



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electrical Power & Machines Department

**GENERATION EXPANSION PLANNING OF THE
EGYPTIAN POWER SYSTEM CONSIDERING THE
HIGH PENETRATION OF RENEWABLE ENERGY
RESOURCES**

A Thesis

Submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

In Electrical Engineering

Submitted By

Mohammed Moustafa Abd-Elzaher

M.Sc. of Electrical Engineering
Ain Shams University, 2012

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Egyptian Electricity Holding Company

Cairo – 2019



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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Doctor of Philosophy in Electrical Engineering (Electrical Power & Machines Department).

The work included in this thesis was carried out by the author at the Electrical Power & Machines Department, Faculty of Engineering, Ain Shams University in collaboration with the Egyptian Electricity Holding Company.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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Contents

Title	Page
Contents	I
List of Figures	IV
List of Tables	VI
List of Abbreviations	VII
Abstract	X
Chapter 1 Introduction & Literature Review	
1-1- General	1
1-2- Thesis Background	1
1-3- Thesis Objective	2
1-4- Thesis Structure	3
1-5- Literature Review	5
1.5.1 Intermittency of RES	5
1.5.2 Capacity Credit of RES	9
1.5.3 Role of Power System Flexibility and Operating Reserves	14
1.5.4 GEP with High Share of RES	20
1-6- General Comments about the Previous Work	25
Chapter 2 Challenges of Integrating RES into the Egyptian Power System	
2-1- Introduction	27
2-2- Power Generation Technologies	27
2-3- Basic power system operation	28
2-4- Intermittency of VRES	30
2-5- Operational Challenges of VRES	31
2.5.1 Technical Challenges	31
2.5.2 Economic Challenges	34
2.5.3 Other Challenges	35
2-6- Quantifying Variability of VRES	35
2-7- RES in Egypt	36
2.7.1 Wind Energy	37
2.7.2 Solar Energy	37
2.7.3 Hydro Energy	38
2-8- RES Penetration	38
2-9- Seasonal patterns	39
2-10- Capacity Factor	42
2-11- Egypt Long Term RES Strategy	42
2-12- Case Study: RES Expansion in the Egyptian Grid	43
2-13- Conclusion	51

Chapter 3 Capacity Credit Evaluation of RES

3-1- Introduction	52
3-2- What is Capacity Credit	52
3-3- Methods to Calculate Capacity Credit	54
3-4- Approximate Methods	54
3.4.1. Load Factor-Based Approaches	55
3.4.2. The Garver Approximation Method	55
3.4.3. Z-Statistic Method	56
3-5- Reliability Based Method	57
3.5.1. Capacity Outage Probability Table (COPT)	59
3.5.2. Calculating LOLP and ELCC	62
3-6-Factors Affecting the ELCC Calculations	63
3-7-Case Study: Capacity Credit Evaluation of Zafarana Wind Farm	64
3.7.1 The Approximation Methods	65
3.7.2 Reliability Based method	67
3.7.3 Sensitivity Analysis	70
3-8-Case Study: Capacity Credit Evaluation of Solar Photovoltaic in Upper Egypt	71
3-9-Comments on the Results and Conclusion	72

Chapter 4 Role of Operating Reserves in Integrating RES

4-1- Introduction	73
4-2-Operating Reserves	73
4-3-Impact of RES on Reserve Requirements	77
4-4-Value of Operating Reserve in Integrating RES	78
4-5-Operating Reserve Assessment Methods	81
4.5.1 Analytical Method	82
4.5.2 Probabilistic Method	83
4-6- Case Study: Reserve Requirements for Integrating VRES in the Egyptian Grid	85
4.6.1 Analytical Methods	86
4.6.2 Probabilistic Method	89
4.6.3 Value of VRES Forecast Accuracy	94
4-7- Conclusion	95

Chapter 5 Role of Generation Mix Flexibility in Integrating RES

5-1- Introduction	96
5-2- Basic Concept of Power System Flexibility	96
5-3- The Need for Flexibility	97
5-4- Sources of Flexibility	98
5-5- Power Plant Flexibility	100
5.5.1 Conventional Power Plants Dynamic Limits	100
5.5.2 Cycling of Thermal Power Plants	103
5-6- Generation Mix Flexibility	106
5.6.1 Minimum Load Level	107
5.6.2 Sufficient Ramping Capability	107
5.6.3 Operating Reserves	107
5-7- Unit Commitment Problem	108

