E.G.S. PILLAY ENGINEERING COLLEGE

(Autonomous)

Approved by AICTE, New Delhi | Affiliated to Anna University, Chennai

Accredited by NAAC with 'A' Grade | Accredited by NBA (CSE, EEE, MECH)

NAGAPATTINAM – 611 002

M.E. POWER ELECTRONICS AND DRIVES

Full Time Curriculum and Syllabus

First Year – First Semester

Course Code	Course Name	L	T	P	C	Maximum Marks		
						CA	ES	Total
Theory Course								
1701PE101	Applied Mathematics for Electrical Engineers	2	2	0	3	40	60	100
1702PE102	Power Semiconductor Devices and Recent Advancements	3	0	0	3	40	60	100
1702PE103	Analysis of Power Converters	3	2	0	4	40	60	100
1702PE104	Analysis of Inverters	3	2	0	4	40	60	100
1702PE105	Modelling and Analysis of Electrical Machines	3	2	0	4	40	60	100
	Elective-I	3	0	0	3	40	60	100
Laboratory Course								
1704PE106	Power Electronic Circuits Laboratory	0	0	2	1	50	50	100
1704PE107	Power Electronics Simulation Laboratory	0	0	2	1	50	50	100
1704PE108	Communication Skills Lab I	0	0	2	1	100	0	100

L – Lecture | T – Tutorial | P – Practical | C – Credit | CA – Continuous Assessment | ES – End Semester

1701PE101 APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS

L	T	P	C
2	2	0	3

COURSE OBJECTIVES:

1. To achieve an understanding of the basic concepts of one dimensional and two dimensional random variables and apply it in electrical engineering problems.
2. To develop the ability to apply the concepts of Linear programming in Electrical Engineering problems.
3. To familiarize the students in Fourier series and solve problems using Fourier transforms associated with engineering applications.

UNIT I ONE DIMENSIONAL RANDOM VARIABLES 9 Hours

Random variables - Probability function – moments – moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Function of a Random Variable.

UNIT II TWO DIMENSIONAL RANDOM VARIABLE 9 Hours

Joint distributions – Marginal and conditional distributions – Covariance – Correlation and Linear regression – Transformation of random variables.

UNIT III INTRODUCTION TO LINEAR PROGRAMMING (LP) 9 Hours

Introduction to applications of operations research in functional areas of Engineering, Linear Programming-formulation, solution by graphical and simplex methods (Primal - Penalty, Two Phase), Special cases. Dual simplex method. Principles of Duality. Sensitivity Analysis.

UNIT IV INVENTORY MODELS, SIMULATION AND DECISION THEORY 9 Hours

Inventory Models – EOQ and EBQ Models (With and without shortages), Quantity Discount Models. Decision making under risk – Decision trees – Decision making under uncertainty. Monte-carlo simulation.

UNIT V FOURIER SERIES 9 Hours

Fourier Trigonometric series: Periodic function as power signals – Convergence of series – Even and odd function: cosine and sine series – Non-periodic function: Extension to other intervals - Power signals: Exponential Fourier series – Parseval's theorem and power spectrum – Eigen value problems and orthogonal functions – Regular Sturm – Liouville systems – Generalized Fourier series.

TOTAL: 45 HOURS

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: Obtain Random variables corresponding to random experiments and able to calculate the distributions for functions of random variables

CO2: Compute Expected value and higher order moments of random variables for two dimensional random variable

CO3: Apply the mathematical tools that are needed to solve optimization problems

CO4: Apply Inventory models in making simulations

CO5: Apply Fourier series in solving real time problems in power signals and spectrum

REFERENCES:

1. Grewal, B.S., Higher Engineering Mathematics, 42nd edition, Khanna Publishers, 2012.
2. O'Neil, P.V., Advanced Engineering Mathematics, Thomson Asia Pvt. Ltd., Singapore,2003.
3. Hamdy A Taha, Introduction to Operations Research, Prentice Hall India, Seventh Edition, Third Indian Reprint 2004.
4. G. Srinivasan, Operations Research – Principles and Applications, PHI, 2007.
5. Gupta P.K, Hira D.S, Problem in Operations Research, S.Chand and Co, 2007.
6. Kalavathy S, Operations Research, Second Edition, Vikas Publishing House, 2004
7. Oliver C. Ibe, "Fundamentals of Applied Probability and Random Processes, Academic Press, (An imprint of Elsevier), 2010
8. Andrews L.C. and Phillips R.L., Mathematical Techniques for Engineers and Scientists, Prentice Hall of India Pvt.Ltd., New Delhi, 2005

1702PE102	POWER SEMICONDUCTOR DEVICES AND RECENT ADVANCEMENTS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. To understand the basic concepts of power semiconductor devices.
2. To analyze the characteristics of various devices
3. To design a power electronic circuit for an application.

