Generatoare sincrone cu magneti permanenti pentru microcentrale eoliene de uz rezidential

1.FLUX RADIAL

In [1] este prezentata o solutie constructiva a unei microcentrale eoliene de 2.25 kW conectata la retea. Turbina functioneaza utilizand efectul Venturi(fenomen al dinamicii fluidelor unde particulele gazoase sau lichide se accelereaza ca urmare a restrangerii zonei lor de circulatie) diametrul nedepasind 2 m, iar principalele avantaje sunt date de intensitatea scazuta a zgomotului produs si de volumul mare de aer atras de catre palele turbinei.

Fig.1 Turbina Venturi amplasata pe acoperisul unei case [1]

Microcentrala este echipata cu un generator sincron actionat direct avand flux radial cu magneti permanenti (NdFeB) si rotorul plasat in exterior, o configuratie cu 12 perechi de poli si 72 crestaturi. Acesta dezvolta o puterea maxima de 2.25 kW la 430 rpm, atingand o eficienta de 80%.

Fig.2 (a) Rotorul exterior cu unul din cele doua randuri de magneti lipiti pe jugul rotoric [1]

(b) Infasurarea distribuita inserata in rotor [1]

Tot un generator sincron cu flux radial si magneti permanenti de 3,5 kW este prezentata in [2] pentru o microcentrala conectata la retea cu carateristicile: viteza de pornire 3,5 m/s; viteza nominal 5-10 m/s; viteza de oprire 20 m/s; viteza medie a vantului 5,5 m/s. In tabele de mai jos sunt prezentati parametrii intregului sistem.

Design parameters	Value	Unit
Nominal voltage	250	v
Nominal output power	3500	watt
Number of slots per pole per phase	2	–
Winding current density	4	A/mm^2
Magnet arc angle	150	Electrical degree
Air-gap length	0.5	mm
Slot opening	1	mm

Parameters	value	Unit
Blade diameter	7.2	m
Air-gap diameter	0.208	m
Axial length	0.162	m
Stator outer diameter	0.298	m
Magnet height	3	mm
Conductors per slot	71	–
Inner rotor diameter	0.185	m
Tooth width	5.5	mm

Parameters	Value	Unit
Nominal turbine speed	7. 522	m/s
Number of pole pairs	10	–
Specific electrical loading	50633	kA/m
Stack length to air-gap diameter ratio	0.766	–
Annual output energy	11.433	MWhr
Total system cost	6852	$
Payback period	9.88	yr
Present worth of system	12119	$
Present worth to initial cost ratio	1.93	–
Leakage inductance	11.5	mH
Magnetizing inductance	62.1	mH
Stator winding resistance	4.7	ohm

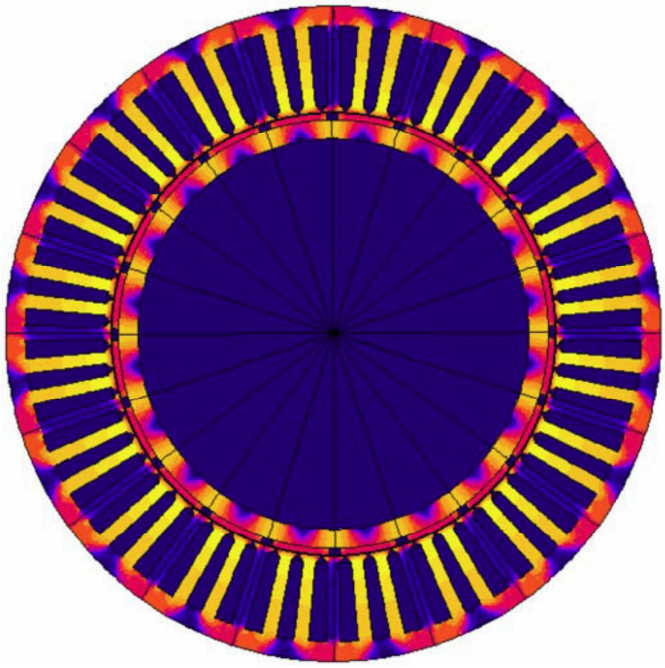

Fig. 3 Configuratia generatorului [2]

O viarianta constructiva de 5 kW a unui generator sincron cu magneti permanenti si flux radial este analizata in [3]. Specificatiile si dimensiunile generatorului sunt prezentate in tabelul urmator:

