



# **Modelling of an Efficient Dynamic Smart Solar Photovoltaic Power Grid System**

**Balogun Emmanuel Babajide**

**B.Sc (University of Lagos, Nigeria – UNILAG) (2005)**

**M.Sc(University of Lagos, Nigeria – UNILAG) (2010)**

**A Thesis Submitted in Requirement for the Degree of Doctor  
of Philosophy (Information Science & Engineering)**

**at**

**University of Canberra.**

**Faculty of Education, Science, Technology and Mathematics**

**September 2015.**

# Abstract

A smart solar photovoltaic grid system is an advent of innovation coherence of information and communications technology (ICT) with power systems control engineering via the internet [1]. This thesis designs and demonstrates a smart solar photovoltaic grid system that is self-healing, environmental and consumer friendly, but also with the ability to accommodate other renewable sources of energy generation seamlessly, creating a healthy competitive energy industry and optimising energy assets efficiency.

This thesis also presents the modelling of an efficient dynamic smart solar photovoltaic power grid system by exploring the maximum power point tracking efficiency, optimisation of the smart solar photovoltaic array through modelling and simulation to improve the quality of design for the solar photovoltaic module. In contrast, over the past decade quite promising results have been published in literature, most of which have not addressed the basis of the research questions in this thesis.

The Levenberg-Marquardt and sparse based algorithms have proven to be very effective tools in helping to improve the quality of design for solar photovoltaic modules, minimising the possible relative errors in this thesis. Guided by theoretical and analytical reviews in literature, this research has carefully chosen the MatLab/Simulink software toolbox for modelling and simulation experiments performed on the static smart solar grid system. The auto-correlation coefficient results obtained from the modelling experiments give an accuracy of 99% with negligible mean square error (MSE), root mean square error (RMSE) and standard deviation.

This thesis further explores the design and implementation of a robust real-time online solar photovoltaic monitoring system, establishing a comparative study of two solar photovoltaic tracking systems which provide remote access to the harvested energy data. This research made a landmark innovation in designing and implementing a unique approach for online remote access solar photovoltaic monitoring systems providing updated information of the energy produced by the solar photovoltaic module at the site location. In addressing the challenge of online solar photovoltaic monitoring systems, Darfon online data logger device has been systematically

integrated into the design for a comparative study of the two solar photovoltaic tracking systems examined in this thesis. The site location for the comparative study of the solar photovoltaic tracking systems is at the National Kaohsiung University of Applied Sciences, Taiwan, R.O.C.

The overall comparative energy output efficiency of the azimuthal-altitude dual-axis over the 45<sup>0</sup> stationary solar photovoltaic monitoring system as observed at the research location site is about 72% based on the total energy produced, estimated money saved and the amount of CO<sub>2</sub> reduction achieved. Similarly, in comparing the total amount of energy produced by the two solar photovoltaic tracking systems, the overall daily generated energy for the month of July shows the effectiveness of the azimuthal-altitude tracking systems over the 45<sup>0</sup> stationary solar photovoltaic system. It was found that the azimuthal-altitude dual-axis tracking systems were about 68.43% efficient compared to the 45<sup>0</sup> stationary solar photovoltaic systems. Lastly, the overall comparative hourly energy efficiency of the azimuthal-altitude dual-axis over the 45<sup>0</sup> stationary solar photovoltaic energy system was found to be 74.2% efficient.

Results from this research are quite promising and significant in satisfying the purpose of the research objectives and questions posed in the thesis. The new algorithms introduced in this research and the statistical measures applied to the modelling and simulation of a smart static solar photovoltaic grid system performance outperformed other previous works in reviewed literature. Based on this new implementation design of the online data logging systems for solar photovoltaic monitoring, it is possible for the first time to have online on-site information of the energy produced remotely, fault identification and rectification, maintenance and recovery time deployed as fast as possible.

The results presented in this research as Internet of things (IoT) on smart solar grid systems are likely to offer real-life experiences especially both to the existing body of knowledge and the future solar photovoltaic energy industry irrespective of the study site location for the comparative solar photovoltaic tracking systems. While the thesis has contributed to the smart solar photovoltaic grid system, it has also highlighted areas of further research and the need to investigate more on improving the choice and quality design for solar photovoltaic modules. Finally, it has also made recommendations for further research in the minimization of the absolute or relative errors in the quality and design of the smart static solar photovoltaic module.