UNIT I INTRODUCTION **9 Hours**

Status of development of power semiconductor Devices – Types of static switches – Controlled and uncontrolled – Ideal and real switches – Static and dynamic performance – Use of heat sinks – Switching losses.

UNIT II POWER DIODES **9 Hours**

Types – Electrical rating – Switching and steady state characteristics – Snubber circuits – Series and parallel operation – Schottly diodes – Fast recovery diodes.

UNIT III THYRISTORS **9 Hours**

Physics of device operation – Electrical rating - Switching and steady state characteristics – Gate circuit requirements – Protection – Series and parallel operation – Driver circuit – Types of thyristors: Asymmetrical thyristor – Reverse conducting Thyristor – Light fired thyristor – Switching losses - TRIACs, GTOs and MCTs - Electrical rating - Switching and steady state characteristics – Protection – Gate circuit requirements.

UNIT IV POWER TRANSISTORS **9 Hours**

Types – Ratings – Static and switching characteristics – Driver circuit – Snubber circuits – Power Darlington - Power MOSFETs -Types – Comparison with BJTs – Structure – Principle of operation – Switching losses – Driver circuit – Snubber circuits.

UNIT V IGBTS AND MODERN POWER DEVICES **9 Hours**

Comparison with power BJT and MOSFET – Structure – Principle of working – Switching characteristics – Gate drive requirements – HV IGBT structure – Principle of working – Comparison with GTO -SITs – Characteristics – Power integrated circuit – Characteristics – Field controlled thyristors – New semiconductor materials for devices – Intelligent power modules. Integrated gate commutated thyristor (IGCT) - Comparison of all power devices.

TOTAL: 45 HOURS

FURTHER READING:

Application of Power Devices in Power System Protection Circuits.

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: Explain the recent developments in Power Semiconductor Devices.
CO2: Describe the construction and working features of Power Devices like power diodes, thyristors, power transistors and IGBTs.
CO3: Explain the characteristics of power semiconductor devices.
CO4: Explain the switching losses present in the devices.
CO5: Explain and apply protection circuit for each device.

REFERENCES:

1. Joseph Vithayathil, *Power Electronics: Principles and Applications*, Delhi, Tata McGraw-Hill, 2010.
2. Ned Mohan, Tore M. Undeland and William P.Robbins, *Power Electronics: Converters, Applications and Design*, New Jersey, John Wiley and Sons, 2003.
3. M.H. Rashid, *Power Electronics: Circuits, Devices and Application*, New Delhi, Prentice Hall of India, 2004.
4. M D Singh and K B Khanchandani, *Power Electronics*, New Delhi, Tata McGraw-Hill, 2008.
5. B.W. Williams, *Power Electronics: Devices, Drivers, Applications and Passive Components*, New York, McGraw-Hill, 1992

1702PE103	ANALYSIS OF POWER CONVERTERS	L	T	P	C
		3	0	0	3

Course Objectives:

1. To understand the classifications of power converters.
2. To analyze the power converters to determine its various performance parameters.
3. To apply PWM techniques for different power converters.

UNIT I SINGLE PHASE AC-DC CONVERTER 9 Hours

Static Characteristics of power diode, SCR and GTO, half controlled and fully controlled converters with R-L, R-L-E loads and freewheeling diodes – continuous and discontinuous modes of operation - inverter operation –Sequence control of converters – performance parameters: harmonics, ripple, distortion, power factor – effect of source impedance and Overlap-reactive power and power balance in converter circuits

UNIT II THREE PHASE AC-DC CONVERTER 9 Hours

Semi and fully controlled converter with R, R-L, R-L-E - loads and freewheeling diodes – inverter operation and its limit – performance parameters – effect of source impedance and over lap – 12 pulse converter.

UNIT III SINGLE PHASE INVERTERS 9 Hours

Introduction to self-commutated switches : MOSFET and IGBT - Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – various harmonic elimination techniques – forced commutated Thyristor inverters – Design of UPS

UNIT IV THREE PHASE INVERTERS 9 Hours

180 degree and 120 degree conduction mode inverters with star and delta connected loads – voltage control of three phase inverters: single, multi pulse, sinusoidal, space vector modulation techniques – Application to drive system – Current source inverters.

