

**ENERGY MANAGEMENT OF A GRID INTERACTIVE
PHOTOVOLTAIC CLUSTER BASED ECO-FRIENDLY
GREENHOUSE FARMING ENVIRONMENT**

ANURADHA TOMAR



**DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI**

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GREENHOUSE FARMING ENVIRONMENT**

by

ANURADHA TOMAR

Department Of Electrical Engineering

Submitted

in fulfilment of the requirements of the degree of Doctor of Philosophy

to the



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Dedicated to my loving & caring Parents . . .

Certificate

This is to certify that the thesis entitled “**Energy Management of a Grid Interactive Photovoltaic Cluster Based Eco-Friendly Greenhouse Farming Environment**” being submitted by **Ms. Anuradha Tomar** for the award of the degree of **Doctor of Philosophy** is a record of bonafide research work carried out by her in the Department of Electrical Engineering at Indian Institute of Technology Delhi, New Delhi.

Ms. Anuradha Tomar has worked under my supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard. The results obtained here, have not been submitted to any other University or Institute for the award of any degree.

Date:

Prof. Sukumar Mishra

Professor,
Department of Electrical Engineering
Indian Institute of Technology Delhi,
New Delhi, Pin: 110016, India.

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Date:

Anuradha Tomar

Place: New Delhi

Abstract

This work is focused on photovoltaic application in farming sector (but equally applicable in other fields) through design, development and experimental research implementation in the field to address a few primary issues based on interaction with farmers. The total research is segmented in four sections including; (1) The PV energy enhancement, (2) PV resources integration and their utilization, (3) Micro level Photovoltaic summation technology of unsymmetrical PV modules with higher efficiency as per load matching and designing and (4) Development of low cost yet high tech automated PV based protected environment controlled farming (PV_PECF) system for climate control as per crop stage development and studying its impact on crop yield, energy management and economy in comparison to open field farming.

The issues pertaining to PV energy enhancement (chapter 3); are addressed with a new dual layer MPPT (DLMPPT) concept; which is based on summation of energy yield due to distributed MPPT across PV module (DMPPT) and central MPPT (CMPPT) across PV arrays. The scheme is implemented using programmable logic controller (PLC) as standard hardware and its software with modified Incremental Conductance (IC) algorithm by adapting subroutine jump control (ASJC) technique to address speedy reduction of multiple maxima points under shadowing trees in the field. The energy flow from PV sources up to inverter stage through common dc bus is dynamically balanced through quick transfer as per load demand.

The second research part (chapter 4), is a comprehensive global solution for integration of neighboring PV resources of farmers through CMPVI using MIDO scheme to enhance total capacity (doubled capacity at no extra investment for two farmers) for solving diminishing water discharge due to increasing ground water level. Through utilization of PV capacities during morning and evening times (concept hardly visible in

literature) additional energy extraction by 13.68% and alternate agro machineries the PV energy cost per watt is reduced by 14.89% and water discharge is improved by 24.74%.

The third research work part (chapter 5), is related to micro level PV module summation technology through add on module hardware (AOMH) as interface between MISO dc bus for addition and subtraction of PV capacity as per load demand and thus avoiding thermal heating and unwanted system energization which ultimately helps in additional reliability while improving efficiency.

The fourth segment of proposed work in (chapter 5 and 6), focus on design and development of PV_PECF system featuring automation within affordable budget; provides climate control as per plant process stage and growth using agro baskets as substrates and encourages farming even on unfertile or hilly land at remotely located farms. It is a unique experimental prototype to explore MPPT through AOMH module as an interface between MISO bus at 24V and connected with photo active radiation (PAR) LED, irrigation, fertigation, sprinklers, fogging devices, ventilation and water pumps and mostly are DC load in nature with PWM duty cycle control for energy saving. The P&O MPPT applied individually to both PV modules which are inclined like upper hut structure; could provide average combined additional energy gain as 10.32% as compared to without MPPT; despite of MISO load variation during morning, evening ,day and night times. The efficiency of interleaved DC-DC boost converter as pre-stage of micro inverter is 77.74% to 96.90% at varying load from 10 to 100%. The micro inverter efficiency is found as 86.88% and 92.59% at 10% and rated load respectively.

Compared to open field, comparative primary data confirms a conservative growth of tomato fruit yield more by 53.13% in PV_PECF system. The ROI for developed PV_PECF system is 9.24% with a return period as 10.82 years.

