Ain Shams University
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Reactive Power and Voltage Control of Offshore Wind Farm Connected to the Grid

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A Thesis Submitted for the Requirement of Master Degree of Sciences in Electrical Power Engineering

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Cairo 2019

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Statement

This thesis is submitted to Ain Shams University in partial fulfillment of the requirements for the degree of Master of Sciences in Electrical Engineering.

The work included in the thesis was carried out by the author at the department of Electrical Power and Machines, Ain Shams University.
No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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Acknowledgement

First and foremost, all praises and thanks to Allah, the Almighty, for his blessings throughout my research work to complete this thesis successfully.

I would like to express my sincere gratitude to **Prof. Dr. Naggar Hassan Saad** for the continuous support of my master study and research and for his motivation, encouragement and immense knowledge.

Also, I would like to express my deep thanks and great appreciation to **Prof. Dr. Said Fouad Mekhamer** for his continuous support and helpful suggestions.

I am also grateful to **Dr. Mohamed Elshafiy**, department of Electrical Engineering, faculty of engineering, Cairo University, for his encouragement and usual support in my research.

Finally, I would like to express my profound gratitude from my deep heart to my beloved father, mother, wife, brother and all my friends for supporting me over my studies and for their continuous encouragement.

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List of Abbreviations

DFIG	Doubly Fed Induction Generator
FACTS	Flexible AC Transmission System
GA	Genetic Algorithm
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
HVDC-LCC	HVDC-Line Commutated Converter
HVDC-VSC	HVDC-Voltage Source Converter
IGBT	Insulated Gate Bipolar Transistor
MW	Mega Watt
PCC	Point of Common Coupling
PI	Proportional Integral
PLL	Phase Locked Loop
PU	Per Unit
SMES	Superconductive Magnetic Energy Storage
STATCOM	Static Synchronous Compensator
SVC	Static Var Compensator

List of symbols

Symbol	Description
I_c	capacitive current
ω	Angular speed
f	Frequency
C	Capacitive
U	Applied voltage
L_c	Critical length
I	Phase current
P_L	Active power
S_G	Apparent power
Q	Reactive power
X	Equivalent reactance of interconnection
δ	Power angle
α	Firing angle
Ls	Stator reactance
R_s, R_r	Stator and rotor resistance
i_d	Current, direct axis
i_q	Current, quadratic axis
$i_a,\ i_b,\ i_c$	Currents in phase a, b and c, respectively
V_d	Voltage, direct axis
V_q	Voltage, quadratic axis
$V_a, V_b,\ V_c$	Voltage in phase a, b and c, respectively
V_{dc}	DC voltage side
k	Relation between DC voltage and the peak phase-to-neutral voltage
V_m	Measured voltage
θ	Reference angle
V_{ref}	Reference voltage
K_d	Allowable voltage error
C_p	Power coefficient
P_w	Effective wind power
P_m	Output mechanical power

V_w	Wind speed
ρ	Air density
R	Turbine radius blade
λ	Tip speed ratio
β	Pitch angle
T_a	Generator Torque
L_m	Mutual inductance
$\lambda_{ds},\ \lambda_{qs}$	Rotor flux linkages in d-q axis
$\lambda_{dr},\ \lambda_{qr}$	Stator flux linkages in d-q axis
ω_s	Stator rotational speed
ω_r	Rotor rotational speed
p	Number of poles
i_{qref}	Reference reactive current

Abstract

Wind energy is considered to be a leading source of renewable energy resources. The offshore wind parks are rapidly growing in the last few years, due to the decrease of onshore available area and also the great advantages of offshore wind resources, the offshore wind turbine can be design with large Mega Watt in compare with onshore wind turbine, due to the high speed of wind in offshore areas, also the offshore wind turbine are more stable than onshore, and the annual operation of offshore wind turbines are higher than the onshore wind turbines. As the trend of construction offshore wind parks increases, many challenges appeared in transmitting the generated power from offshore to onshore grid. Reactive power and voltage control are considered to be the big challenges when transmitting the produced power to the utility for long distance of high voltage alternating current (HVAC) submarine cables. These problems made the transmission of power are not complying with the grid code requirements. This research work studies these problems and proposes a solution for solving these issues. Static Synchronous Compensator (STATCOM) was implemented to solve these problems.

To investigate the influence of STATCOM on the system, a simulation model was built by using MATLAB Simulink. The results were obtained with and without consideration of STATCOM effect. The simulation results show the critical operation of the system without compensation, the beneficial performance of STATCOM compensation in the system and the optimum operation of STATCOM with conventional tuning of proportional–integral (PI) controller. Also the optimum operation of STATCOM with PI controller using genetic algorithm (GA) for long distance HVAC submarine cables is obtained.

Keywords— Offshore wind parks, reactive power control, voltage control, STATCOM, PI controller