

Palestine Polytechnic University
Deanship of Graduate Studies and Scientific Research
Master Program of Renewable Energy and Sustainability

***Techno – Economic Assessment of PV Power Plants utilizing
artificial intelligence – Case Study of Wahaj Al Ghuzlan Power
Plant at Al Dhahriya***

By
Iyad Abdul Jawwad Isaila

Supervisor
Dr. Fouad Zaro

*Thesis submitted in partial fulfillment of requirements of the degree
Master of Science in Renewable Energy & Sustainability*

January, 2024

The undersigned hereby certify that they have read, examined and recommended to the Deanship of Graduate Studies and Scientific Research at Palestine Polytechnic University and the Faculty of Science at Al-Qdus University the approval of a thesis entitled:

**Techno – Economic Assessment of Photovoltaic Power Plant utilizing artificial intelligence –
Case Study of Wahaj Al Ghuzlan Power Plant at Al Dhahriya**

Submitted by

Iyad Abdul Jawwad Isaila

in partial fulfillment of the requirements for the degree of Master in Renewable Energy & Sustainability.

Graduate Advisory Committee:

Dr. Fouad Zaro
(Supervisor), Palestine Polytechnic University,

Signature: _____

Date: _____

Prof. Abdelkarim Daud
(Internal committee member), Palestine Polytechnic University,

Signature: _____

Date: _____

Dr. Hakam Shehadeh
(External committee member), Birzeit University,

Signature: _____

Date: _____

Thesis Approved by:

Name: Dr. Nafeth Nasereddin

Dean of Graduate Studies & Scientific Research
Palestine Polytechnic University

Signature:.....

Date:.....

ABSTRACT

The energy demand has been increased as the population increased all over the world, due to this increment and the harmful effect of conventional energy sources, renewable sources have become a preferable solution. A lot of tools and parameters have been used for evaluating renewable energy projects, the current study aims to techno-economic assessment of a 1.5 MW photovoltaic (PV) power plant located in Al Dhahriya south of Hebron district. The weather, climate, and energy parameters data of two years of continuous monitoring have been achieved from the PV power plant. The techno-economic performance parameters: final yield, reference yield, capacity utilization factor, net present value, simple payback period, and the annual average monthly Performance Ratio have been calculated through related mathematical expressions, the values of final energy yields for the years 2021 and 2022, are 1902 kWh/kW_p and 1867 kWh/kW_p, respectively, this result can be deemed as reasonable and acceptable values. The value of simple payback period on average is 4.82 years, this indicates that the project is feasible because all project costs will be reimbursed over the first five years of its lifetime. The optimal PV power plant location has also been studied utilizing Particle Swarm Optimization (PSO) method, the required inputs for this analysis have been obtained and entered to MATLAB software, The analysis process indicates that the optimal locations for all the proposed Distribution Generation (DG) plants for all scenarios are located in the furthest points from the main electricity feeding point in the grid, Those locations are associated with minimum real power losses in the grid as well as the most improved voltage profile. It concluded that the PSO method is an effective principle for the assessment of the studied aspects, it indicates the optimal location of the studied PV power plant within a few iterations, which makes PSO a very effective developed procedure in power system applications.

المخلص

التقييم التقني و الاقتصادي لمحطة طاقة كهروضوئية باستخدام تقنيات الذكاء الاصطناعي – دراسة حالة محطة كهرباء وهج الغزلان في الظاهرية