सार

यह काम किसानों के साथ बातचीत के आधार पर कुछ प्राथमिक मुद्दों को संबोधित करने के लिए क्षेत्र में डिजाइन, विकास और प्रयोगात्मक अनुसंधान कार्यान्वयन के माध्यम से खेती के क्षेत्र में फोटोवोल्टिक अनुप्रयोग (लेकिन अन्य क्षेत्रों में समान रूप से लागू) पर केंद्रित है। कुल शोध चार खंडों में खंडित है; (1) पीवी ऊर्जा वृद्धि, (2) पीवी संसाधनों का एकीकरण और उनका उपयोग, (3) माइक्रो लेवल फोटोवोल्टिक समन टेक्नॉलॉजी ऑफ अनसिमिटेड पीवी मॉड्यूल्स विथ हाई एफिशिएंसी विथ लोडिंग और डिजाइनिंग और (4) निम्न विकास का उच्च तकनीक। स्वचालित पीवी आधारित संरक्षित पर्यावरण नियंत्रित खेती (PV_PECF) फसल नियंत्रण के अनुसार जलवायु नियंत्रण के लिए प्रणाली और खुले खेत की खेती की तुलना में फसल की उपज, ऊर्जा प्रबंधन और अर्थव्यवस्था पर इसके प्रभाव का अध्ययन।

पीवी ऊर्जा वृद्धि (अध्याय 3) से संबंधित मुद्दे; एक नई दोहरी परत MPPT (DLMPPT) अवधारणा के साथ संबोधित किया जाता है; जो PV सरणियों में वितरित MPPT (DMPPT) और केंद्रीय MPPT (CMPPT) के बीच ऊर्जा की उपज के योग पर आधारित है। इस योजना को प्रोग्रामेबल लॉजिक कंट्रोलर (पीएलसी) को मानक हार्डवेयर के रूप में लागू किया गया है और इसके सॉफ्टवेयर को संशोधित वृद्धिशील चालकता (IC) एल्गोरिथ्म के साथ उप-प्रादुर्भावी छलांग नियंत्रण (ASJC) तकनीक से जोड़ा गया है ताकि क्षेत्र में पेड़ों की कटाई के तहत कई अधिकतम बिंदुओं की त्वरित कमी का पता लगाया जा सके। सामान्य डीसी बस के माध्यम से इन्वर्टर चरण तक पीवी स्रोतों से ऊर्जा प्रवाह लोड की मांग के अनुसार त्वरित हस्तांतरण के माध्यम से गतिशील रूप से संतुलित है।

दूसरा अनुसंधान भाग (अध्याय 4), बढ़ती क्षमता के कारण घटते पानी के निर्वहन को सुलझाने के लिए MIDO योजना (दो किसानों के लिए कोई अतिरिक्त निवेश पर दोगुनी क्षमता) बढ़ाने के लिए CMPVI के माध्यम से किसानों के पड़ोसी पीवी संसाधनों के एकीकरण के लिए एक व्यापक वैश्विक समाधान है। भूजल स्तर। सुबह और शाम के समय में पीवी क्षमता का उपयोग (अवधारणा शायद ही साहित्य में दिखाई देती है) अतिरिक्त ऊर्जा निष्कर्षण 13.68% और वैकल्पिक कृषि मशीनरी द्वारा प्रति वाट पीवी ऊर्जा लागत 14.89% कम हो जाती है और पानी के निर्वहन में 24.44% सुधार होता है।

तीसरा अनुसंधान कार्य भाग (अध्याय 5), माइक्रो लेवल पीवी मॉड्यूल सम्मिलन तकनीक से संबंधित है, जो मॉड्यूल हार्डवेयर (एओएमएच) के माध्यम से एमओएसओ डीसी के बीच इंटरफेस के रूप में है, इसके अलावा लोड की मांग के अनुसार पीवी क्षमता और घटाव के लिए घटाव और इस प्रकार थर्मल हीटिंग से

बचा जा सकता है। अवांछित प्रणाली ऊर्जाकरण जो अंततः दक्षता में सुधार करते हुए अतिरिक्त विश्वसनीयता में मदद करता है।