# Acknowledgements

This dissertation would have never been written, much less completed without acknowledging the unmerited mercies, love and favour of the Almighty God for His unfailing grace, strength, knowledge and wisdom throughout the learning process of my doctoral studies.

I would like to express sincere gratitude to my primary supervisor, Prof. Xu Huang, for his excellent guidance and counsel, patience, providing insightful comments, valuable contribution and support over the course of my research. I would also like to thank my co-supervisor A/Prof. Dat Tran for his encouragement and moral support in every step of this research work. I wish to express my indebtedness to fellow research colleagues, and all administrative staffs at the National Kaohsiung University of Applied Sciences, Taiwan, the Republic of China for their guidance, cooperation and support during my research visit for data collection.

My sincere thanks also go to Mrs Carmela Thambirajah Adisa and family for their timely and invaluable support at the hour of distress during my study. I would also like to express sincere gratitude to Dr Abayomi Adeniyi and family for their moral guidance and support. I would like to thank every member and friends of the Ammish family, especially Dr Ammish Adu and Dr Joyce Adu for their unflinching and unfailing assistance and encouragement to persevere in finishing my doctoral research.

I would like to thank Dr Michael S. Adelana and all members of the Deeper Christian Life Ministry, Australia for their timely and financial support in the period of crisis and ceaseless prayers supporting me spiritually throughout this study period. I would like to thank my fellow research mates for their thought-provoking discussions across all works of life, for the opportunities to work together, and for all the fun in sports, we had in the last three years.

I am indebted to the Lagos State Government Scholarship Board, Nigeria for granting me the opportunity to undertake this research study at the University of Canberra, Australia for their financial commitment was invaluable to me in completing my doctoral studies. Special thanks to all who have crossed my paths during this journey, who has in one way or another been a blessing contributing to the successful completion of this dissertation.

Last but not the least, I would like to thank my parents, especially my mother for her ceaseless prayers and mobile calls since I left for this doctoral studies and my beloved wonderful sisters for their concern on my study progress and unconditional support in taking good care of my dad.

# List of Acronyms

AADAT	Azimuth-Altitude Dual Axis Tracker
ANN	Artificial Neural Network
CCD	Charge Coupled Device
Cfcs	Chlorofluorocarbons
CO <sub>2</sub> -e	Carbondioxide Equivalent
CPV	Concentrated Photovoltaic
CR	Time Constant
CSP	Concentrated Solar Power
CVR	Conservation Voltage Reduction
DLS	Damped Least-Squares
EPA	Environment Protection Agency
EPRI	Electric Power Research Institute
FDIR	Fault Detection, Isolation And Restoration
GDP	Gross Domestic Product
GHG	Green House Gases
GM-Estimators	Generalized M-Estimators
GNA	Gaussian-Newton Algorithm
GPS	Global Positioning System
GUI	Graphical User Interface
HSAT	Horizontal Single Axis Tracker
IAAS	Infrastructure As A Service
ICT	Information and Communication Technology
IP	Internet Protocol
IREAs	International Renewable Agencies
ISA	International Society Of Automation
ISP	Internet Service Providers
IVVCO	Integrated Volt-Var Control Optimisation

IoT	Internet of Things
LAD	Least Absolute Deviation
LDRs	Light Dependent Resistors (Or Photo-Resistors),
LMA	Levenberg-Marquadt Algorithm
LREs	Large Renewable Energy Schemes
LT	Local Times
LTS	Least Trimmed Squares
MLP	Multilayer Perceptron
MPPT	Maximum Power Point Tracking
MSE	Mean Square Error
NERC CIP	North American Electric Reliability Corporation Critical Infrastructure Protection
NIPP	National Infrastructure Protection Plan
NIST	National Institute Of Standard And Technology
NREAP	National Renewable Energy Action Plan
O&M	Operations And Maintenance
OLS	Ordinary Least Squares
PAAS	Platform As A Service
PASAT	Polar Aligned Single Axis Tracker
PC	Personal Computers
P-I-N Diode	Photo-Diode
PLC	Programmable Logic Control
PSpice	Personal Computer Simulation Program with Integrated Circuit Emphasis
PV	Photo-Voltaic
QoS	Quality of Service
RBF	Radial Basis Function
REAs	Renewable Energy Agencies
RECs	Renewable Energy Credits
RES	Renewable Energy Sources

