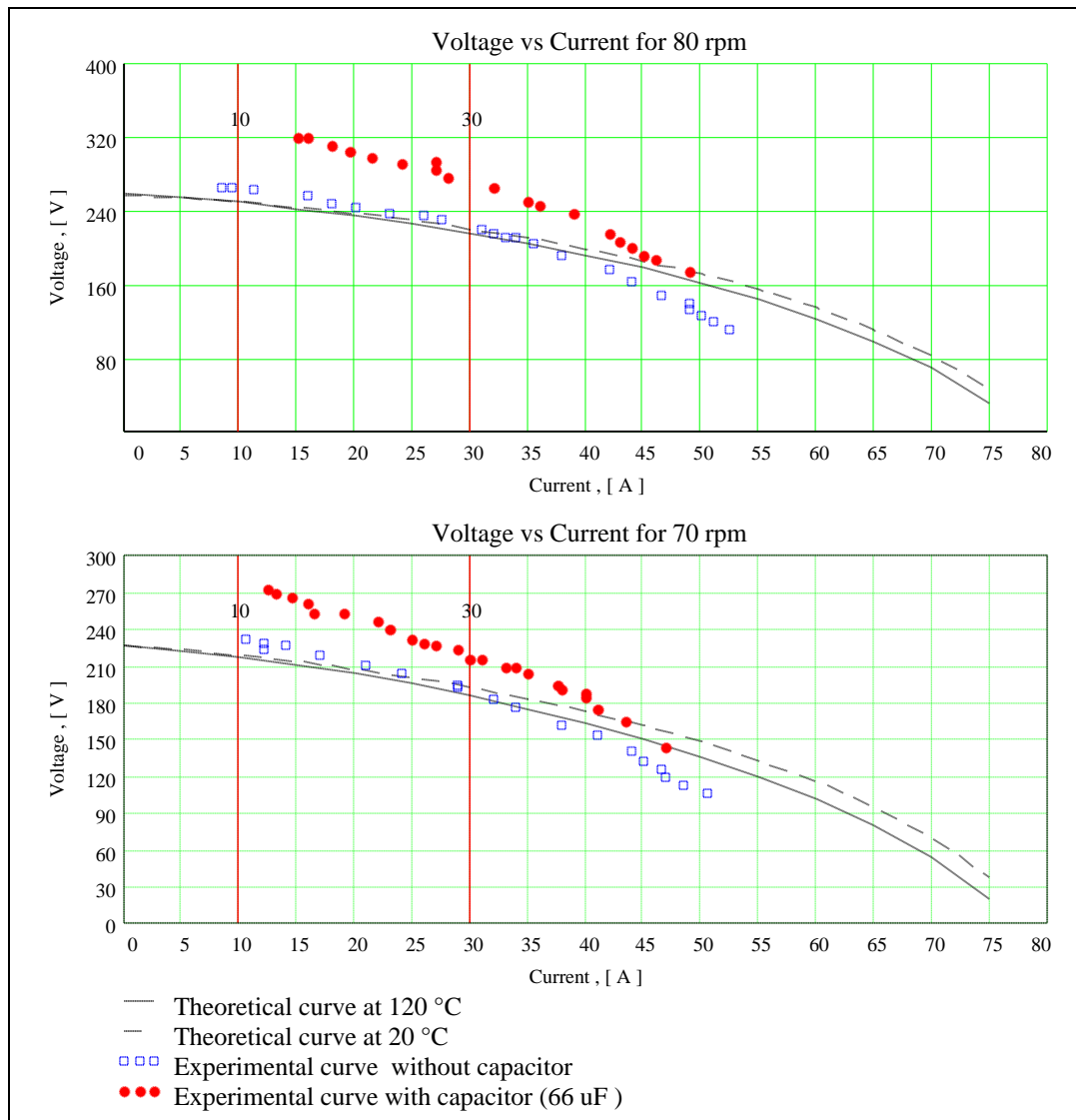
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Power output of the generator [kW]	Parameters of the PMG - 20 kW without voltage stabilisation		Parameters of the PMG - 20 kW with optimal voltage stabilisation	
	current [A]	efficiency [%]	current [A]	efficiency [%]

Tab. 3: Current and efficiency data of PMG - 20 kW with and without voltage stabilisation

Power output of the generator	Efficiency of PMG- 20 kW with voltage stabilisation	Efficiency of traditional 20 kW solution	Relative superiority of the PMG- 20 kW	Weighting

Tab. 4: Comparison of the efficiency of PMG - 20 kW to a traditional 20 kW solution

Fig. 6. Calculated and experimental characteristics of PMG - 20 kW for $\cos j = 1$

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6. References

