

## Table of Contents

	الآية	
	Dedication	
	Acknowledgment	
	Content	<b>i</b>
	List of Figures	<b>iii</b>
	List of Tables	<b>iv</b>
	Abbreviation	<b>v</b>
	Abstract	<b>vi</b>
	المستخلص	<b>vii</b>
<b>Chapter One Introduction</b>		
1.1	Introduction	<b>1</b>
1.2	Power of the sun	<b>2</b>
1.3	solar energy	<b>2</b>
1.4	photovoltaic powers	<b>3</b>
1.5	module and array	<b>4</b>
1.6	Major advantages and disadvantages of the photovoltaic power	<b>7</b>
1.7	Dissertation Layout	<b>11</b>
<b>Chapter Two Literature review and background study</b>		
2.1	Introduction	<b>12</b>
2.2	Micro grids – An integration of Renewable Energy Technologies	<b>13</b>
2.3	Gird – Connected Photovoltaic Systems	<b>14</b>
2.4	Optimized Integration of Renewable Energy	<b>15</b>
2.5	Smart Integration of Future Grid – Connected PV Systems	<b>16</b>
2.6	Planning Model for Photovoltaic Generation Integration	<b>18</b>
2.7	Control and Analysis of Hybrid Renewable Energy–Based Power System	<b>19</b>
2.8	Development of MATLAB/ Simulink model of single – phase Grid – connected photovoltaic system	<b>20</b>
2.9	Power electronics, a key technology for energy efficiency and renewable	<b>22</b>
2.10	Harmonic current reduction control for grid-connected PV generation systems:	<b>24</b>
<b>Chapter Three Mathematical Model of Photovoltaic Modules</b>		
3.1	Introduction	<b>27</b>
3.2	Building Integrated PV System	<b>27</b>

3.3	PV Cell Technologies	27
3.4	Equivalent Electrical	29
3.5	The Control and Stability Problem	32
3.6	Signal diode model	39
3.7	Newton-Raphson method	42
3.8	Neural network modeling	44
3.8.1	Neuron structure	45
3.8.2	Multilayer Perception Structure	46
<b>Chapter Four Grid Connected Solar Photovoltaic Systems</b>		
4.1	Introduction	48
4.2	Basic Components of Grid Connected PV System	49
4.3	Working Principle of Grid Connected Photovoltaic System	50
4.4	Conditions for Grid Interfacing	51
4.5	Advantages of Small Units Instead of Single Large Unit	51
4.6	Calculations about Amount of Energy is Fed to the Grid From Solar Power	52
4.7	Grid Connected PV Power Generation All Over the World	52
4.8	Grid Interactive SPV Plant Installed	53
4.9	System Design	53
4.10	System Sizing and Specifications	54
4.11	Cost Analysis for 9 KW Grid Connected Solar PV Plant	56
4.12	Annual Energy Generation	57
4.13	Summary	57
<b>Chapter Five Simulink implementation and Results Discussions</b>		
5.1	Introduction:	58
5.2	Simulink blocks	58
5.3	Grid Connected Photovoltaic System Model	64
5.4	Validation of the Grid Connected Photovoltaic System Model	65
<b>Chapter Six Conclusions and Future Work</b>		
6.1	Conclusions	71
6.2	Future Research and Development	72
	References	73

## List of Figures

- Figure (1.1) Kelly cosine curve for PV cell at sun angle from  $0^\circ$  to  $90^\circ$
- Figure (3.1) equivalent circuit of PV module showing the diode and ground leakage current
- Figure (3.2) block diagram of proposed PV utility grid system configuration
- Figure (3.3) proposed feedback configuration for stability proposes
- Figure (3.4) Logic diagram of the combined generator/power network/inverter dynamic
- Figure (3.5) Transfer function representation of the combined dynamics
- Figure (3.6) The signal exponential models of photovoltaic cell.
- Figure (3.7) the double exponential model of photovoltaic cell
- Figure (3.8) structure of a neuron
- Figure (4.1) grid connected photovoltaic system
- Figure (4.2) block diagram of grid connected system
- Figure (5.1) component of experiment model
- Figure (5.3) mask of PV array
- Figure (5.4) mask of inverter
- Figure (5.5) mask of three-phase source
- Figure (5.6) flow chart of controller block
- Figure (5.7) grid connected PV system
- Figure (5.8) solar cell voltage
- Figure (5.9) infinite bus bar voltage
- Figure (5.10) solar cell active & reactive power
- Figure (5.11) infinite bus bar active & reactive power
- Figure (5.12) solar cells current
- Figure (5.13) infinite bus bar current
- Figure (5.14) solar cell terminal voltage.