RETs	Renewable Energy Targets
RMSE	Root Mean Square Error
RPS	Renewable Portfolio Standards
SAAS	Software As A Service
SGN	Smart Grid Network
SRES	Small Renewable Energy Schemes
T&D	Transmission And Distribution
TSAT	Tilted Single Axis Tracker
TTDAT	Tip-Tilt Dual Axis Tracker
UCAAS	Unified Communication As A Service
UV	UltraVoilet
VSAT	Vertical Single Axis Tracker.
WCRE	World Council For Renewable Energy



# List of Symbols

$I_{ph}$	<i>photo current generator</i>
$I_o$	<i>leakage or reverse saturation current</i>
$q$	<i>electron charge</i>
$V$	<i>solar cell voltage</i>
$A$	<i>ideality factor</i>
$k$	<i>Boltzmann constant</i>
$R_S$	<i>series cell resistance</i>
$R_{sh}$	<i>shunt cell resistance</i>
$T_a$	<i>ambient temperature</i>
$w_s$	<i>wind speed</i>
$S$	<i>solar irradiation</i>
$I_{or}$	$I_o$ at reference temperature at $T_r = 301.18K$
$E_G$	<i>band gap energy</i>
$T_r$	<i>reference temperature</i>
$T$	<i>solar cell temperature</i>
$I_{scr}$	<i>short circuit current at <math>T_r</math></i>
$k_i$	<i>short circuit current temperature coefficient</i>
$V_{OC}$	<i>open circuit voltage</i>
$V_{mp}$	<i>maximum power voltage</i>
$I_{mp}$	<i>maximum power current</i>
$n_p$	<i>number of parallel modules</i>
$n_s$	<i>number of series modules</i>
$P$	<i>output power</i>

# List of Publications

- **Balogun, Emmanuel B.**, Xu Huang, and Dat Tran. "Efficiency of Sensor Devices Used in Dynamic Solar Tracking System: Comparative Assessment Parameters Review." *Applied Mechanics and Materials* 448 (2014): 1437-1445.
- **Balogun, Emmanuel B.**, Xu Huang, and Dat Tran "Solar optimisation based on different tracking techniques". Proceedings of the 2013 International Conference on Agriculture Science and Environment Engineering (ICASEE 2013), 19-20 December, Beijing, China. DEStech Publications, Inc.
- **Balogun, Emmanuel B.**, Xu Huang, and Dat Tran. "A Revolution in Green Energy: Solar Tracking System". Proceedings of the 2013 International Conference & Exhibition on Clean Energy (ICCE 2013), 9-13 September, Ottawa, Canada.
- **Balogun, Emmanuel B.**, Xu Huang, and Dat Tran. "The Prospective Grid: The Smart Grid Network". Proceedings of the 2014 International Conference & Exhibition on Clean Energy (ICCE 2014), 20-24 October, Quebec city, Canada.
- **Balogun, Emmanuel B.**, Xu Huang, and Dat Tran. "Comparative Study of Different Artificial Neural Networks Methodologies on Static Solar Photovoltaic Module." "International Journal of Emerging Technology and Advanced Engineering" Volume 4, Issue 10, October 2014(ISSN 2250-2459(Online)): 674-685.
- **Balogun, Emmanuel B.**, Xu Huang, Dat Tran, Yun-Chuan Lin, Mingyu Liao, and Michael Adaramola. "Regression estimation modelling techniques on static solar photovoltaic module" "International Journal of Emerging Technology and Advanced Engineering" Volume 5, Issue 4, April 2015 (ISSN 2250-2459(Online)): 451-461.
- **Balogun, Emmanuel B.**, Xu Huang, Dat Tran, Yun-Chuan Lin, Mingyu Liao, and Michael Adaramola. "A robust real-time online comparative monitoring of an azimuthal-altitude dual axis GST 300 and a 45° fixed solar photovoltaic energy tracking systems." In *SoutheastCon 2015*, pp. 1-10. IEEE, 2015.
- **Balogun, Emmanuel B.**, Xu Huang, Dat Tran, Yun-Chuan Lin, Mingyu Liao, and Michael Adaramola. "Power quality improvement by integration of Distributed Networks" "International Journal of Emerging Technology and Advanced Engineering" Volume 5, Issue 7, July 2015 (ISSN 2250-2459(Online)): 465-471.