(अध्याय 5 और 6) में प्रस्तावित काम का चौथा खंड, सस्ती बजट के भीतर स्वचालन की विशेषता PV_PECF प्रणाली के डिजाइन और विकास पर ध्यान केंद्रित; संयंत्र प्रक्रिया चरण के अनुसार जलवायु नियंत्रण प्रदान करता है और सबस्ट्रेट्स के रूप में एगो बास्केट का उपयोग करते हुए और दूर स्थित खेतों में भी बेघर या पहाड़ी भूमि पर खेती को प्रोत्साहित करता है। यह 24V में MISO बस के बीच इंटरफेस के रूप में AOMH मॉड्यूल के माध्यम से MPPT का पता लगाने के लिए एक अनूठा प्रयोगात्मक प्रोटोटाइप है और फोटो सक्रिय विकिरण (PAR) एलईडी, सिंचाई, प्रजनन, छिड़काव, उपकरणों, वेंटिलेशन और पानी के पंपों के साथ जुड़ा हुआ है और ज्यादातर डीसी लोड में हैं ऊर्जा की बचत के लिए पीडब्लूएम कर्तव्य चक्र नियंत्रण के साथ प्रकृति। पी एंड ओ एमपीपीटी दोनों पीवी मॉड्यूल के लिए व्यक्तिगत रूप से लागू होता है जो ऊपरी हट संरचना की तरह झुका हुआ होता है; MPPT के बिना औसत संयुक्त अतिरिक्त ऊर्जा लाभ 10.32% प्रदान कर सकता है; MISO लोड भिन्नता के बावजूद सुबह, शाम, दिन और रात के समय के दौरान। माइक्रो इनवर्टर के प्री-स्टेज के रूप में इंटरलेसीड डीसी-डीसी बूस्ट कनवर्टर की दक्षता 10 से 100% तक अलग-अलग लोड पर 77.74% से 96.90% है। माइक्रो इन्वर्टर की दक्षता 86.88% और 92.59% 10% और रेटेड लोड के रूप में क्रमशः पाई जाती है।

खुले मैदान की तुलना में, PV_PECF प्रणाली में तुलनात्मक प्राथमिक डेटा 53.13% से अधिक टमाटर फलों की उपज के रूढ़िवादी विकास की पुष्टि करता है। विकसित PV_PECF प्रणाली के लिए ROI 10.4 वर्षों की वापसी अवधि के साथ 9.24% है।

Table of Contents

Certificate	i
Acknowledgement	ii
Abstract	iii
List of Figures	xii
List of Tables	xix
1 Introduction	1
1.1 Background of Indian Farming and RES Technology	1
1.2 Literature Review	2
1.2.1 DLMPPPT	2
1.2.2 CMPVI based MISO Scheme	3
1.2.3 AOMH & MISO	5
1.2.4 PV_PECF	6
1.3 Motivation	8
1.4 Research Objectives	9
1.5 Scope of Research Work	11
1.6 Research Limitations	11
1.7 Overview of Research Work	12
1.7.1 Energy Yield	12

1.7.2	PV Integration of PV sources to increase PV capacity and power sharing on Co-operative consent basis	14
1.7.3	Micro-level Photovoltaic summation technology using AOMH-MISO based PV-VCI Irrigation System Using ASCIM Pump	15
1.7.4	Low Budget PV_PECF System Design & with Prototype Development For Crop Growth	15
1.8	Thesis Organization	16
2	Synthesis of a New DLMPPT Technique with PLC for Enhanced PV Energy Extraction under Varying Irradiance and Load Changing Conditions	19
2.1	Introduction	19
2.2	Concept of Dual Layer MPPT with PLC	21
2.3	System Description & Operation	22
2.3.1	Distributed MPPT/Inner Layer Control	22
2.3.2	PLC Based Centralized/Outer Layer MPPT Control	22
2.4	Hardware Selection Considerations	26
2.5	Simulation Results & Discussion	31
2.6	Analysis & Hardware Validation	35
2.6.1	Centralized MPPT	35
2.6.2	Distributed MPPT	36
2.6.3	Dual Layer MPPT	37
2.7	MPPT Verification	40
2.8	Proposed DLMPPT Scheme Cost Considerations	41
2.9	Conclusion	42
3	CMPVI based MIDO scheme under SSE for Optimum Energy Balance & Reduced ROI	43
3.1	Introduction	43
3.2	CMPVI Concept Motivation	46
3.3	Description & Working of Proposed CMPVI Scheme	47