لقد تزايد الطلب على الطاقة مع زيادة عدد السكان في جميع أنحاء العالم، وبسبب هذه الزيادة والتأثير الضار لمصادر الطاقة التقليدية أصبحت المصادر المتجددة هي الحل المفضل، وقد تم استخدام الكثير من الأدوات والمعايير لتقييم مشاريع الطاقة المتجددة ، تهدف الدراسة الحالية إلى التقييم الفني والاقتصادي لمحطة توليد طاقة كهروضوئية بقدرة ١,٥ ميجاواط ، وتقع المحطة في الظاهرية جنوب محافظة الخليل. تم الحصول على بيانات الطقس والمناخ والطاقة لمدة عامين من المراقبة المستمرة من محطة الطاقة الكهروضوئية. تم حساب معايير الأداء الفني والاقتصادي: العائد النهائي، العائد المرجعي، عامل استغلال القدرة، صافي القيمة الحالية، فترة الاسترداد البسيطة، ومتوسط نسبة الأداء الشهري السنوي من خلال معادلات رياضية محددة، كانت قيم إنتاج الطاقة النهائية للأعوام ٢٠٢١ و ٢٠٢٢ هي ١٩٠٢ كيلو وات ساعة/كيلو وات و ١٨٦٧ كيلو وات ساعة/كيلو وات على التوالي، ويمكن اعتبار هذه النتيجة قيمة معقولة ومقبولة. بلغت قيمة فترة الاسترداد البسيطة في المتوسط ٤,٨٢ سنة، وهذا يدل على أن المشروع مجدي لأنه سيتم سداد جميع تكاليف المشروع على مدى السنوات الخمس الأولى من عمره. تمت دراسة الموقع الأمثل لمحطة الطاقة الكهروضوئية باستخدام طريقة Particle Swarm Optimization (PSO) ، وتم الحصول على المدخلات المطلوبة لهذا التحليل وإدخالها في برنامج MATLAB ، وتشير عملية التحليل إلى أن المواقع الأمثل لجميع محطات الطاقة الشمسية المقترحة تقع في أبعد النقاط عن نقطة التغذية الرئيسية بالكهرباء في الشبكة، وترتبط هذه المواقع بالحد الأدنى من فقدان الطاقة الحقيقي في الشبكة بالإضافة إلى تحسين جهد الشبكة. وخلصت الدراسة إلى أن طريقة PSO هي مبدأ فعال لتقييم هذه الجوانب المدروسة، فهي تشير إلى الموقع الأمثل لمحطة الطاقة الكهروضوئية ضمن تكرارات ومحاولات قليلة ، مما يجعل PSO إجراء متطور وفعال للغاية في تطبيقات أنظمة الطاقة.

DECLARATION

I declare that the Master Thesis entitled "**Techno – Economic Assessment of Photovoltaic Power Plant utilizing artificial intelligence – Case Study of Wahaj Al Ghuzlan Power Plant at Al Dhahriya**" is my own original work, and hereby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

Iyad Abdul Jawwad Isaila

Signature: _____

Date: _____

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for the joint Master's degree in Renewable Energy & Sustainability at Palestine Polytechnic University and Al-Quds University, I agree that the library shall make it available to borrowers under rules of the library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of the source is made.

Permission for extensive quotation from, reproduction, or publication of this thesis may be granted by my main supervisor, or in his absence, by the Dean of Graduate Studies and Scientific

Research when, in the opinion of either, the proposed use of the material is for scholarly purposes.

Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Iyad Abdul Jawwad Isaila

Signature: _____

Date: _____

DEDICATION

This thesis is dedicated to:

The sake of Allah, my Creator and my Master,

My great teacher and messenger, Mohammed (May Allah bless

and grant him), who taught us the purpose of life,

My homeland Palestine, the warmest womb;

The great martyrs and prisoners, the symbol of sacrifice;

The Polytechnic University, my second magnificent home;

My great parents, who never stop giving of themselves in countless ways,

My beloved wife, daughter, and sons; leads me through the valley of darkness with
light of hope and support

My supervisor Dr. Fouad Zaro

My friends who encourage and support

All the people in my life who touch my heart,

I dedicate this research.

ACKNOWLEDGEMENT

I would like to express my gratitude towards all the people who have contributed their precious time and efforts to help me in completing this thesis, without whom it would not have been possible for me to understand and analyze the thesis.

I would like to thank my thesis Supervisor Dr. Fouad Zaro for his guidance, support, motivation and encouragement throughout the period this work was carried out. His readiness for consultation at all times, his educative comments, his concern, and assistance have been invaluable.

I am also grateful to Prof. Sameer Khader Head of Department of JAMILA project, for providing the necessary facilities in the department. The co-operation showed by Eng. Mustafa Suwayti of PV Power plant supervisor.