# Table of Contents

Abstract.....	i
Certificate of Authorship of Thesis.....	iii
Acknowledgements.....	v
List of Acronyms .....	vii
List of Symbols .....	xi
List of Publications .....	xiii
List of Tables .....	xix
List of Figures.....	xxi
Chapter 1 Introduction .....	1
1.1 Introduction to the Study .....	1
1.2 Characteristics of the Term Smart Power Grid.....	2
1.3 Smart Power Grid Concept.....	3
1.4 Evolution in the Power Grid Systems.....	5
1.5 Background and Context.....	6
1.6 Research Objectives and Questions .....	9
1.6.1 Research Objectives.....	9
1.6.2 Research Questions .....	9
1.7 Research Methods.....	10
1.8 Research Works, Contribution and Justification.....	11
1.9 Limitation and Assumptions .....	13
1.10 The Outline of this Thesis.....	14
1.11 Conclusion .....	16
Chapter 2 Literature Review .....	17
2.1 Introduction.....	17
2.2 Solar Photovoltaic Sensor and Tracking Optimisation Devices .....	18
2.2.1 Dynamic Characteristics of Solar Photovoltaic Sensors.....	19
2.2.2 Assessments of Physical Sensor Parameters.....	22
2.3 Solar Photovoltaic Tracking Optimisation Techniques .....	28
2.3.1 Dynamic Single axis Tracking Optimisation .....	29
2.3.2 Dynamic Dual- axis Solar Tracker.....	31

2.4 Smart Solar Power Grid System .....	33
2.4.1 Smart Solar Photovoltaic Power Grid Network .....	33
2.4.2 Concept of the Smart Solar Photovoltaic Grid Network.....	34
2.4.3 Challenges and Issues on the Smart Solar Photovoltaic Grid System .....	36
2.5 Green Energy Revolution and Policy.....	38
2.5.1 Overview of the State of Evolution.....	38
2.5.2 Determinants of Green Energy Revolution.....	41
2.5.3 Impacts of Green Renewable Energy .....	45
2.6 The Prospective Grid: A Smart Grid Network.....	48
2.6.1 The Smart Grid Network.....	48
2.6.2 Conceptual Framework of the Smart Grid Network .....	50
2.6.3. A Smart Grid Network Policy and Implementation Guidelines .....	52
2.6.4. The Smart Grid Network Challenges .....	53
2.6.5. Benefits of the Smart Grid Network .....	54
2.7 Conclusion .....	55
Chapter 3 Modelling and Simulation Techniques for a Solar Photovoltaic System.....	59
3.1 Introduction.....	59
3.2 Static Solar Photovoltaic Modules Modelling and Simulation Performance.....	59
3.3 Static Solar Farm Photovoltaic Modules Modelling .....	61
3.4 Solar Photovoltaic Module Simplest Model and Parameter Definitions .....	61
3.4.1 Solar Photovoltaic Module Simplest Model .....	61
3.4.2 Module Parameter Definitions .....	62
3.5 Proposed Research Methodology.....	65
3.5.1 Neural Network Model .....	65
3.5.2 Sparse Based Algorithm.....	81
3.6 Conclusion .....	100
Chapter 4 Astronomical and Analytical Derivation for Solar Photovoltaic Tracking Systems .....	101
4.1 Introduction.....	101
4.2 An Astronomy of Dynamic Solar Photovoltaic Tracking System .....	101
4.3 Geometric Modelling Equation Derivations for Dynamic Smart Solar Photovoltaic Systems .....	104
4.4 Simulink Modelling Approach.....	111
4.5 Simulink Implementation for Smart Solar Photovoltaic Systems.....	112