5.7.1 Basic Methodology	109
5.7.2 Problem Constraints	115
5-8- Modeling Energy Storage Technologies	117
5-9- Case study: Impact of Generation Mix Flexibility on Integrating VRES	119
5.9.1 Results	123
5.9.2 Sensitivity Analysis	128
5-10- Conclusion	130
Chapter 6 Generation Expansion Planning with High Shares of RES	
6-1- Introduction	131
6-2- Basic Definition of GEP Problem	131
6.2.1 Capital Investment Cost	132
6.2.2 Fuel Cost	133
6.2.3 Operation and Maintenance Cost	133
6.2.4 Cost of Expected Unserved Energy	134
6.2.5. Representation of Demand Pattern	134
6.2.6. Modeling RES Generation	136
6.2.7. Generation System Reliability	137
6-3- GEP Problem Considering RES	137
6.3.1 Objective Function	139
6.3.2 Problem Constraints	141
6.3.3 Representing Load and RES Patterns	142
6-4- Solution Technique	142
6-5- Case Study: Expanding VRES in Egypt Energy Mix up to Year 2037	144
6.5.1 Load and Energy Forecast	144
6.5.2 Existing and Committed Generation Capacities	145
6.5.3 Representation of Actual Renewable and Demand Patterns	145
6.5.4 Generation System Reliability	147
6.5.5 Power Generation Candidates	148
6.5.6 Fuel Price Projections	149
6.5.7 Other Constraints and Assumptions	150
6.5.8 Study Scenarios	150
6.5.9 Results	151
6.5.10 Role of Energy Storage	157
6.5.11 Analysis of the Results	163
6-6- Conclusion	166
Chapter 7 Conclusions and Recommendations	
7-1- Conclusion	167
7-2- Recommendations for the Future Work	169
References	170

List of Figures

Figure	Page
Chapter 2	
Fig (2.1) Power system operation time-frames	28
Fig (2.2) Load and net load patterns for Minnesota power system under the 25% wind penetration scenario	33
Fig (2.3) Impacts of VRES on the different time and area scales of power systems	33
Fig (2.4) Wind atlas for Egypt	37
Fig (2.5) Monthly normalized average wind output power in year 2015/2016	39
Fig (2.6) Monthly normalized average solar PV output power in year 2015/2016	40
Fig (2.7) Seasonal histograms for the normalized wind output power in year 2015/2016	40
Fig (2.8) Seasonal histograms for the normalized solar PV output power in year 2015/2016	41
Fig (2.9) Egyptian strategy for RES up to year 2022	42
Fig (2.10) Electricity generated by type under reference scenario in year 2035	43
Fig (2.11) Duration curve of normalized wind output power variations for the Zafarana wind site in year 2015/2016	45
Fig (2.12) Duration curve of normalized solar PV output power variations in sunny hours of year 2015/2016	45
Fig (2.13) Cumulative distribution functions of (a) wind and (b) solar power variations	46
Fig (2.14) Duration curves of absolute (a) wind and (b) solar variations (In GW) for different installed capacities	47
Fig (2.15) Variation of maximum net load positive and negative ramps with increasing wind penetration level presented as 0.1 % and 1 % percentiles	48
Fig (2.16) Net LDCs curves for the different wind power penetration scenarios	49
Fig (2.17) Variation of maximum net load positive and negative ramps with increasing solar PV penetration level presented as 0.1 % and 1 % percentiles	49
Fig (2.18) Net LDCs curves for the different solar power penetration scenarios	50
Chapter 3	
Fig (3.1) Effect of generator addition on reliability curve	63
Fig (3.2) Development of the wind generation and load factor for the period (2011/2012 – 2015/2016)	65
Fig (3.3) Wind generation probability distribution 2011/2012	66
Fig (3.4) Wind generation probability distribution 2012/2013	66
Fig (3.5) Effect of wind power addition on LOLE curve of the Egyptian power system 2011/2012	68
Fig (3.6) Effect of wind power addition on LOLE curve of the Egyptian power system 2012/2013	68
Fig (3.7) Result comparison of the capacity credit methods for Zafarana wind farm for the study period (2011/2012 – 2015/2016)	69
Fig (3.8) Sensitivity of the capacity credit to the share of wind penetration	70
Fig (3.9) Sensitivity of the capacity credit to the system reliability target	71
Fig (3.10) Effect of solar power addition on LOLE curve of the Egyptian power system 2015/2016	71
Chapter 4	
Fig (4.1) Example of operating reserve classification	74
Fig (4.2) Typical power system response to the loss of large generation unit	76
Fig (4.3) Actual vs. 4-hour persistence forecast for typical daily wind generation profile	80
Fig (4.4) Three-sigma approximation of normal distribution	81