Rated output power (W)	5000
Rated rotational speed (rpm)	120
Rated output phase voltage (V)	145
Number of poles	32
Number of stator slots	33
Inner stator diameter (mm)	370
Stator winding factor ξ_1	0,954
Air-gap (mm)	1,4
Length of stator core (mm)	120
Magnet radial thickness (mm)	7
Magnet width (mm)	32
The stator winding resistance R (Ω)	0,98
The magnetizing reactance X_m (Ω)	1,05
The leakage reactance X_σ (Ω)	4,7
Permanent magnet NdFeB	N35SH

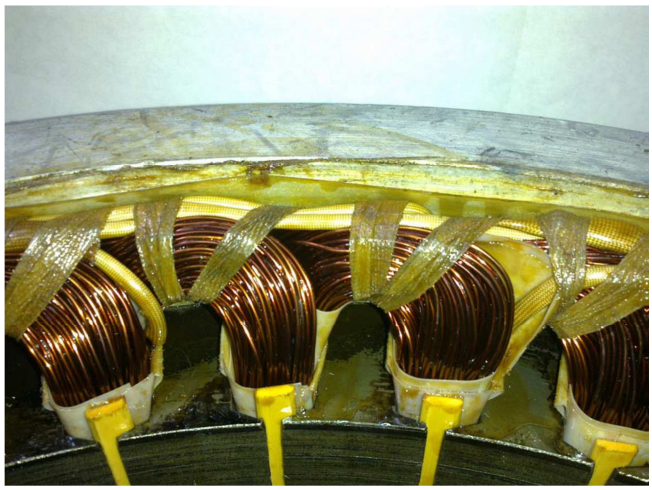

Fig. 4 Infasurarea concentrata a generatorului [3]

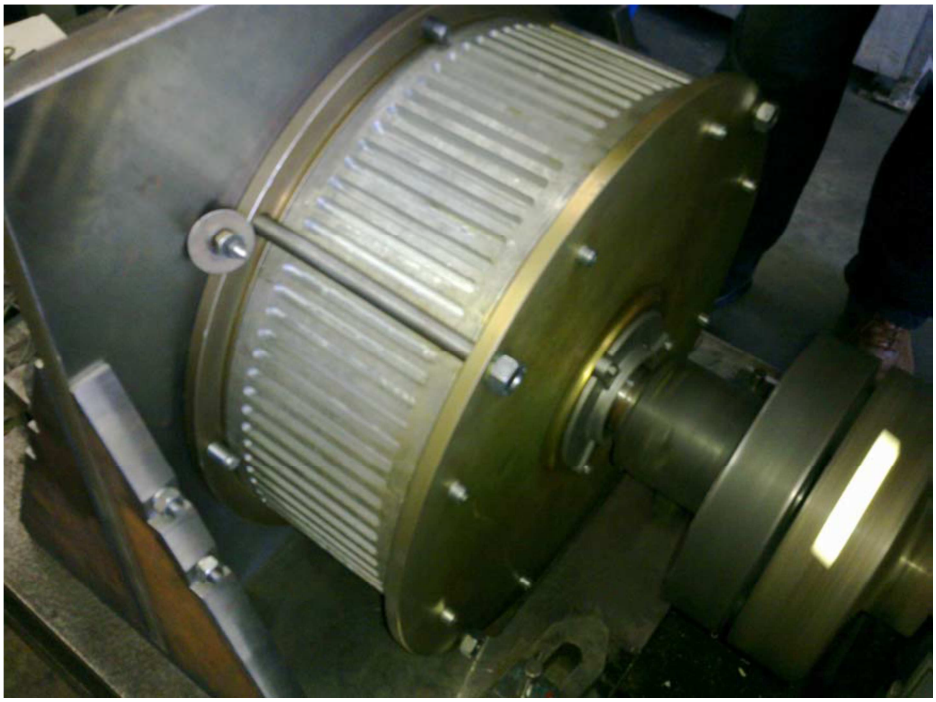

Fig. 5 Fotografie a generatorul de 5 kW [3]

2. FLUX AXIAL

Generatorul sincron cu magneti permanenti si flux axial prezentat in [4] este alcatuit din 2 rotoare exterioare si un stator sandwich intre cele doua rotoare. Infasurarile de forma trapezoidala sunt montate folosind o rasina epoxidica avand ca rezultat eliminarea cuplului parazitar de dantura. Neavand jug stator se elimina o sursa importanta de pierderi, totodata si forta magnetic dintre rotor si stator este scazuta. Magnetii din pamanturi rare (NdFeB) sunt lipiti pe jugul rotoric, pozitionarea lor fiind posibila cu ajutorul unor cadre din aluminiu. Puterea obtinuta la o viteza de 300 rpm a turbinei este de 1kW.