4.5.1 Simulink Implementation of a Solar Photovoltaic Module.....	112
4.5.2 Simulink Implementation of a Static Smart Solar Photovoltaic off-grid model .....	117
4.5.3 General Photovoltaic Model Characteristics.....	121
4.5.4 Simulink Implementation of Five thousand Solar Photovoltaic Modules .....	126
4.6 Conclusion .....	129
Chapter 5 Robust Real-Time Online Solar Photovoltaic Data Monitoring Systems .....	131
5.1 Introduction.....	131
5.2 An Overview of Robust Real-Time Remote Solar Photovoltaic Monitoring and Tracking Systems .....	131
5.3 Robust Real-Time Online Solar Photovoltaic Monitoring Infrastructure.....	133
5.4 Solar Photovoltaic Data Monitoring and Acquisition Energy System.....	137
5.5 Comparative Solar Photovoltaic Tracking Systems under Investigation.....	140
5.6 Data Management and Presentation of a Solar Photovoltaic Tracking System.....	145
5.7 Presentation of Results and Discussions .....	148
5.8 Conclusion .....	151
Chapter 6 Conclusion.....	153
6.1 Introduction.....	153
6.2 Impacts and Conceptualisation Benefits of this Research Study .....	154
6.3 Significance of Classical Modelling Algorithms on solar photovoltaic systems.....	155
6.4 Significance of the Simulink Solar Photovoltaic Design Model.....	156
6.5 Benefits of Robust Online Cloud Computing Solar Photovoltaic Tracking Systems.....	157
6.6 Evaluation of Simulation Smart Solar Photovoltaic Tracking Systems.....	158
6.7 Significance of this Research.....	159
6.8 Recommendations for Future Research .....	161
Bibliography .....	163
Appendix A.....	173
Thesis Appendices .....	173
A.1 Regression Algorithm Model.....	173
A.2 Real-time online Solar photovoltaic monitoring data .....	178

# List of Tables

Table 1.	The existing traditional power grid system compared with the Smart power grid system .....	6
Table 2.	A Summary of sensor assessment parameters.....	23
Table 3.	Conceptual framework for the smart grid network .....	51
Table 4.	Summary of the sub-sections of literature chapter review.....	56
Table 5.	Parameter definitions used in solar photovoltaic model.....	62
Table 6.	Photovoltaic parameters used in the simulation experiments .....	76
Table 7.	The summary of the experimental results.....	77
Table 8.	Comparison of standard error estimates of the static solar photovoltaic module.....	96
Table 9.	Comparison of the MSE and RMSE regression methods of the static solar photovoltaic module.....	96
Table 10.	The simulated output characteristics at ten different irradiance levels.....	127
Table 11.	Stationary 45 <sup>0</sup> solar photovoltaic obtained raw data.....	176
Table 12.	Dual-axis solar photovoltaic obtained raw data.....	193
Table 13.	Comparative total energy generated for a month.....	211
Table 14.	Comparative hourly energy efficiency.....	212

# List of Figures

Figure 1.	Smart power grid system characteristics and its capabilities.....	3
Figure 2.	Divisions of smart power grid concept.....	4
Figure 3.	Hybrid smart power grid system.....	5
Figure 4.	Frequency characteristic and response of a first-order sensor.....	20
Figure 5.	Frequency characteristic with limited upper and lower cut-off frequencies $\tau_u$ and $\tau_L$ are the corresponding time constants.....	20
Figure 6.	Responses of sensors with different damping characteristics.....	22
Figure 7.	Solar intensity wavelength.....	26
Figure 8.	Horizontal single axis tracking.....	30
Figure 9.	A vertical single axis tracking (VSAT).....	30
Figure 10.	Tilted single axis tracker.....	31
Figure 11.	Dual axis tracker architecture.....	32
Figure 12.	Summary of types of sun trackers.....	33
Figure 13.	A green smart grid network concept.....	40
Figure 14.	Solar PV Global capacity, shares of top 10 countries, 2012 (Global status report).....	41
Figure 15.	A Green energy revolution determinant.....	42
Figure 16.	Conceptual framework for smart grid network .....	52
Figure 17.	Parameter indicator for smart grid network policy and implementation.....	53
Figure 18.	Challenges facing a smart grid network.....	55
Figure 19.	Static solar farm photovoltaic module.....	61
Figure 20.	Simplest model of equivalent circuit solar photovoltaic module.....	62
Figure 21.	Basic neural network model.....	66
Figure 22.	Radial basis function architecture.....	68
Figure 23.	MLP feed forward neural network.....	71
Figure 24.	Training performance for MLP model.....	78
Figure 25.	Training state for MLP model.....	79
Figure 26.	Training fit for MLP model.....	79
Figure 27.	Training error histogram for MLP model.....	80
Figure 28.	Training regression performance for MLP model.....	80