3.3.1	CMPVI Power Stage Scheme	48
3.3.2	MIDO Controller Structure	49
3.4	Design & Sizing of MIDO Converter	50
3.5	Steady State & Dynamic Response of Proposed System	56
3.5.1	Performance under SSE (Scenario I)	57
3.5.2	Performance of CMPVI Scheme at Morning Time (Scenario II)	59
3.6	Experimental Verification at Farmer’s Field	60
3.6.1	System Response During Morning Hours (duration 6 to 8.30 hrs.) with Sample Period of 15 Minutes	61
3.6.2	System Response During Full Day (6 to 18 hrs) with Sample Period of 1 Hr	62
3.6.3	System response during evening hours (16.30 to 18 hrs.) with 15 minutes sample period	63
3.7	Economic Aspect	67
3.8	Conclusion	68
4	AOMH-MISO Based PV-VCI Irrigation System Using ASCIM Pump	69
4.1	Introduction	69
4.2	AOMH-MISO System and Operation	72
4.3	Design & Selection of Hardware Components	76
4.4	PV Vector Control Inverter (PV-VCI)	80
4.5	Simulation Results & Analysis	86
4.6	System Performance & Discussion	89
4.7	Economic Overview	94
4.8	Conclusion	95
5	Low Budget PV_PECF System Design & Prototype Development	97
5.1	Motivation	97
5.2	Problem Definition & Objectives of PV_PECF	99
5.3	Proposed PV_PECF System Description	100
5.3.1	Layer Concept of PV_PECF Variables	101

5.3.1.1	PV_PECF Parameters Classification	102
5.3.2	Overview of Crop Growth Process Control	102
5.3.3	Proposed PV_PECF Scheme	105
5.4	PV_PECF System Design & Specification	112
5.4.1	Load Specification & Energy Estimation	114
5.4.2	PV Specification	114
5.4.3	MISO DC Bus Specification	114
5.4.4	BES Specification	115
5.4.5	Automation Specification	115
5.4.6	Software Programme Structure	116
5.5	Design of PECF System Structure & Agro basket	117
5.5.1	PV_PECF system Roof Top PV Support Considerations	118
5.5.2	PV Potential at the PV_PECF Site	119
5.5.3	Sizing Prototype PV_PECF system	120
5.5.3.1	Sizing of Structure	120
5.5.3.2	PV Panel and BES Sizing	121
5.5.3.3	Agro Basket & Growing Medium	123
5.5.4	Cladding & Ventilation	123
5.5.5	Design / Operational Aspect of PV_PECF System	124
5.5.5.1	Ventilation Schedule for the Year (Implemented matrix in software data block)	124
5.5.5.1	Creation of PAR	124
5.5.6	Other Considerations of a General Greenhouse	128
5.6	Design of AOMH Module as interface with PV and MISO Bus	129
5.7	Design of Single phase Micro Inverter	132
5.7.1	Specification of Micro Inverter	132
5.7.2	Architecture of PV based Micro Inverter	132
5.7.2.1	Advantages of Micro Inverter	134
5.7.3	Design of Inter Leaved Boost DC-DC Converter as a boost stage of Micro Inverter	135

5.7.4	High Frequency Transformer Design as a next stage of DC-DC Boost Converter	141
5.7.4.1	Overview of Properties of Magnetic Ferrite Cores as part of Design Study	142
5.7.4.2	HF Transformer Design Calculation	143
5.7.4.3	Design Checks to for Expected Performance	146
5.7.4.4	Output Rectifier Stage	149
5.7.4.5	DC-AC Converter Design next to HF Transformer stage	149
5.7.4.6	Bridge MOSFET Device Sizing	150
5.7.4.7	EMI Filter between Micro Inverter and Grid	151
5.8	Operation and Monitoring of PV_PECF	153
6	PV_PECF System Results & Performance Discussion	156
6.1	MATLAB Simulation Results & Discussion	156
6.1.1	MATLAB Simulation Scenario 1 (4-6 am)	157
6.1.2	MATLAB Simulation Scenario 2 (6-8 am)	158
6.1.3	MATLAB Simulation Scenario 3 (8-4 am)	159
6.1.4	MATLAB Simulation Scenario 4 (Grid Interactive Mode)	160
6.2	Hardware Results & Discussion	161
6.2.1	PV Power generation	161
6.2.2	Power Flow among PV, MISO DC Bus, BES and Load at Morning, Day& Evening	161
6.2.3	Power Flow among Grid, PV, MISO DC Bus, BES and Load at Night	163
6.3	MPPT Efficiency and Performance of AOMH Modules of PV_PECF	164
6.3.1	MPPT and Efficiency at Source 1 (PV ₁) via AOMH 1 to MISO dc bus	166
6.3.2	Determination of Efficiency of AOMH Module	167
6.4	Inverter Performance Evaluation	169
6.4.1	DC-DC Boost Converter Stage	169
6.4.2	AC Inverter Stage	170