Finally, I render my respect to my parents for giving me mental support and inspiration for carrying out my research work

List of Abbreviations

AC	Alternative Current
AI	Artificial Intelligence
ALO	Ant-Lion Optimization Algorithms
BBO	Biogeography-Based Optimization
CO ₂	Carbon dioxide
CUF	Capacity Utilization Factor
DC	Direct Current
DCF	Discounted Cash Flow
DE	Differential Evolution
DG	Distributed Generation
DHI	Diffuse Horizontal Irradiance
DNI	Direct Normal Irradiance
DPBP	Disconnected Payback Period
FC	Fuel Cells
FiT	Feed in Tariff
FLC	Fuzzy Logic Controller
F _v	Future Value
GA	Genetic Algorithm
GHG	Green House Gases
IRR	Internal Rate of Return
LCOE	Levelised Cost of Electricity
MENA	Middle East and North Africa
MPPT	Maximum Power Point Tracking
NOCT	Nominal Operating Cell Temperature
NPV	Net Present Value
PI	Profitability Index
POA	Plane of Array
PR	Performance Ratio
PR	Performance Ratio
PSO	Particle Swarm Optimization
PV	Photovoltaic
P _v	Present Value
SLD	Single Line Diagram
SPBP	Simple Payback Period
SSA	Salp Swarm Algorithm
TAPL	Total Active Power Losses

List of Nomenclature

Y_A	Array Yield
E_{DC}	DC energy output
Y_F	Final yield
E_{AC}	AC energy output
H_T	Solar Insolation
H_R	Reference Irradiance
Y_R	Reference yield
L_C	Array Capture Losses
L_S	System Loss
A_M	PV Module total Area
η_{pv}	Array Efficiency
η_{sys}	System Efficiency
η_{Inv}	Inverter Efficiency
T_{cell}	Cell Temperature
T_{amb}	Ambient Temperature
r	Interest Rate
n	Number of years
S_{Loss}	Power Losses
P_{Loss}	Active Power Losses
Q_{Loss}	Reactive Power Losses
V	Voltage
I	Current
I_{DC}	DC Input Current
I_{AC}	AC Output Current
P_{DCr}	Rated DC Input Power
R	Resistance
X	Reactance
Z	Impedance

List of Figures

Figure	Description	Page
3.1	Schematic of grid-connected PV generation system [75].....	18
3.2	Line model to calculate Line flow [87].....	24
3.3	flowchart of the used PSO technique.	26
4.1	site location (Al Dhahriya map).[88].....	28
4.2	Wahaj Al Ghuzlan PV power plant location.....	29
4.3	Hourly POA solar irradiance (W/m ²) for the year 2021.....	31
4.4	Hourly POA solar irradiance (W/m ²) for the year 2022.....	31
4.5	Hourly solar insolation (kWh/m ²) for the year 2021.....	32
4.6	Hourly solar insolation (kWh/m ²) for the year 2022.....	32
4.7	wind speed (m/s) for the year 2021.....	33
4.8	wind speed (m/s)for the year 2022.....	34
4.9	Hourly ambient temperature (C°) for the year 2021.....	35
4.10	Hourly ambient temperature (C°) for the year 2022.....	35
4.11	Average monthly Ambient Temperature (Co)for the year 2021.....	37
4.12	Average daily solar Insolation for each month(kWh/m ² /day) for year 2021.....	38
4.13	Average monthly Wind speed (m/s) for the year 2021.....	38
4.14	Average monthly Ambient Temperature (Co)for the year 2022.....	40
4.15	Average daily solar Insolation for each month (kWh/m ² /day) for year 2022....	41
4.16	Average monthly Wind speed (m/s) for the year 2022.....	41
4.17	Photovoltaic panels arrangement.....	44
4.18	Al Dhahriya grid bus diagram.....	45
5.1	monthly energy expected output (kWh).....	53
5.2	monthly expected, and measured energy output. (kWh).....	54
5.3	Average monthly Insolation (kWh/m ²) for the year 2021.....	56
5.4	Average monthly Insolation (kWh/m ²) for the year 2022.....	57
5.5	average performance ratio, 2021, 2022.....	59
5.6	Hourly cell temperature (C°) for the year 2021.....	62
5.7	Hourly cell temperature (C°) for the year 2022.....	62
5.8	Real power losses (kW) for assumed 1 DG, 2 DGs, and 3 DGs.....	69
5.9	Optimal location of PV power plant – scenario 3 : 1 DG.....	71
5.10	Optimal location of PV power plants – scenario 4 : 2 DGs.....	71

5.11	Optimal location of PV power plants – scenario 5 : 3 DGs.....	72
5.12	current location of Wahaj Al Ghuzlan PV power plants.....	73
5.13	Bus 28 (Jamooq) site location.....	74
5.14	Bus 33(Doma Hospital) site location.....	74
5.15	Bus 39 (Al Jebrini) site location.....	75
5.16	Bus voltage profile (PU).....	78