Figure 29.	RBF Training window.....	81
Figure 30.	Dispersion diagram of $P_{mp}$ vs. $S$ .....	97
Figure 31.	Dispersion diagram of $V_{mp}$ vs. $S$ .....	97
Figure 32.	Dispersion diagram of $I_{mp}$ vs. $S$ .....	98
Figure 33.	Dispersion diagram of $V_{mp}$ vs. $S$ .....	98
Figure 34.	Dispersion diagram of $P_{mp}$ vs. $S$ .....	99
Figure 35.	Dispersion diagram of $I_{mp}$ vs. $S$ .....	99
Figure 36.	The Solar tracking elevation and azimuth angles.....	102
Figure 37.	Geometrical setup of a concentrated solar photovoltaic system using two mirror-symmetrically disposed on the left (M1) and right (M2).....	105
Figure 38.	Euler's observatory angle compared to altazimuthal coordinate system.....	106
Figure 39.	Simplest model of an equivalent circuit solar photovoltaic module.....	112
Figure 40.	PV cell photocurrent, $I_{ph}$ Matlab/Simulink subsystem.....	114
Figure 41.	PV cell photocurrent, $I_{ph}$ Matlab/Simulink masked subsystem.....	114
Figure 42.	Diode reverse saturation current, $I_o$ Matlab/Simulink subsystem.....	115
Figure 43.	Diode reverse saturation current, $I_o$ Matlab/Simulink masked subsystem.....	115
Figure 44.	Simulink model of the characteristics equation of the solar photovoltaic module.....	116
Figure 45.	Masked Simulink model of the characteristics equation of the solar photovoltaic module.....	116
Figure 46.	I-V & P-V characteristics of solar photovoltaic module.....	117
Figure 47.	A series connection of ten solar photovoltaic modules.....	119
Figure 48.	Masked subsystem of the series connection.....	119
Figure 49.	Functional block parameter of a solar PV cell.....	120
Figure 50.	Functional block parameter of a solar PV cell.....	120
Figure 51.	Masked subsystem block units of a hundred solar photovoltaic modules.....	120
Figure 52.	Simulink Model of a single block of hundred solar photovoltaic modules.....	120
Figure 53.	A five thousand series-parallel configurations of solar photovoltaic modules.....	122
Figure 54.	Solar photovoltaic array model for GUI environment of Simulink.....	123
Figure 55.	I-V Characteristics behaviour of the solar photovoltaic model.....	124
Figure 56.	P-V characteristics behaviour of the solar photovoltaic model.....	124
Figure 57.	I-V characteristics of the parallel configuration model.....	125
Figure 58.	P-V characteristics of the parallel configuration model.....	125
Figure 59.	Masked subsystem for the five thousand solar photovoltaic module.....	126
Figure 60.	Full Simulink model for the five thousand solar photovoltaic modules arrangement...	126



Figure 61.	Simulation results of the output current, power and voltage against simulation time....	127
Figure 62.	Output power, voltage generated with increased irradiance level.....	128
Figure 63.	Output current generated with increased irradiance level.....	128
Figure 64.	A robust real-time online solar monitoring system at roof building platform.....	135
Figure 65.	A schematic solar photovoltaic monitoring wiring system architecture.....	136
Figure 66.	Client/server internet architecture.....	137
Figure 67.	Client/server intranet architecture.....	137
Figure 68.	Real-time solar monitoring and acquisition infrastructure architecture.....	138
Figure 69.	Basic fundamental cloud computing service model.....	139
Figure 70.	Fixed solar energy system installed at a 45 <sup>0</sup> inclination.....	141
Figure 71.	GST 300 tracker deployed at the roof platform.....	144
Figure 72.	Architectural framework of the GST 300 tracker.....	145
Figure 73.	Graphic User Interface of the remote Darfon data logger.....	147
Figure 74.	An overview of the solar photovoltaic modules installed on roof building.....	147
Figure 75.	GUI for the 45 <sup>0</sup> stationary solar systems.....	148
Figure 76.	GUI for the azimuthal-altitude dual solar systems.....	148
Figure 77.	Daily profile of the mean daily total energy for the azimuthal-altitude solar systems...	150
Figure 78.	Daily profile of the mean daily total energy for 45 <sup>0</sup> stationary solar systems.....	150
Figure 79.	Hourly profile of the mean daily total energy for 45 <sup>0</sup> stationary solar systems.....	151
Figure 80.	Hourly profile of the mean daily total energy for the azimuthal-altitude solar systems	151
Figure 81.	Ordinary Least Regression algorithm.....	174
Figure 82.	Logistic Robustfit regression code.....	176
Figure 83.	Least Trimmed Squares regression code.....	178