Fig (4.5) Typical daily load curve for the Egyptian grid in year 2015/2016	86
Fig (4.6) One-hour forecast vs. actual wind generation for a typical day in year 2015/2016	87
Fig (4.7) Required hourly operating reserve for integrating 1000 MW wind power as calculated by the analytical method	88
Fig (4.8) Required hourly operating reserve for integrating 1000 MW solar power as calculated by the analytical method	88
Fig (4.9) Required hourly operating reserve for integrating 1000 MW wind power as calculated by the probabilistic method	91
Fig (4.10) Reserve requirements for integrating 1000 MW wind power calculated by the analytical and probabilistic methods	91
Fig (4.11) Required hourly operating reserve for integrating 1000 MW solar power as calculated by the probabilistic method	92
Fig (4.12) Reserve requirements for integrating 1000 MW solar power as calculated by analytical and probabilistic methods	92
Fig (4.13) Reserve requirements for integrating 1000 MW wind power as calculated by the analytical and probabilistic methods with non-parametric representation	93
Fig (4.14) Reserve requirements for integrating 1000 MW solar power as calculated by the analytical and probabilistic methods with non-parametric representation	93
Fig (4.15) Sensitivity of the required operating reserve levels to wind forecast accuracy	94
Chapter 5	
Fig (5.1) Flexibility needs, sources and enablers	98
Fig (5.2) Classification of energy storage technologies	99
Fig (5.3) Power plant efficiency for different output levels	104
Fig (5.4) Thermal power plant typical input output curve	105
Fig (5.5) Thermal power plant typical incremental cost curve	106
Fig (5.6) Typical thermal generation unit quadratic cost function approximated by piecewise linear functions	114
Fig (5.7) Schematic diagram of typical pump storage power plant	117
Fig (5.8) IEEE_RTS system schematic diagram	119
Fig (5.9) IEEE26 system load and net load for the different renewable expansion scenarios	122
Fig (5.10) Number of starts per type of generation - group (A)	124
Fig (5.11) Hourly thermal generation output per type (group (A) -HF mix)	124
Fig (5.12) Number of starts per type of generation - group (B)	126
Fig (5.13) Hourly thermal generation output per type (group (B) -HF mix)	126
Fig (5.14) Number of starts per type of generation -group (C)	127
Fig (5.15) Hourly thermal generation output per type - (group (C) -HF mix)	128
Chapter 6	
Fig (6.1) Load duration curve	135
Fig (6.2) Load regions representation	136
Fig (6.3) Flow chart for the model solution algorithm	143
Fig (6.4) Evolution of system peak load and electricity generation over the period (2015/2016 -3034/2035)	144
Fig (6.5) Installed capacity and energy generated by type in year 2015/2016	145
Fig (6.6) Applied load region representation normalized to the system peak load	146
Fig (6.7) Applied representation of RES generation patterns normalized to its installed capacity	147
Fig (6.8) LCOE for each power generation candidate (\$/MWh)	149
Fig (6.9) Added non-hydro VRES capacities for each of the study scenarios	151
Fig (6.10) Added dispatchable generation capacities for the study scenarios	152

Fig (6.11) Total installed capacities by type for the study scenarios in year 2037	153
Fig (6.12) Total generated energy by type for the study scenarios in year 2037	154
Fig (6.13) Hourly unit commitment in year 2037 for each of the study scenarios	155
Fig (6.14) Total CO ₂ emissions for each of the study scenarios	156
Fig (6.15) Total plan cost for the study scenarios	156
Fig (6.16) Added dispatchable generation capacities for the study scenarios with PHES	158
Fig (6.17) Total installed capacities by type for the study scenarios in year 2037 with PHES	159
Fig (6.18) Total generated energy by type for the study scenarios in year 2037 with PHES	160
Fig (6.19) Total CO ₂ emissions for each of the study scenarios with PHES	161
Fig (6.20) Hourly unit commitment in year 2037 for each of the study scenarios with PHES	162
Fig (6.21) Total plan cost for the study scenarios with PHES	162