6.4.2.1	Determination of Micro Inverter Efficiency	171
6.5	PAR Controlled LED Light Performance	172
6.5.1	Ventilation Control	174
6.6	Crop Growth in PV_PECF	174
6.6.1	Plant Nodes, Leaves, Vegetation	174
6.6.2	Plant Leaf Growth and LAI (Leaf Area Index)	175
6.6.3	Determination of Specific Leaf Area (SLA) Weight Constant	177
6.6.4	Determination of Dry Weight of different plant Constituents	180
6.6.5	Tomato Crop Yield in Open Field and PV_PECF System	183
6.6.6	Quality Assessment of Fruits	184
6.6.7	Study of PAR Impact on Crop Growth	185
6.7	Irrigation Cost in PV_PECF and open Field	186
6.8	Economic Feasibility & Adaption of PV_PECF by Farmers	186
6.8.1	PV_PECF Cost Estimation	187
6.8.2	Estimation of Daily consumed Load Energy	188
6.8.3	Operating Expenses & Profitability	188
6.8.4	Economic Achievements as a Result of PV_PECF Farming	190
7	Conclusions	191
7.1	Summary of Research Work	191
7.1.1	DLMPTT	191
7.1.2	PV Integration (CMPVI +MIDO) and Utilization	192
7.1.3	Add On Modular Hardware	193
7.1.4	PV_PECF	193
7.2	Novelty/Uniqueness/Contribution	195
7.3	Research Limitations & Corrective Measures as Future Work Scope	197
7.4	Conclusion	198
	References	202
	Publication Based on Research Work	214

Appendix 1	216
Appendix 2	227
Appendix 3	238
Brief Biodata	240

List of Figures

2.1	Block diagram for implementation of proposed DLMPPT concept	23
2.2	Representation of one PV unit with MLPE as shown in Fig. 2.1	23
2.3	4-phase interleaved DC-DC boost converter hardware using SPV1020 module embedded with P&O algorithm.	24
2.4	Block diagram of PLC set up	24
2.5(a)	PLC control scheme for DC bus voltage regulation	25
2.5(b)	PLC control scheme for inverter	25
2.6	Flowchart of modified IC MPPT algorithm	27
2.7	Various functional block diagram used in PLC software.	28
2.8	PV system considered for MATLAB simulation of CMPPT method	32
2.9	PV system considered for MATLAB simulation of DMPPT method	32
2.10(a)	Variation in P_{pv1} for CMPPT, DMPPT and proposed DLMPPT method	33
2.10(b)	Variation in P_{pv2} for CMPPT, DMPPT and proposed DLMPPT method	33
2.10(c)	Variation in P_{pv3} for CMPPT, DMPPT and proposed DLMPPT method	33
2.10(d)	Variation in P_{pv4} for CMPPT, DMPPT and proposed DLMPPT method	34
2.11	Variation in P_{dc} for CMPPT, DMPPT and proposed DLMPPT	34