UNIT V MODERN INVERTERS 9 Hours

Multilevel concept – diode clamped – flying capacitor – cascade type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters – PWM techniques for MLI – Single phase & Three phase Impedance source inverters - Filters.

TOTAL: 45 HOURS

FURTHER READING:

Application of Random PWM techniques for Power Converters

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: List the classifications of power converters
CO2: Explain the different modes of operation of power converters like AC- DC & DC – AC converters (Single Phase & Three phase).
CO3: Explain the control of power converters with various PWM techniques like Single, Multi, Sine and SVPWM.
CO4: Analyze the performance parameters of power converters.
CO5: Explain the application of power converters.

REFERENCES:

1. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hall India, Third Edition, New Delhi, 2004.
2. Jai P.Agrawal, “Power Electronics Systems”, Pearson Education, Second Edition, 2002.
3. Bimal K.Bose “Modern Power Electronics and AC Drives”, Pearson Education, Second Edition, 2003.
4. Ned Mohan,T.MUndeland and W.P Robbin, “Power Electronics: converters, Application and design” John Wiley and sons.Wiley India edition, 2006.
5. Philip T. krein, “Elements of Power Electronics” Oxford University Press -1998.
6. P.C. Sen, “Modern Power Electronics”, Wheeler Publishing Co, First Edition, New Delhi,1998.
7. P.S.Bimbra, “Power Electronics”, Khanna Publishers, Eleventh Edition, 2003.

1702PE104	ANALYSIS OF INVERTERS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. To understand the classifications of Inverters.
2. To analyze the Inverters to determine its various performance parameters.
3. To analyze ZVS and ZCS in a inverter.

UNIT I BASIC INVERTERS 9 Hours

Basic series inverter – Modified series inverter- High frequency series inverter- Design of L and C – Parallel inverter- Design of parallel inverter.- Line commutated inverter – Concepts of PWM techniques.

UNIT II VOLTAGE SOURCE INVERTERS 9 Hours

Principle of operation of half and full bridge inverters – Three phase inverters with 180 degree and 120 degree conduction mode with star and delta connected loads- Performance parameters – Voltage control of single phase and three phase inverters using various PWM techniques – Various harmonic elimination techniques.

UNIT III CURRENT SOURCE AND IMPEDANCE SOURCE INVERTERS 9 Hours

Load commutated current source inverter- Single phase and three phase auto sequential current source inverter (ASCI) – Principle of operation of impedance source inverter- Shoot thro zero state – Comparison of current source inverter, Voltage source inverters and impedance source inverter

UNIT IV MULTILEVEL INVERTERS 9 Hours

Multilevel concept – Diode clamped – Flying capacitor – Cascade type multilevel inverters – Hybrid multi level inverter- FFT analysis- Comparison of multilevel inverters - Applications of multilevel inverters.

UNIT V RESONANT INVERTERS 9 Hours

Concept of Zero Voltage Switching and Zero Current Switching - Series and parallel resonant inverters - Voltage control of resonant inverters – Class E resonant inverter – Resonant DC Link inverters.

TOTAL: 45 HOURS

FURTHER READING:

Applications of Inverters in Renewable Energy system

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: Explain the performance of series and parallel inverter with PWM techniques
CO2: Explain the working of voltage source inverters and also its control with PWM techniques.
CO3: Explain the working of current source inverter and impedance source inverter.
CO4: Explain the classifications, working and applications of multilevel inverter.
CO5: Explain the concept of ZVS, ZCS and resonant inverters.

REFERENCES:

1. P.S. Bimbra, *Power Electronics*, New Delhi, Khanna Publishers, 2006.
2. M.H. Rashid, *Hand Book of Power Electronics: Circuits, Devices and Application*, New Delhi, Prentice Hall of India, 2007.
3. Ned Mohan, Tore M. Undeland and William P.Robbins, *Power Electronics: Converters, Applications and Design*, 3rd Edition, John Wiley and Sons, 2002.
4. Jai P. Agrawal, *Power Electronics Systems*, 2nd Edition, Pearson Education, 2002.
5. Bimal K. Bose, *Modern Power Electronics and Motor Drive- Advances and Trends*, 2nd Edition, Pearson Education, 2006.

1702PE105 MODELING AND ANALYSIS OF ELECTRICAL MACHINES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To understand the classifications of power converters.
2. To analyze the power converters to determine its various performance parameters.
3. To apply PWM techniques for different power converters.