List of Tables

Table	Page
Chapter 3	
Table (3.1) Capacity table for a single generation unit	61
Table (3.2) Results of the Z-method for the study period (2011/2012 – 2015/2016)	67
Table (3.3) ELCC values and capacity credit estimated using the reliability method for the study period (2011/2012 – 2015/2016)	69
Chapter 5	
Table (5.1) Flexibility characteristics of thermal generation units	102
Table (5.2) Typical dynamic limits for different power plant types	103
Table (5.3) Proposed generator states for classical P.L method	110
Table (5.4) FEPL generator states for 10 units' system	111
Table (5.5) IEEE_RTS bus locations for generation units	120
Table (5.6) Classification of IEEE-26 system thermal units by flexibility	120
Table (5.7) Data for case studies	120
Table (5.8) Technical and economic indicators for group (A) cases	123
Table (5.9) Technical and economic indicators for group (B) cases	125
Table (5.10) Technical and economic indicators for group (C) cases	126
Table (5.11) Sensitivity analysis of the results to generators' MSG level	128
Table (5.12) Sensitivity analysis of the results to generators' ramp rate	129
Chapter 6	
Table (6.1) The load regions definition for base year 2015/2016	146
Table (6.2) Technical and economic data for candidate generation units	148
Table (6.3) Projected fossil fuel prices up to year 2037 (\$/MBTU)	149
Table (6.4) Emission factors per type of fossil fuel	150
Table (6.5) Main assumptions of the case study scenarios	151
Table (6.6) Techno-economic data for PHES generation unit	157
Table (6.7) Results of the study scenarios with/without PHES	165

List of Abbreviations

AGC: Automatic Generation Control
A.G.R: Average Growth Rate
AHN: Augmented Hopfield Network
AI: Artificial Intelligence
CCS: Carbon Capture and Storage
CCGT: Combined Cycle Gas Turbine
COPT: Capacity Outage Probability Table
CSP: Concentrated Solar Power
DNI: Direct Normal Irradiance
DP: Dynamic Programming
DSM: Demand Side Management
ED: Economic Dispatch
ELCC: Effective Load Carrying Capability
EMA: Egyptian Meteorological Authority
EFOR: Equivalent Forced Outage Rates
EFP: Equivalent Firm Power
ECP: Equivalent Conventional Power
EEHC: Egyptian Electricity Holding Company
EU: European Union
EUE: Expected Unserved Energy
FEPL-MILP: Flexibility Enhanced Priority List-Mixed Integer Linear Programming
FEPL: Flexibility Enhanced Priority List
FL: Fuzzy Logic
FOR: Forced Outage Rates
GA: Genetic Algorithms
GEP: Generation Expansion Planning
GHG: Green House Gas
GHI: Global Horizontal Irradiance
GT: Gas Turbine
HF: High Flexible
HFO: Heavy Fuel Oil
HNN: Hopfield Neural Network

IEA: International Energy Agency
IEEE: Institute of Electrical and Electronics Engineers
IRENA: International Renewable Energy Agency
ISCC: Integrated Solar Combined Cycle Power Plant
LCC: Load Carrying Capability
LCOE: Levelized Cost of Electricity
LDC: Load Duration Curve
LF: Low Flexible
LFO: Light Fuel Oil
LOLH: Loss of Load Hours
LOLE: Loss Of Load Expectation
LOLP: Loss Of Load Probability
LT: Long Term
MF: Medium Flexible
MILP: Mixed Integer Linear Programming
MLE: Maximum Likelihood Estimation
MLL: Minimum Load Level
MOERE: Ministry of Electricity and RES
MOP: Ministry of Petroleum
MSG: Minimum Stable Generation
NASA: National Aeronautics and Space Administration
NECC: National Electricity Control Center
NEM: National Electricity Market
NG: Natural Gas
Non-VRES: Non-variable RES
NREA: New and Renewable Energy Authority NREA
NREL: National Renewable Energy Laboratory
NWP: Numerical Weather Prediction
OC: Operation Cost
O&M: Operation and Maintenance
PHES: Pumped Hydro Energy Storage
PJM: Pennsylvania-New Jersey-Maryland
PL: Priority List
PMF: Probability Mass Function

PV: Photovoltaic
PDA: Probabilistic Dynamic Approach
PSO: Particle Swarm Optimization
RES: Renewable Energy Resources
R.M: Reserve Margin
SA: Simulated Annealing
SCUC: Security Constrained Unit Commitment
SoDa: Solar Radiation Data
SQP: Sequential Quadratic Programming
TARES: Technical Assistance to Support the Reform of the Energy Sector
TS: Tabu Search
TSC: Total System Cost
UC: Unit Commitment
UCC: Unit Construction and Commitment
UCR: Unit Commitment Risk
USA: United States of America
VRES: Variable Renewable Energy Resources
VG: Variable Generation