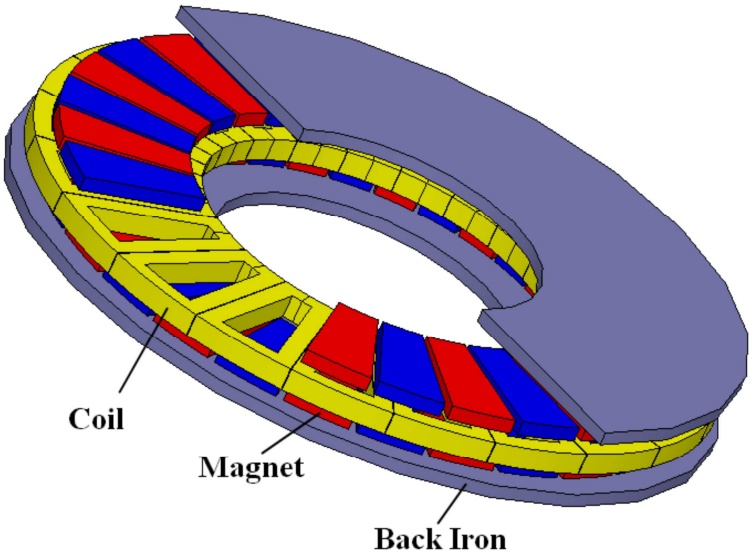

Fig. 6 Structura generatorului sincron cu magneti permanenti si flux axial [4]

MAIN DESIGN PARAMETERS

Parameter	Value	Unit
Stator coil number	21	
Rotor pole number	28	
Pole embrace	0.89	
Magnet outer radius	175	mm
Magnet inner radius	105	mm
Magnet thickness	7.5	mm
Thickness of back iron	6	mm

In [5] este descries un generator sincron cu magneti permanenti si flux axial de 1,6 kW cu infasurare concentrata.

PARAMETERS OF PROTOTYPE GENERATOR

Parameter	Definition	Value
P	Nominal output power at speed 250 rpm	1.6 kW
U_{ph}	Output voltage (RMS) at speed 250 rpm	75 V
h_m	Thickness of PM	5.0 mm
g	Physical length of airgap	1.0 mm
Q	Number of stator slots	12
p	Number of rotor poles	14
D_{out}	Stator outer diameter	258 mm

Fig. 7 (a) Structura generatorului, (b) Generatorul ca parte integranta a turbinei [5]

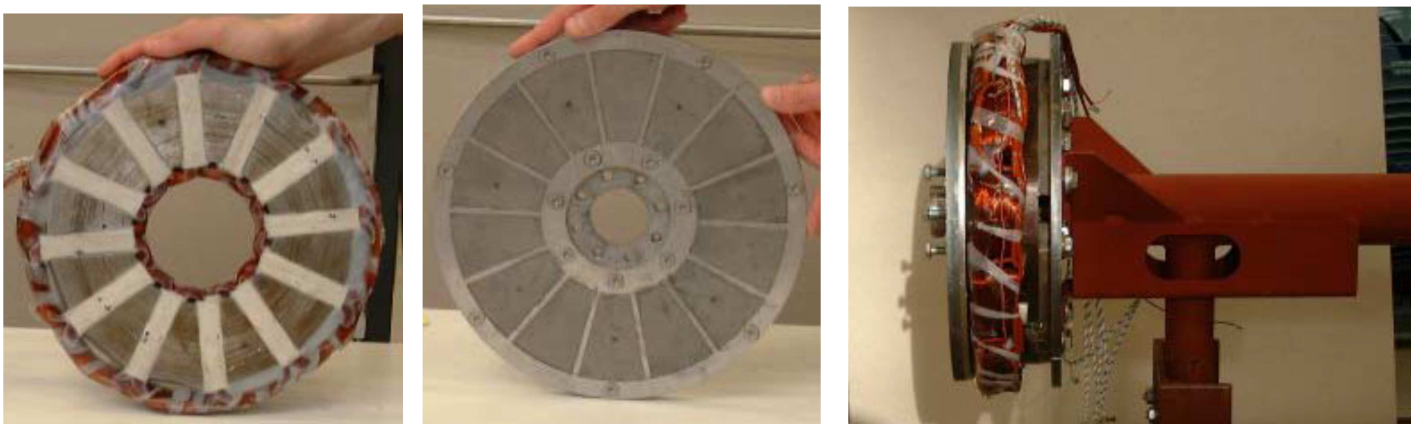

Fig. 8 Statorul si rotorul prototipului

Structura unui generator sincron cu magneti permaneti si flux axial de 5 kW este prezentata in [6]. Valoarea de 5 kW este atinsa la o viteza de 200 rpm. Configuratia generatorului este una de tip sandwich cu un rotor dublu incadrat de 2 statoare.

