IMPROVING THE CAPABILITY CURVES OF A GRID-CONNECTED WIND FARM: GABEL EL-ZEIT, EGYPT

By

Mohamed Hosny Hassan salamaa

A Thesis Submitted to the
Faculty of Engineeringat Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTERS OF SCIENCE
in
Electrical Power and Machines Engineering

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DIgSILENT PowerFactory, LVRT Capability, Grid-Connected Wind Farms , PQ & QV Capability Curves.

Summary:
Recently, wind power technology is one of the most common renewable energy resources that are being developed in these days. Egypt has started to develop grid code to facilities operation of new wind farms. Egypt is one of the African countries which has a better wind power technology and the government is giving a lot of subsidies to develop this technology.
In this thesis, an analysis of the requirements of Egyptian grid code is made concerning to the reactive power and Low Voltage Ride Through (LVRT) capabilities and how the wind farm fulfills these requirements. The results approved that the wind farm needs to higher reactive power to fulfill grid code requirements. Static Synchronous Compensator (STATCOM) is used to provide these reactive and improve the capabilities of wind farm.

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To my ***Father****, on him God Mercy*

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List of Symbols and Abbreviations

AC	Alternating Current
DC	Direct Current
DFC	Dynamic Power Flow Controller
DFIG	Double Fed Induction Generator
DPL	DIgSILENT Programming Language
DSL	Digsilent Simulation Language
EGC	Egyptian Grid Code
FACTS	Flexible AC Transmission System
FRT	Fault Ride Through
GC	Grid Code
GSC	Grid-Side Converter
GWEC	Global Wind Energy Council
HAWT	Horizontal Axis Wind Turbines
HVRT	High Voltage Ride Through
IG	Induction Generator
IPFC	Interline Power Flow Controller
KE	Kinetic Energy
LF	Load Flow
LV	Low Voltage
LVRT	Low Voltage Ride Through
MV	Medium Voltage
NREA	New and Renewable Energy Authority
PCC	Point of Common Coupling
PF	Power Factor
PI	Proportional-Integral
PV	Solar Photovoltaic

RE	Renewable Energy
RSC	Rotor-Side Converter
SC	Short Circuit
SCIG	Squirrel Cage Induction Generator
SG	Synchronous Generator
STATCOM	Static Synchronous Compensator
SSSC	Static Synchronous Series Compensator
SVC	Static VAR Compensator
TCO2	Total Carbon Dioxide
TCSC	Thyristor Controlled Series Compensator
T.O.E	Tonne of Oil Equivalent
U	Voltage during fault
UPFC	Unified Power Flow Controller
VAWT	Vertical Axis Wind Turbines
VI	Virtual Instrument
VSC	Voltage Source Converter
WECS	Wind Energy Conversion Systems
WEGS	Wind Energy Generation System
WF	Wind Farm
WPP	Wind Power Plant
WRIG	Wound Rotor Induction Generator
WT	Wind Turbine
WTG	Wind Turbine Generator
β	the blade pitch angle
λ	the tip speed ratio
ρ	air density
v	Wind Speed
A	Area of the wind turbine rotor

c_p	power coefficient
U_n	Rated Voltage
I_n	Rated Current
ΔU	Relevant Voltage change during fault
U_o	Pre-fault Voltage
IB_o	Reactive Current before the fault
IB	Reactive Current
ΔIB	Required Reactive Current change during fault
i_{rd}	d-axis component of the current
i_{rq}	q-axis component of the current
K_d	proportional gain of d-axis component
K_q	proportional gain of q-axis component
T_d	integration time of d-axis component
T_q	integration time of q-axis component
c	Voltage factor
X_m	Magnetizing Reactance
T_p	Time constant of the active power control
K_p	Active power control gain
K_v	Voltage control gain
T_v	Time constant of the voltage control

Abstract

The use of wind energy is rapidly expanded due to technological developments and increased global energy demands. Therefore, large-scale wind farms (WFs) are being connected directly to power grids. However, the integration of wind farms into power systems presents various challenges. One of these challenges is the PQ-capability, which has a particular influence on WF operations. Another challenge is the Low-Voltage Ride Through (LVRT) capability, which is one of the most serious challenges in designing wind turbines (WTs) and their manufacturing technology. One such requirement is that the installed turbine should provide voltage regulation through injection of reactive current.

Egypt has started to develop grid code to facilities operation of new wind farms. It is one of the African countries which has a better wind power technology and the government is giving a lot of subsidies to develop this technology. This Thesis explains the modern wind power systems and discusses the requirements of connecting WFs to power grids.Also, the control systems of Double Fed Induction Generator (DFIG) are presented. In addition, the various operation and control methods needed for WTs to meet these requirements are investigated.

To analyse the impacts of wind energy integration on the Egyptian power grid, we utilize DIgSILENT PowerFactory programming to illustrate the present scenario and the challenges of the reactive power and LVRT capabilities of the Gabel El-Zeit wind farm according to the requirements of Egyptian grid code and how the wind farm fulfills these requirements. The simulation results show that adding a Static Synchronous Compensator (STATCOM) to the system allows the higher reactive power injection needed to support the system performance during the steady state operation and support the voltage during LVRT situations.