	method	
2.12(a)	Current at inverter output I_{inv} for CMPPT case	36
2.12(b)	Current at inverter output I_{inv} for DMPPT case	37
2.12(c)	Current at inverter output I_{inv} for DLMPPT case	38
2.12(d)	Voltage at the inverter output V_{inv} using potential transformer	39
2.13	Utilization percentage comparison for CMPPT, DMPPT and DLMPPT method	39
2.14	Comparison of PV unit efficiency with CMPPT, DMPPT and DLMPPT method	39
3.1(a),	Schematic diagram of existing PV based water pumping with	47
3.1(b) &	BLDC motor for Farmer 1 and Farmer 2 respectively; Fig.	
3.1(c)	3.1(c) Proposed CMPVI scheme	
3.2	Schematic of SEPIC topology used in CMPVI	49
3.3	MIDO controller control structure	50
3.4(a)	PV power with varying irradiation (scenario I)	58
3.4(b)	PV current injection at MIDO DC bus with varying irradiation at constant DC bus voltage (scenario I)	58
3.4(c)	Power extraction with varying irradiation (scenario I)	59
3.5	Power extraction with varying irradiation in scenario II	59
3.6(a)	Extraction of PV energy during morning hours for considered three cases	61
3.6(b)	Comparison of water discharge during morning hours for three cases	61
3.6(c)	Comparison of BES W-hr during morning hours for considered cases	62
3.7(a)	Comparison of energy on full day basis for three cases	62
3.7(b)	Comparison of water discharge on day basis for considered cases	63
3.7(c)	Comparison of BES W-hr on day basis among three cases	63
3.8(a)	Comparison of energy at evening hours for three cases	64

3.8(b)	Comparison Water discharge at evening hours for three cases	64
3.9	MIDO DC bus voltage recovery under SSE	64
3.10	Current injection at MIDO DC under SSE	65
3.11	MIDO common DC Bus and inverter output AC waveform	65
3.12(a)	BES W-hr charge rise at morning	66
3.12(b)	BES W-hr charge fall at evening	66
3.13	Coreloss for three types of magnetic material with switching frequency	66
3.14	SEPIC efficiency under varying load conditions	66
4.1	Proposed AOMH-MISO scheme with PV-VCI for ASCIM driven irrigation pump or Agro-equipment	74
4.2	Schematic of proposed SEPIC-QDPR (N=4) for PV _{source3}	74
4.3(a)	Block diagram for flux estimation and angle frequency calculation with SVPWM generation of a vector controlled inverter	81
4.3(b)	Representation of PV-VCI scheme based water discharge control	82
4.3(c)	Flowchart of capacity selection for AOMH operation	82
4.4	Flowchart for Sensor-less FOC algorithm	85
4.5(a)	Numerical simulation for proposed AOMH based MISO dc bus under steady state condition	87
4.5(b)	Power variation of PV source1, 2 (SEPIC+ZVS) and PV source 3 (SEPIC+QDPR) under partial shading condition	87
4.5(c)	Numerical simulation for MPPT impact on MISO DC bus under partial shading conditions	87
4.6	Cumulative effect on I _{DC} flowing to MISO dc bus at full load condition	88
4.7	Cumulative effect on P _{dc} response at MISO dc bus under 75% load switch over conditions	88

4.8	Cumulative effect on V_{dc} at MISO dc bus under full load change over conditions	88
4.9	Efficiency of PV source1/AOMH1SEPIC+ZVS	89
4.10	Efficiency of PV source 3/AOMH3 SEPIC+QPDR	90
4.11	Efficiency of AOMH+MISO System	90
4.12	Proposed scheme power utilization with and without MPPT	91
4.13	Proposed scheme water yield difference with and without MPPT	91
4.14	Previous [2] and proposed scheme comparison for power utilization	91
4.15	Previous [2] and proposed scheme comparison for water yield	92
4.16	Proposed AOMH based MISO dc bus under steady state condition	93
4.17	MPPT impact on MISO DC bus under partial shading conditions	93
4.18	MISO dc bus stability under load change conditions	93
4.19	Dynamic MISO dc bus condition with increase in injected current at switching on AOMH module at PV source addition	94
5.1	PV_PECF based Input Variables Interface with plant processes & resulting Crop Growth under influence of External Weather and Market	101
5.2	Plant Process involving classified activities and external environment factors	104
5.3 (a)	Proposed PV_PECF schematic key block diagram	106
5.3(b)	Schematic electrical control of PV_PECF	107
5.3(c)	Part III Power & control PV source integration as MISO using AOMH module	108
5.3(d)	Part IV of PV_PECF system using micro inverter along with control architecture	109
5.3(e)	Automation Scheme of PV_PECF	111

