Design of High Speed Permanent Magnet Generator for Solar Co-Generation System Using Motor-CAD

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Certificate of Original Authorship:

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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List of symbols and special characteristics

V_{tip}	Tip speed
ω_m	Rotational speed
R	Radius
N	Speed (RPM)
p	Number of pole pairs
f	Electrical frequency (Hz)
K_{sn}	Skew factor
θ_s	Skew angle, radE
N	Harmonic number
B_g	Air gap flux density
h_m	Magnet height (mm)
g	Air gap (mm)
B_r	Magnet remnant flux density (T)
P	Real power (W)
Q	Reactive power (VAR)
q	Number of phases
V	RMS phase voltage (V)
I	RMS current (A)
m	Fractional number
(_)	pitch of the winding
N_s	Number of slots
p	Pole pairs
q	Number of phases
K_d	Distribution factor
N_{spp}	Number of slots per pole per phase
N_m	Number of magnet poles
N_{ph}	Number of phase
R_{ro}	Rotor outside radius
R_{so}	Stator outside radius
Km	Motor constant
α_{sk}	Skew angle

R_a	Winding resistance
l	Length of conductor
σ	Winding conductivity
A_{ac}	Winding cross-sectional area
A_s	Area of slot
N_c	No of turns per coil
K_{wn}	Winding factor
K_{pn}	Pitch factor
K_{bn}	Breadth or distribution factor
n	Harmonic order
m	Slots per pole per phase
γ	Coil electrical angle
K_{gn}	Magnetic gap factor
R_s	Outer magnetic boundary
R_2	Outer boundary of magnet
R_i	Inner magnetic boundary
R_1	Inner boundary of magnet
K_L	Leakage factor
K_r	Reluctance factor
K_c	Carter's coefficient
W_s	Width of slot
W_t	Width of tooth
g_e	Effective air gap
PC	Permanent coefficient
CΦ	Flux concentration factor (Am/Ag)
μ_{rec}	Recoil permeability
Br	Remnant flux density
θ_m	Magnet physical angel
B_{flux}	Radial flux through coil
L_{ag}	Air gap inductance
$Perm$	Slot permeance
L_{as}	Slot self-inductance

L_{am}	Slot mutual inductance
L_{slot}	Slot leakage inductance
L_e	End turn inductance
L_s	Total inductance
X_s	Total reactance
ω_0	Angular frequency
P_{cu}	Core losses
m_1	Number of phases
I	Armature current
R	DC armature resistance
δ	Skin depth
ω	Angular frequency
P_{stray}	Stray losses
P_h	Hysteresis losses
η	Material constant
P_e	Eddy current losses
t	Thickness of the material
B	Peak flux density
ρ	Resistivity of the material
β	Geometric structure coefficient
P_{iron}	Iron losses
K_h	Coefficients of hysteresis loss
K_e	Coefficient of excess eddy current loss
E	Electric field
J	Eddy currents density
V	Volume of the material
μ	Kinematic viscosity of cooling media (m^2/s)
r	Radius of the rotor (m)
φ	Radial gap between rotor and stator (m)
λ	Length of the rotor (m)
τ	Shear stress (Psi)
K_z	Surface current density
B_g	Air-gap flux density

L_{st}	Stack length
N_c	Turns per coil
N_a	Assumes each coil has two half coils
ω_m	Mechanical frequency (rad/sec)
V_a	Terminal voltage

Abstract:

Permanent-magnet generators may be the most suitable choice for small co-generation systems due to a variety of merits. For instance, permanent-magnet generators are thermally optimised high-power density systems, which reduce the running costs by their performance and reliability. High-speed generators are currently being used in spindle drives, aircraft, power generation and electric vehicles. Distributed power generation has proven to be very effective and costs efficient in rural or remote areas as compared to building big power plants or long-distance transmission lines. The small distributed power co-generation unit using high speed permanent magnet generator is very efficient and cost-effective project. Moreover, high efficiencies i.e. over 90%, light-weight, low operating temperature, high insulation, no brushes/slip rings and almost negligible cogging torque make PMG's ideal for distributed co-generation systems.

In the past few years, most attention has been paid to "high speed brushless permanent magnet generators (HSBPMGs)", for their many advantages i.e. substantial reduction in the size of the machine, higher efficiencies and power densities, etc. However, because of very high rotor speed and higher stator frequency, the design of HSBPMG is quite different from a conventional generator with low speed and low frequency. As speed increases, losses and temperature go up, so careful attention is needed while selecting the design parameters and material for the machine.

This study aimed to use basic design process for high speed brushless permanent magnet generators, keeping the losses minimum by using appropriate material and cooling method. All the design parameters calculated analytically, finite element analysis (FEA) is carried by using Motor-Cad simulation software, results obtained are compared and verified, and a prototype modelling of the machine is presented.