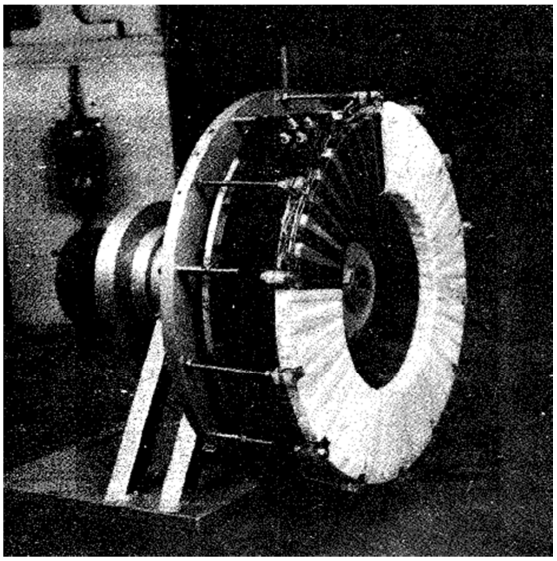

Fig. 9 Constructia generatorului de 5 kW [6]

PRINCIPAL DESIGN DETAILS

Number of poles	28
Number of phases	3
Number of winding layers	4
Outer diameter of stator core	465 mm
Inner diameter of stator core	275 mm
Axial thickness of stator core	20 mm
Magnet material	Sintered Nd-Fe-B, Crumax 3714 B_r: 1.25 T $(BH)_{max}$: 37 MGOe
Magnet thickness	12.7 mm
Magnet mass	15.8 kg
Total machine mass	98.5 kg

EFFICIENCY AND POWER OVER THE SPEED RANGE

Speed, rev/min	200	180	160	140	120	100	80	60
Shaft power, kW	6.41	4.67	3.28	2.20	1.38	0.80	0.41	0.173
Output power, kW	5.08	3.73	2.66	1.81	1.14	0.66	0.33	0.129
Efficiency, %	79.3	79.8	81.1	82.1	82.6	82.3	80.7	74.5

3. Generatoare sincrone cu ferrite

Pentru a obtine rezultate apropiate de cele ale generatoarelor cu magneti permanenti din NdFeB, generatoarele cu ferite trebuie sa functioneze la viteze de rotatie mult mai mari, fapt ce duce la aparitia cutiei de viteze in ansamblul microcentralei eoline.

In [7] este prezentat un generator sincron cu reluctanta variabila, avand infasurare distribuita si o structura cu un numar de 6 poli si 36 crestaturi.

Item	Value (Unit)
Stator outer diameter	145 mm
Rotor outer diameter	92.54 mm
Stack length	30 mm
Air gap length	0.3 mm
PM material	Ferrite (NMF12G)
Coercive force of PM	342 kA/m (20°C)
Turns of armature winding	192 turns/phase
Winding space factor	60 %
Rated current (continuous)	10 A
Maximum current (peak)	20 A
Current density (continuous)	7.5 A/mm^2
Current density (peak)	15 A/mm^2
Base speed	2,400 min^{-1}
Rated power (continuous)	2,500 W (at 2,400 min^{-1})
Maximum power (peak)	5,000 W (at 2,400 min^{-1})
Expected maximum efficiency	94 %

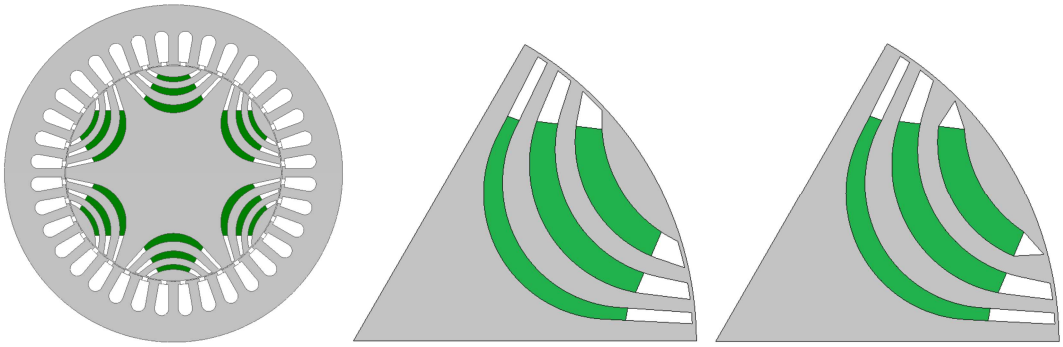

Fig. 10 (a)Configuratia generatorului sincron cu reluctant variabila

(b),(c) configuratii diferite cu bariere de flux [7]

Bibliografie

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