## **List of Table**

Table (2.1)	predication of solar for 2017 and 2030
Table (4.1)	grid specification
Table (4.2)	solar photovoltaic power plant specification
Table (4.3)	inverter specification
Table (4.4)	transformer specification
Table (4.5)	solar panel specification
Table (4.6)	protection specification

## Abbreviation

AC	Alternative current
ANN	Artificial Neural Network
CHP	Combined Heat and Power
DER	Distributed Energy Resource
DG	Distribution Generation
DSG	Dispersed Storage and Generation
ELI	Energy Location Information
FC	Fuel Cell
HVDC	High Voltage Direct Current
MPP	Maximum power point
MPPTs	Maximum power point Tracking
MVDC	Medium Voltage Direct Current
MLP	Multi layer Perception
MSE	Mean square Error
NOCT	Nomical Operation Cell Temperature
NN	Neural Network
PCS	Power Conversion System
PEMFCs	Proton Exchange Membrane Fuel Cells
PG	photovoltaic Generator
PQR	Power Quality and Reliability
PV	photo Voltaic
PWM	Pulse Width Modulation
RES	Renewable Energy source
RET	Renewable Energy Technologies
S R U F	Solar Resource Unavailability frequency
SRAUD	Solar Resource Average Unavailability Duration
UC	Ultra Capacitor
VLST	Very Large Scale Integration
VSI	Voltage Source Inverter
WG	Wind Generator

# **Abstract**

Categorized as one of the renewable energies, Photovoltaic system has a great potential compared to its counterparts of renewable energies. Photovoltaic makes use of the most abundant energy on earth that is sunlight. This is promising in countries where sunlight is available all year round, for example Australia, Sudan. Experimental models have been developed to study the solar modules. Some of these models develop an understanding to successfully integrate the PV as an embedded or as a distribution generation to the grid. In this thesis, an experimental model is developed to study the characteristic of the PV arrays connected to the grid. This is done by monitoring the output of the PV array module in the presence of frequency and voltage deviations. It will also study the effects of connected the PV system to grid and how it affects the output of the system. The objective of this thesis is to the experimental PV system model that could also disconnect itself from the grid when there are critical changes in the grid system. In the future, the model can be developed further to study other problems that come with interconnection to the grid.

## المستخلص

أنظمة الطاقة الشمسية هي إحدى الطاقات المتجددة التي تتميز بجهد عالي مقارنة بنظيراتها من الطاقات المتجددة الأخرى.

يمكن استخدام أنظمة الطاقة الشمسية في المناطق التي تتوفر فيه أشعة الشمس طول العام مثل استراليا والسودان. تم تطوير بعض النماذج التجريبية لدراسة أنظمة الطاقة الشمسية، وبعضها طور بنجاح لربط هذه الأنظمة بالشبكة.

وفي هذه الأطروحة تمت دراسة خصائص أنظمة الطاقة الشمسية المرتبطة بالشبكة وذلك بمراقبة مخرجات هذه الأنظمة في حالة انحراف الجهد والتردد ودراسة تأثيرها على النظام .

والهدف من هذه الدراسة هو ربط أنظمة الطاقة الشمسية بالشبكة ودراسة كل التغيرات الحرجة التي يمكن أن تحدث في نظام الشبكة ،وفي المستقبل يمكن دراسة المشاكل التي تنتج من الاتصال بالشبكة.