List of Tables

Table	Description	Page
4.1	Average temperature, daily solar Insolation and wind speed for the months of 2021	36
4.2	Average temperature, daily solar Insolation and wind speed for the months of 2022	39
4.3	PV panels specifications [89].....	42
4.4	Inverter specification. [90].....	43
4.5	Distribution Transformers.....	46
4.6	Resistance (R), Reactance (X), and Impedance (Z) for Distribution Transformers...	47
4.7	Distribution Cables.....	48
4.8	Resistance (R), and Reactance (X), for cable types per unit km.....	48
4.9	Resistance (R), Reactance (X), and current capacity for distribution cables.....	49
5.1	monthly measured energy compared with simulated expected output energy.....	53
5.2	system yields (2021), (2022).....	55
5.3	Energy losses 2021, 2022.....	57
5.4	PV system's efficiencies 2021, 2022.....	58
5.5	Performance ratio 2021, 2022.....	58
5.6	capacity utilization factor (CUF) 2021, 2022.....	59
5.7	performance indicators in 2021.....	60
5.8	performance indicators in 2022.....	60
5.9	Average ambient temperature, average cell temperature, solar Insolation and Energy output for the months of 2021.....	63
5.10	Average ambient temperature, average cell temperature, solar Insolation and Energy output for the months of 2022.....	64
5.11	Present Value of the income for each year of the project period.....	65
5.12	Net Income for each year of the project period.....	65
5.13	PV system yearly Simple Payback Period.....	66
5.14	Real Power Losses (kW).....	68
5.15	DG's capacity, and location, grid real power losses.....	70
5.16	financial losses associated with grid real power losses.....	75
5.17	Bus voltage profile.....	76

Table of Content

Abstract.....	III
الملخص.....	IV
Declaration.....	V
Statement of Permission to Use.....	VI
Dedication.....	VII
Acknowledgement.....	VIII
List of Abbreviations.....	IX
List of Nomenclature	X
List of Figures.....	XI
List of Tables.....	XIII
Table of content.....	XIV
CHAPTER 1:	1
Introduction.....	1
1.1 Background to the Study.....	1
1.2 Research objective.....	3
1.3 Statement of the problem.....	3
1.4 Motivation.....	4
1.5 Thesis Structure.....	5
 CHAPTER 2:.....	 6
Literature review.....	6
2.1 Introduction	6
2.2 Photovoltaic (PV) systems	7
2.3 Techno-economic assessment of PV systems	8
2.4 Artificial Intelligence techniques.....	11
2.4.1 Particle Swarm Optimization (PSO).....	12
2.4.2 Optimal Placement and Sizing of Renewable Distributed Generation ..	14
 CHAPTER 3.....	 16
Modelling of PV system.....	16
3.1 Introduction.....	16
3.2 Modelling of grid-connected PV systems.....	17
3.3 Modelling of energy techno-economics.....	18
3.3.1 Modelling of energy techniques.....	

3.3.2 Modelling of energy economics.....	19
3.4 Modelling of location optimization for PV systems.....	22
3.4.1 Particle Swarm Optimization (PSO).....	23
CHAPTER 4.....	25
Methodology	27
4.1 Introduction.....	27
4.2 Study area.....	27
4.3 Weather Data.....	28
4.4 PV System Specifications	29
4.4.1 Specification of PV modules.....	41
4.4.2 Specification of Inverters.....	41
4.5 Economic data.....	42
4.6 PV Array Distribution.....	43
4.7 PV power plant location optimization.....	43
4.7.1 Al Dhahriya grid component	44
CHAPTER 5.....	44
Analysis and Discussion of Results	51
5.1 Overview.....	51
5.2 simulation results of PV system.....	51
5.3 Techno-economic assessment of the grid connected PV power plant.....	51
5.3.1 Technical PV system analysis.....	55
5.3.2 Economic PV system analysis.....	55
5.4 Plant location optimization utilizing PSO	64
5.4.1 Real power losses evaluation.....	67
5.4.2 Voltage profile.....	67
CHAPTER 6.....	76
Conclusion and Remarks.....	79
6.1 Summary.....	79
6.2 Recommendations.....	79
REFERENCES.....	81
APPENDIX.....	82
	92