UNIT I CONCEPTS OF ROTATING MACHINES **9 Hours**

Calculation of air gap mmf of a single turn full pitch distributed armature windings - Per phase full pitched and short pitched armature coils (AC machines) - Calculation of air gap mmf of a DC machine - Introduction to direct axis and quadrature axis theory in salient pole machines - Calculation of air gap inductances of a synchronous machine.

UNIT II INDUCTION MACHINE MODELING **9 Hours**

Static and rotating References: frames, transformation relationships - Stationary circuit variables transformed to the arbitrary Reference frame treating R, L, C elements separately - Application of Reference frame theory to three phase symmetrical induction machine - Direct and quadrature axis model in arbitrarily rotating Reference frame - Voltage and torque equations.

UNIT III SYNCHRONOUS MACHINE MODELING **9 Hours**

Application of reference frame theory to three phase synchronous machine-dynamic model analysis-Park‟s equation - Voltage and torque equations - Deviation of steady state phasor relationship from dynamic model - Generalized theory of rotating electrical machine and Kron‟s primitive machine.

UNIT IV SYNCHRONOUS MACHINE MODELING **9 Hours**

Synchronous machine dynamic equivalent circuit parameters - Standard and derived machine time constants - Frequency response test, Analysis and dynamic modeling of two phase asymmetrical induction machine and single phase induction machine.

UNIT V SPECIAL MACHINES **9 Hours**

Permanent magnet synchronous machine, Surface permanent magnet (square and sinusoidal back emf type) and interior permanent magnet machines - Construction and operating principle - Dynamic modeling and self controlled operation – Dynamic analysis of Switched Reluctance Motors.

TOTAL: 45 HOURS

FURTHER READING:

Dynamic Modeling of Linear motors

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: Brief the fundamental concepts of rotating machines.
CO2: Determine the air gap mmf of DC and AC machines.
CO3: Explain the application of reference theory Induction Machine, Synchronous Machine and Special Machines.
CO4: Analyze the dynamic modeling of Induction Machine, Synchronous Machine and Special Machines.
CO5: Analyze the electrical machine equivalent parameters.

REFERENCES:

1. Charles Kingsley Jr., A.E. Fitzgerald and Stephen D.Umans, *Electric Machinery*, New York, McGraw-Hill Higher Education, 2010.
2. Paul C. Krause, Oleg Wasynczuk and Scott D. Sudhoff, *Analysis of Electric Machinery and Drive Systems*,New Jersey, Wiley Student Edition, 2013.
3. R. Krishnan, *Electric Motor & Drives: Modeling, Analysis and Control*, New Delhi, Prentice Hall of India,2001.
4. T.J.E. Miller and J R Hendershot Jr., *Design of Brushless Permanent Magnet Motors*, USA, Oxford University Press, 1994.
5. T.J.E. Miller, *Reluctance Motor and their Controls*, USA, Oxford University Press, 1993

1704PE106	POWER ELECTRONICS LABORATORY	L	T	P	C
		0	0	4	2

COURSE OBJECTIVES:

1. To obtain the switching characteristic of different types of power semi-conductor devices.
2. To determine the operation, characteristics and performance parameters of controlled rectifiers.
3. To apply switching techniques and basic topologies of DC-DC switching regulators.

LIST OF EXPERIMENTS:

1. Design of RC & UJT Firing Circuit
2. Design and study of Driver and Commutation Circuits for chopper and inverters.
3. Design and analysis of Series and Parallel Inverter.
4. Develop a Single phase 7 level multilevel inverter.
5. Design and analysis of CSI.
6. Analysis of single phase Cycloconverter.
7. Design the MOSFET driver using Driver IC IR2110.
8. Fabricate the OPTO Isolator for Three phase converter.
9. Design of firing circuit for three phase voltage source inverter.
10. Generate the three phase SPWM pulse using Embedded controller.

TOTAL: 45 HOURS

ADDITIONAL EXPERIMENTS:

Fabricate the Boost converter for Photovoltaic applications

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: Draw the characteristics of Power electronics devices.
CO2: Determine the various parameters of single phase and three phase rectifier.
CO3: Demonstrate the response of chopper for a dc load
CO4: Diagnose the various causes of harmonics
CO5: Design a PWM converter and an ac voltage regulator

REFERENCES:

1. Ned Mohan,T.M. Undeland and W.P Robbin, “Power Electronics: converters, Application and design” John Wiley and sons. Wiley India edition, 2006.
2. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hal India, New Delhi, 1995

1704PE107 POWER ELECTRONICS SIMULATION LABORATORY

L	T	P	C
0	0	4	2

COURSE OBJECTIVES:

1. To determine the performance curves for various power electronic circuits.
2. To determine the performance parameters of various power electronic circuits
3. To determine the solutions for differential equations.