5.4	Software Structure implemented in PV_PECF Automation	117
5.5	Transportable Fabricated PV_PECF system	122
5.6	Fabricated Agro basket Size with growing medium	123
5.7	LED based SSL application for photosynthesis to reduce crop growth cycle and higher yield	127
5.8	Optimum Nutrients Composition for Tomato crop as Fertigation with water drip	154
5.9	Optimum Micro Nutrients Composition for as fertigation with a water drip	154
6.1	Showing MATLAB Simulation in part (a) showing load and power transition and their resources values (b) The SOC variation with load change over (c) The BES potential constancy at load	157
6.2	Showing MATLAB simulation in part (a) Power sharing by resource PV, BES, grid as per load requirement (b) Current flow from different resources (d) SOC status of BES (e) Switching of AOMH 1 & AOMH 2 to match load & resource power	158
6.3	MATLAB results for Scenario 3 in parts (a) Power Flow From PV, Grid and BES to Load (b) SOC status during change in load demand (c) Current changeover as per energy and load varying condition (d) MISO bus variation under changing load demand and its support from various resources	159
6.4	Fig. 6.3 MATLAB results for Scenario 4 in parts (a) Power Flow From PV, Grid and BES to Load (b) SOC status during a change in load demand (c) Current changeover as per energy and load varying condition (d) MISO bus variation under changing load demand and its support from various resources	160
6.5	Waveform showing MISO as input source and micro inverter output 230 Ac 50 Hz sine wave	162

6.6	BES burst charging at its deep Discharge case from MISO dc bus	162
6.7	BES floats charging after 80% SOS by MISO dc bus	163
6.8	Fig.6.8 showing stability of MISO dc bus at load (water pump) like a soft load	163
6.9	PV ₁ Module Energy Yield with & without MPPT during day Time	165
6.10	PV ₂ Module Electricity Yield including MPPT during day time	166
6.11	Influence on instability of MISO dc bus at Load switching during temperature control at boundary threshold level	166
6.12	Depicting Gate PWM across MOSFET during P&O MPPT through AOMH 2	167
6.13	Showing the AOMH Efficiency performance under varying load duty cycle	168
6.14	Showing SEPIC Inductor L1 current in CCM mode in AOMH Module as Interface between PV & MISO	169
6.15	Showing Noise free TTL Clock Pulses at Arduino Card (Impact of Opto card Isolation)	169
6.16	Efficiency Variation of Interleaved Boost Converter as Pre-stage of micro inverter at different load duty cycle at switching Frequency 30 KHz	170
6.17	Hourly Efficiency Performance of proposed PV_PECF system with PV+AOMH switching as per MISO Load	172
6.18	Showing symmetrical PAR Creation through RGB led light fixtures	173
6.19	Yearly Automatic Air Flow profile Variation inside PV_PECF based on day timings and Seasons	174
6.20	Comparison of nodes development in PV_PECF and open field	174

6.21	Comparison of LAI of Tomato Crop in Open Field and PV_PECF based farming	176
6.22	Comparing LAI over one square meter area in a PV_PECF and that in open Field	176
6.23	LAI Variation in Open Field and PV_PECF over crop period starting from day of planting	177
6.24	SLA results of Tomato plants in case of Open Field farming and that in PV_PECF system	179
6.25	Showing leaf weight comparison for Tomato plants in same area (1.61m ²) in PV_PECF and open field	179
6.26	Dry weight ratio of tomato plant at fruit stage grown in PV_PECF system	181
6.27	Dry weight constituents of tomato plant grown in designated area in open field	182

List of Tables

1.1	Showing integration of research phases of proposed work as series of PV solutions and finally as PV_PECF system	13
2.1	Specification of System Parameters	28
2.2	Ratings of Various Devices used in the System	31
2.3	Control Signal and Execution Time	31
2.4	Considered irradiation pattern for MATLAB simulation	32
2.5	Primary Data Recorded for CMPPT Method	35
2.6	Primary Data Recorded for DMPPT Method	36
2.7	Primary Data Recorded for DLMPPT Method	37
2.8	Comparison of Strength and Weakness of CMPPT, DMPPT and DLMPPT	41
2.9	DLMPPT, DMPPT, CMPPT Investment Growth Recovery Comparison	41
3.1	Specification of proposed CMPVI based system	48
3.2	Design Parameters for calculation of SEPIC elements	52
3.3	Operating conditions for SEPIC	55
3.4	Core magnetic material overview	56
3.5	Brief summary of main hardware components for implementation of CMPVI scheme	57
3.6	Assumed solar irradiation intensity for simulation of CMPVI scheme	58
3.7	Classification of test setup for comparative study	60
3.8	Result Summary	67
3.9	Economy Growth of farmers due to CMPVI	67
4.1	Specification for proposed AOMH-MISO system	75

