بسم الله الرحمن الرحيم

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تم رفع هذه الرسالة بواسطة / هناء محمد علي

بقسم التوثيق الإلكتروني بمركز الشبكات وتكنولوجيا المعلومات دون أدنى مسئولية عن محتوى هذه الرسالة.

ملاحظات:
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AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electrical Power and Machines Engineering

Microgrid Planning in Egypt Based on Geographic Information Systems

A Thesis submitted in partial fulfilment of the requirements of the degree of

Doctor of Philosophy in Electrical Engineering

(Electrical Power and Machines Engineering)

by

Amany Belal Mohamed Ahmed

Master of Science in Electrical Engineering

(Electrical Power and Machines Engineering)

Faculty of Engineering, Ain Shams University, 2013

Supervised By

Prof. Hisham Temraz

Prof. Walid El-khattam

Cairo - (2022)

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Date:1 March 2022

Statement

This thesis is submitted as a partial fulfilment of Doctor of Philosophy in Electrical Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

Several countries around the world realized the necessity of generating electricity from renewable resources, but reliability and economic feasibility of these resources needs detailed investigations. An energy mix which incorporates renewable energy is essential, yet providing sustainability, security, and competitiveness for an energy mix is a challenge.

This thesis presents an application of Geographic Information System to build a suitability model for the evaluation of renewable energy microgrid locations in Egypt. The proposed methodology exploits the extensive capabilities of GIS software in analyzing several forms of database especially maps. Throughout this work, the data collection process spans several data sources to identify the availability and geographic distribution of renewable energy resources specially wind and solar. A Geo-Energy summation is applied to combine these resources to generate a Wind-Solar Atlas of Egypt. The produced atlas is a raster dataset which allocates the highly recommended areas to invest in renewable energy in Egypt.

The main objective is to maximize the overall renewable generation capability while satisfying technical economic, and environment constraints. Applying specific constraints to the Microgrid planning have been presented in the form of data layering and a sequential filtering procedure was utilized to eliminate unsuitable sites. The main constraints for Microgrid site selection applied to this work are availability of renewable energy resources, distance from national electricity grid, access to transportation networks, land height, slope, urban areas, protected areas, environmental resources, etc.

GIS technology and Multi Criteria Decision Making (MCDM) approach was utilized to convert these criteria into factors and limitation layers. Various scenarios for renewable-based microgrid site selection have been explored, the selection is directly related to the properness of the weights given to the parameters.

Keywords:

Microgrid, wind energy, solar energy, network planning, geographic information system, site selection, renewable energy

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To my dear father, who gave me wings. And husband, who encourages me to fly.

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List of Abbreviations

AHP	Analytic Hierarchy Process
ANNs	Artificial Neural Networks
BWM	Best Worth Method
BOOT	Build Own Operate and Transfer
CPV	Concentrator solar PhotoVoltaic
CSP	Concentrating Solar Power
DE	Differential Evolution algorithm
DG	Distributed Generator
DEM	Digital Elevation Model
DER	Distributed Energy Resource
DIF	Diffuse Horizontal Irradiation
DNI	Direct Normal Irradiation
EEHC	Egyptian electricity holding company
EgyptERA	Egyptian Electric utility and consumer protection Regulatory Agency
ESMAP	Energy Sector Management Assistance Program
ESS	Energy Storage System
GA	Genetic Algorithm
GEF	Global Environment Facility
GHG	Green House Gas
GHI	Global Horizontal Irradiation
GIS	Geographic Information System
GSA	Global Solar Atlas

GTI	Global Tilted Irradiation
GWA	Global Wind Atlas
HOMER	Hybrid Optimization of Multiple Energy Resources
IMC	Industrial Modernization Center
MENA	Middle East and North Africa
MG	Microgrid
MCDM	Multi Criteria Decision Making
NREA	New and Renewable Energy Authority
OPTA	OPtimum Tilt Angle of PV module to maximize the yearly yield
PSO	Particle Swarm Optimization
PV	PhotoVoltaic
PVOUT	PhotoVoltaic power OUTput
RE	Renewable Energy
REMGS	Renewable Energy Microgrid Systems
RES	Renewable Energy Sources
RO	Robust Optimization
STATCOM	STATic synchronous COMpensator
TEMP	air TEMPerature at 2 m above ground level in °C
TOPF	Three-phase Optimal Power Flow
UNDP	United Nations Development Program
UTM	Universal Transverse Mercator
VPP	virtual power plant
WGS	World Geodetic System
WT	Wind Turbine

List of Symbols

A	rotor swept area
$AngIn_{\theta,\alpha}$	angle of incidence between the centroid of the sky sector and the axis normal to the surface
$AngInSky_{\theta,\alpha}$	Angle of incidence between the intercepting surface and a given sky sector with a centroid at θ angle and α angle
C_p	power coefficient of the turbine
$Dif_{\theta,\alpha}$	DIFfuse insolation at zenith angle θ, azimuth angle α
Dif_{tot}	total DIFfuse radiation
$Dir_{\theta,\alpha}$	DIRect insolation at zenith angle θ, azimuth angle α
Dir_{tot}	total DIRect radiation
Div_{azi}	The number of azimuthal divisions in the sky map
Dur	The time interval for analysis.
E	energy
ELE	Terrain elevation above sea level in meters
G_a	The surface azimuth angle
G_z	The surface zenith angle.
$Global_{tot}$	Total Global radiation
$H(V_i)$	*number of hours in wind speed bin* V_i
m(θ)	The relative optical path length
P	power output
P_{dif}	The proportion of global normal radiation flux that is diffused. It varies from 0.2 to 0.7 for very clear sky and very cloudy sky conditions respectively.
$P(V_i)$	power output of the wind turbine at wind speed V_i
R_{glb}	The global normal radiation.