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***Power Management of Open Winding PM Synchronous Generator for
Unbalanced Voltage Condition***

by

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ABSTRACT

Wind energy is currently the fastest growing electricity source worldwide. Since wind generators have to compete with other energy sources, their cost efficiency is effective. In this thesis, a system utilizing an open-winding Permanent Magnet Synchronous Generator (PMSG) is studied for wind energy generation. The proposed system controls generated power using an auxiliary voltage source inverter. The volt ampere (VA) rating of the auxiliary inverter is only a fraction of the system rated power. An adjusted control system, which consists of two main parts, the first is implemented to control the generator power and the second is control the active and the reactive power injected into the grid. Balanced and unbalanced voltage effects are studied for the wind generation model. Theoretical and experimental results are demonstrated which verify the validity of the proposed system to achieve the power management requirements for balanced and unbalanced voltage condition of the grid. The proposed system is designed and simulated utilizing MATLAB /Simulink software.

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List of Abbreviations

A/D	Analogue to Digital
CVVF	Constant volt variable frequency
D/A	Digital to Analogue
DFIGs	Doubly fed induction generators
DG	Distributed generation
DSP	Digital Signal Processor
GSC	Grid side converter
GB	Gear box
HAWT	Horizontal-Axis Wind Turbines
HCC	Half-controlled-converters
HEVs	Hybrid electric vehicles
HVDC	High voltage direct current
I/O	Input-Output
LVRT	Low voltage right through problem
MERC	Magnetic energy recovery
MPPT	Maximum power point tracking
NPC	Neutral point clamped
NREA	New and Renewable Energy Authority
NRSE	Renewable Sources of Energy
ORB	Optimum relationship-based
PCC	Point of common coupling
PID	Proportional Integral Differential
PLLs	Phase-lock loops
PM	Permanent magnet
PMSG	Permanent Magnet Synchronous Generator
PWM	Pulse Width Modulation
RSC	Rotor-side converter
RES	Renewable energy source
SCIG	Squirrel-cage induction generator

SSSC	Static synchronous series compensator
SHE	Selective Harmonic Elimination
WEC	World Energy Council
WPS	Wind power system
WRIG	Wound rotor induction generators
WRSGs	Wound-rotor synchronous generators
WT	Wind turbine
THD	Total harmonic distortion
TSR	Tip speed ratio
UPQC	Unified power quality conditioner
VA	Volt ampere
VAWT	Vertical-Axis Wind Turbines
VOC	Voltage oriented control
VSC	Voltage source converter
VSI	Voltage source inverter
VSR	Voltage source rectifier

LIST OF NUMENCLEATURE

i_d, i_q	d-and q-axis components of stator currents.
R_a	Generator resistance
J	Rotor and shaft moment of inertia.
L_d, L_q	d-and q-axis inductances.
$\frac{d}{dt}$	Differential operator.
P	Number of pole pairs.
v_d, v_q	d-and q-axis components of stator voltages.
P_{wind}	Wind power
ρ	Wind density
A	Blades swept area
V	Wind speed
C_p	power coefficient
λ	Tip speed ratio
β	pitch blade angle
$[c_1 \dots c_9]$	Characteristic constants for each wind turbine
R	Wind turbine radius
Θ	Angle between phase a-axis and direct axis.
v_{abcg}	Three phase stator voltages
i_{abcg}	Three phase stator currents
Φ_{abc}	Three phase stator flux
R_a	Resistance of the three phase stator winding
Φ_f	The amplitude of the flux linkages established by the permanent magnet
l_{aa}, l_{bb}, l_{cc}	Self-inductances of phase abc
$l_{ab} = l_{ba}$	Mutual inductance between phase a and b
$l_{bc} = l_{cb}$	Mutual inductance between phase b and c
$l_{ac} = l_{ca}$	Mutual inductance between phase a and c
ω_e	Electrical angular frequency
ω_r	Rotor mechanical angular frequency
T_e	Electromechanical torque
T_L	Load torque
ω_s	Supply voltage angular frequency
V_{PH}	RMS value of the phase voltage
f	Supply frequency
V_{LL}	Rms value line-to-line voltage.
m_a	Modulation index
\hat{V}_m	Amplitude of the modulating signals