4.2	600V MISO DC Bus specification of AOMH	75
4.3	Design Parameters for SEPIC Elements Calculation	78
4.4	Design calculation of AOMH hardware for all three PV sources	79
4.5	AOMH hardware specifications for all three sources	80
4.6	Economic Overview of Proposed AOMH Based MISO Scheme	95
5.1	Climate control variables categorization	103
5.2	Broad Specification of PV_PECF System	113
5.3	Enlisting Connected Load inside PV_PECF system	114
5.4	PV Source Specification used at Roof Top in PV_PECF system	115
5.5	Projected Crop Growth yield Target in PV_PECF system	117
5.6	Assessment of PV Potential at PV_PECF site (latitude: 26.431, longitude: 74.707)	119
5.7	Estimated PV Losses at Azimuth:180°	120
5.8	Energy Requirement of PV_PECF system	121
5.9	Properties of Glazing Materials	124
5.10	Schedule & Quantification of Air flow inside PV_PECF system	125
5.11	Specification of PAR Led Light	126
5.12	Specifications of AOMH for 24V MISO DC bus	129
5.13	Design Parameters for SEPIC Elements Calculation	131
5.14	List of Designed Hardware Components of AOMH 1 & 2	132
5.15	Micro Inverter Specification	133
5.16	DC-DC boost converter stage specification for micro inverter (230V AC 50 Hz)	135
5.17	List of selected Boost DC-DC Converter Items as a part of micro inverter	141
5.18	Projected Design Specification of HF Transformer	141
5.19	Design properties of selected Ferrite core material for comparative study	142
5.20	Summary of Topology constants used in Inductor/ transformer designs	144

5.21	Possible core shapes, size and power handling capacity at 30 KHz operation	145
5.22	Magnetic properties of magnetic cores under design consideration for HF Transformer	145
5.23	List of Designed Hardware Components of Micro Inverter	150
5.24	Summary of LCL filter components between micro inverter and grid	152
5.25	PV_PECF Preset Chart for VPD, Humidity, Temperature, Ventilation climate control	153
6.1	Simulation Scenario conditions of proposed PV_PECF system	156
6.2	Status of power generation, consumption by PV_PECF load at MISO DC bus & excess power to micro inverter during morning, day & evening times	162
6.3	Assessment of BES back up period in PV_PECF during Night (PAR+ ventilation)	163
6.4	Summaries of BES Back up Assessment during Night in PV_PECF	164
6.5	Showing MPPT performance at both PV Modules PV ₁ and PV ₂ inclined in opposite sun facing direction	165
6.6	Record of SEPIC based AOMH module efficiency at 30 kHz switching frequency at varying load	168
6.7	Interleaved Boost DC-DC Converter as Pre-stage of micro inverter at 30 KHz	170
6.8	Performance of Micro Inverter and Efficiency Determination (contd. Table 6.1)	171
6.9	Photo flux Generation as per crop and its stage like vegetation, flowering or fruit	173
6.10	Leaf Area Index in PV_PECF	175
6.11	Leaf Area Index in Designated Open Field	175
6.12	Specific Leaf Area Weight in PV_PECF	177
6.13	Specific Leaf Area Weight in Open Field	178

6.14	SLA Result Summaries for Tomato Crop From Table 6.3 for PV_PECF and Table 6.4 for Open Field	178
6.15	Dry matter Determination of Tomato Crop constituents grown in PV_PECF	180
6.16	Dry matter Determination of Tomato Crop constituents grown in Open Field	181
6.17	Result summaries of Tomato Growth Comparison w.r.t Dry matter content basis between farming in Open Field and PV_PECF	182
6.18	Yield Determination of Tomato Crop in PV_PECF system	183
6.19	Result Summaries of Tomato Yield in Open Field and PV_PECF based on data fetched from table 6.9 to explore other variable determination for performance comparison	184
6.20	Quality assessment of variables which are most affected by conditions and influenced by type of market	185
6.21	Bill of A and B class of material used in PV_PECF	187
6.22	Estimation of energy balance based on load demand and PV generation	188
6.23	Operating expenses estimation of PV_PECF system	189