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Integrating A Battery Energy Storage System On Micro Grids For Power Quality Improvement

Master of Science Thesis
By

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. **Abstract**

As renewable resources become more commonly connected to assist the generation of electricity, energy storing systems increasingly come to life. The need for energy storing systems became very crucial with the integration of renewable resources for power quality improvement, back up generation and economics. Due to the huge integration of renewable resources, the necessity of using the power electronics in transmission and generation systems became progressively important.

The Battery Energy Storage Systems (BESS) is one of the devices that have enjoyed much interest lately. It poses great challenges to whom would design and implement the following generation of smart grids to help integrating both solar power and wind power. To make these resources more economical and efficient, the location and the rating of the batteries is very crucial with respect to the performance.

This study introduces an investigation on a micro grid before and after integrating a BESS on a network with photovoltaic (PV) cells and a network with a wind farm (WF), illustrating the effect on power quality on both frequency and voltage wave forms. Also, the study will examine the BESS effect on a hybrid system connection during the normal operation and after insertion of a sudden three phase to ground fault on the transmission lines. The investigation will be divided into five sections; section (A) will represent the integration of renewable resources (PV and WF) on the micro grid. Section (B) will represent the PV case before and after the insertion of the BESS at the source side and

at the load side. Section (C) will represent the WF case before and after the insertion of the BESS at the source side and at the load side. Section (D) will represent the hybrid system connection after integrating the BESS at the source side and at the load side. Section (E) will represent the hybrid system connection with integrated BESS at the load side and after the insertion of a sudden three phase to ground fault on the transmission lines. Also, an overview on the results showing the effect on the voltage and frequency waveforms before and after the integration of each case will be presented.

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List of Symbols

°C	Degree Celsius
%	Percent
$\boldsymbol{\alpha}$	Temperature coefficient
$\boldsymbol{\rho}$	Air density
q	Electron charge
k	Boltzmann's constant
T	Temperature
n	Ideality Factor
J	Joule

List of Abbreviations

V	Voltage
I	Current
A	Ampere
W	Watt
KW	Kilo Watt
MW	Mega Watt
KV	Kilo Volt
KVA	Kilo Volt Ampere
KVAR	Kilo Volt Ampere Reactive
Wh	Watt hour
KWh	Kilo Watt hour
MWh	Mega Watt hour
PV	Photovoltaic
WF	Wind Farm
BESS	Battery Energy Storage System
Km	Kilo Meter
MPPT	Maximum Power Point Tracking
FESS	Fly Wheel Energy Storage Systems
SMES	Super Conducting Magnetic Energy Storage System
ECS	Energy Capacitor System
Li-Ion	Lithium Ion
Ni-Cd	Nickle Cadmium

Na-S	Sodium Sulphur
DSTATCOM	Distribution Static Synchronous Compensator
PMSG	Permanent Magnet Synchronous Generator
WECS	Wind Energy Conversion System
GTD	Generation, Transmission And Distribution
CAES	Compressed Air Energy Storage
EDLC	Electric Double-Layer Capacitors
SRAM	Static Random-Access Memory
Ni-MH	Nickel-Metal Hydride
H2SO4	Sulphuric Acid
Ah	Ampere hour
mAh	Milli Ampere hour
Pb-acid	Advanced Lead-Acid
AGC	Automatic Generation Control
PSOC	Partial State Of Charge Duty
SOC	State Of Charge
PCC	Point Of Common Coupling
OSC	Optimal Control Of Residential Storage
LS-FESS	Low Speed Flywheel Energy Storage System
HS-FESS	High Speed Flywheel Energy Storage System
SiCOM	Site Condition Manager
EHV	Extra High Voltage

UPS	Uninterrupted Power Supply
KE	Kinetic Energy
SEPIC	Single Ended Primary Inductance Converter
PHEV	Plug In Hybrid Electric Vehicles
PHS	Pumped Hydroelectric Storage Systems
ISDM	Ideal Single Diode Model
SDM	Single Diode Model
SSDM	Simplified Single Diode Model
PVSC	Photovoltaic Solar Cells
TBESS	Transportable Battery Energy Storage System
STATCOM	Static Synchronous Compensator
BMS	Battery Management System
SCR	Silicon Controlled Rectifier
ESD	Electro-Static Discharge
PEMFC	Polymer Electrolyte Membrane Fuel Cell
GSM	Global System For Mobile Communications
SMS	Short Message Service
VSFP	Variable Speed Fixed Pitch
SCADA	System Control And Data Acquisition
DG	Distributed Generator

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CHAPTER ONE

INTRODUCTION

1.1. General

The importance of the energy generation from the renewable energy sources existed over a wide range of areas, compared to other energy sources. The increasingly deployment of renewable energy and energy efficiency with the diversification of energy resources, definitely benefited the energy security and economics. Also, it reduced the environmental pollution such as air pollution which is caused by the fossil fuels burning, and consequently improved the public health.

The importance of reliable power systems may include but not limited to the global warming, protection of environment and nurture the economy of the nation. The need for a reliable renewable power system emerged due to the increase in carbon emission pricing and the new regulatory requirements on renewable energy targets.

Renewable energy sources that derive their energy from the sun or wind are expected to supply humanity with energy for almost another million years. Climate changes and global warming concerns, engaged with the oil prices increase and government support, increased the legislation, incentives and marketing of renewable energy. Generating electricity from renewable resources became a trend in smart grids, delivered new chances for employment of renewable energy resources. Advancements of PV and wind power technologies have improved their usage with hybrid arrangements. The integration of renewable resources power generation to smart grids, posed unique challenges to system operators and utilities. The power generated from the grid-connected solar PV units or wind turbines, may vary starting from limited kilowatts to megawatts, and afterwards distributed along the network, from the substation to the customer. In climates with plenty of sunshine or wind during the day, it reflects a wide spread of power generated from the solar PV and wind turbines along the grid. The inherent intermittency of renewable resources output power varies with regard to power quality and reliability. In a bad weather occasion such as a thunder storm possibly will affect, in a small period, solar and wind generation from high up to negligible levels.

The resultant output posed obstacle for utilities and manufacturers affecting several smart grid constraints. The On-grid solar power systems generation extremely varies the load profile of the electric utility customers on the distribution system line, due to the sudden weather changes in generation, and poses obstacles to system operators. In steady state and transient modes, with problems comprising voltage swings, voltage sags, frequency variations and output power fluctuations, this might lead to instability. The resulting ramping from the power output due to clouds increases the need for highly dispatch-able and fast responding generation.