\widehat{V}_c	Amplitude of the carrier signals
P_{gen}	Generator power
P_{grid}	Active power injected to the grid
φ_{grid}	Grid power factor angle
Q_{grid}	Reactive power injected to the grid
Q_{grid}^*	Reference for the reactive power
v_{di}	Decoupled controller in the d-axes
v_{qi}	Decoupled controller in the q-axes
L_{1k}	Leakage inductance
I_a	Armature current
V_{gen}	Generator output volt
V_{sc}	Compensator voltage
V_{rect}	Rectifier voltage
δ	Power angle
φ_{sc}	Angle defined from the compensator voltage to the rectifier voltage.

ملخص البحث

تعد طاقة الرياح حالياً من مصادر الكهرباء الأسرع نمواً في العالم. حيث أن مولدات الرياح التي تستخدم في طاقة الرياح تتنافس مع غيرها من مصادر الطاقة من حيث الكفاءة و التكلفة الفعلية. تتناول هذه الرسالة دراسة الاستفادة من المولد متزامن مفتوح الملفات ذي مغناطيس دائم (PMSG) الذي يستخدم في طاقة الرياح. وتم التحكم في النظام المقترح باستخدام العاكس المساعد. و يتميز العاكس المساعد بأنه ليس سوى جزء صغير من إجمالي طاقة النظام. نظام التحكم يتكون من جزئين رئيسيين الأول يتحكم في السيطرة على طاقة المولد و الثانى يتحكم في الطاقة المرسله إلى الشبكة. تم دراسة تأثير الجهد المتوازن وغير المتوازن لنظام المقترح. وأظهرت النتائج النظرية والتجريبية من صلاحية النظام المقترح لتحقيق متطلبات إدارة الطاقة لحالة الجهد المتوازن و الغير متوازن من الشبكة. تم تصميم النظام المقترح ومحاكاة باستخدام برنامج MATLAB / SIMULINK. وتحتوي هذه الرسالة علي ستة فصول، تم تناولها على النحو الآتي:

الفصل الأول:

يتناول بعض المفاهيم الأساسية حيث يقدم انواع الطاقة المتجددة و خاصة طاقة الرياح. كما يعرض جميع انواع المولدات التي يتم استخدامها. حيث يعرض ايضا تعريف المشكلة و هي ادارة الطاقة.

الفصل الثانى:

يعرض هذا الباب مسحا علمياً شاملاً للأبحاث و الدراسات التي أجريت و المتعلقة للفكرة التي تم دراستها.

الفصل الثالث:

عمل نموذج لمولد متزامن مفتوح الملفات ذي مغناطيس دائم بواسطة محاكاة برنامج MATLAB / SIMULINK. و يعرض نظرة عامة عن نظام التحويل في طاقة الرياح.

الفصل الرابع:

يقدم شرح لنظام المقترح تعريفه واستخداماته وطريقه اتصاله ومميزاته. و يعرض نتائج البرنامج MATLAB / SIMULINK علي الحالات التي تم دراستها. وأظهرت النتائج النظرية من صحة النظام المقترح لتحقيق متطلبات إدارة الطاقة لحالة الجهد المتوازن و الغير متوازن من الشبكة.

الفصل الخامس:

هذا الفصل يوضح العمل التجريبي (العملي). ففي الجزء الأول، يتم توضيح وتحليل النظام. و تم استخدام DSP لتوليد نبض تعديل العرض (PWM) و تم دراستها والنتائج أظهرت صحة النظام المقترح لتحقيق متطلبات إدارة الطاقة لحالة الجهد المتوازن.

الفصل السادس:

يشمل خلاصة البحث والتوصيات المقترحة والدراسة المستقبلية.