



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

By

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Thesis submitted as a requirement for the degree of Master

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**May 2017**

# 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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# Acknowledgement:

I would first like to thank my thesis supervisors Prof. Dr David Dorrell, A/Prof. Dr Youguang Guo Dr LiLi of the Faculty of Engineering and Information Technology at University of Technology Sydney (UTS). The door to Prof. Dr David Dorrell and A/Prof. Dr Youguang Guo office was always open whenever I ran into a trouble spot or had a question about my research or writing. They consistently allowed this study to be my own work, but steered me in the right direction whenever they thought I needed it.

I would also like to thank the experts who were involved in selecting machine's material for this research project: Special thanks to Mr. Hideki Ichinose from JFE steel corporation Tokyo, Japan. Without their passionate participation and input, the material selection could not have been successfully conducted.

I would also like to acknowledge Mr. Ahmad Salah of the FEIT at UTS as the second reader of this thesis, and I am gratefully indebted to his/her for his/her very valuable comments on this thesis.

Finally, I must express my very profound gratitude to my parents and to my wife for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Author

Khurram Shahzad

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## List of symbols and special characteristics

$V_{tip}$	Tip speed
$\omega_m$	Rotational speed
R	Radius
N	Speed (RPM)
p	Number of pole pairs
f	Electrical frequency (Hz)
$K_{sn}$	Skew factor
$\theta_s$	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
$\alpha_{sk}$	Skew angle



$R_a$	Winding resistance
$l$	Length of conductor
$\sigma$	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
$\gamma$	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
$C\Phi$	Flux concentration factor ( $A_m/A_g$ )
$\mu_{rec}$	Recoil permeability
Br	Remnant flux density
$\theta_m$	Magnet physical angle
$B_{flux}$	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
$\omega_0$	Angular frequency
$P_{cu}$	Core losses
$m_1$	Number of phases
I	Armature current
R	DC armature resistance
$\delta$	Skin depth
$\omega$	Angular frequency
$P_{stray}$	Stray losses
$P_h$	Hysteresis losses
$\eta$	Material constant
$P_e$	Eddy current losses
t	Thickness of the material
B	Peak flux density
$\rho$	Resistivity of the material
$\beta$	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
$\mu$	Kinematic viscosity of cooling media (m <sup>2</sup> /s)
r	Radius of the rotor (m)
$\varphi$	Radial gap between rotor and stator (m)
$\lambda$	Length of the rotor (m)
$\tau$	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
$\omega_m$	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 cost 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.