LIST OF EXPERIMENTS:

1. Simulation of single phase half wave controlled converter fed RLE load2.
2. Simulation of single phase fully controlled converter fed RLE load.
3. Simulation of three phase half controlled converter fed RL load.
4. Simulation of three phase fully controlled converter fed RL load.
5. Simulation of dynamics of armature plunger / relay contactor arrangement.
6. Simulation of dynamics of doubly excited system.
7. Simulation of single phase VSI fed RL/RC load.
8. Simulation of i) LC tank circuit resonance, ii) Basic / modified series inverter, iii) Series loaded series resonant inverter
9. Simulation of single phase current source inverter fed induction heating load.
10. Simulation of multi level inverter topologies.
11. Numerical solution of ordinary differential equations.
12. Numerical solution of partial differential equations

TOTAL: 45 HOURS

ADDITIONAL EXPERIMENTS:

Simulation of a Power Converter with SVPWM technique.

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: Simulate the different power converters with RL Load to determine the performance curves.
CO2: Simulate the different power converters with RLE Load to determine the performance curves.
CO3: Simulate the different power converters with RL Load to determine the performance parameters.
CO4: Simulate the different power converters with RLE Load to determine the performance parameters.
CO5: Simulate the differential equations to find out the numerical solution.

REFERENCES:

1. Ned Mohan,T.M. Undeland and W.P Robbin, “Power Electronics: converters, Application and design” John Wiley and sons. Wiley India edition, 2006.
2. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hal India, New Delhi, 1995.

1704PE108	COMMUNICATION SKILLS LAB I (Common to all M.E Progarmmes)	L	T	P	C
		0	0	2	1

COURSE OBJECTIVES:

1. To acquire skills for using English in workplace effectively.
2. To communicate for essential business needs.
3. To prepare students for taking BEC Vantage level examination which is an International Benchmark for English language proficiency of Cambridge English Language Assessment

LIST OF EXPERIMENTS:

1. GRAMMAR AND VOCABULARY

Forming asking complex questions – expressing purpose and function –modal verbs – impersonal passive voice– Reported speech – cause and effect – relative pronouns – expressions followed by – *ing* forms– acronyms – marketing terms / vocabulary – financial terms – collocations – discourse markers

2. LISTENING

Purposes of listening – features of listening texts – potential barriers to listening – specific listening skills – strategies to use when listening– distinguishing relevant from irrelevant information – gap filling exercise – multiple-choice options – note completion – matching and multiple choice questions – listening for specific information, gist, topic, context and function.

3. SPEAKING

Word and sentence stress – clear individual sounds – turn taking – initiating and responding - intonation patterns – pronunciation – mother tongue intrusion– conversation practice – turn-taking and sustaining the interaction by initiating and responding appropriately- Public Speech – Lectures.

4. READING

Purposes of reading – potential barriers to reading – paraphrasing – identifying facts and ideas – skimming and scanning for information – matching statements with texts– spotting reference words – understanding text structure – understanding the ideas in a text – distinguishing between the correct answer and the distracter – understanding cohesion in a text – deciphering contextual meaning of words and phrases – cloze – proof reading - transcoding.

5. WRITING

Paragraphing a text – using appropriate connectives – editing practice –Longer Documents: writing a proposal & Reports, Agenda – Minutes – Circular

TOTAL: 30 HOURS

ADDITIONAL EXPERIMENTS:

1. Body Language: Kinesics, Proxemics, Para linguistic, Nuances of Speech Delivery
2. Personality Development: Building self esteem
3. Team work

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: To enable students to get International recognition for work and study.

CO2: To use English confidently in the International business environments.

CO3: To be able to take part in business discussion, read company literature, write formal and informal business correspondences and listen and understand business conversations

REFERENCES:

1. Guy Brook-Hart, "BEC VANTAGE: BUSINESS BENCHMARK Upper-Intermediate – Student's Book", 1st Edition, Cambridge University Press, New Delhi, 2006.
2. Cambridge Examinations Publishing, "Cambridge BEC VANTAGE – Self-study Edition", Cambridge University Press, UK, 2005.
3. Swets, Paul. W. 1983. The Art of Talking So That People Will Listen: Getting
4. The Process of Writing: Planning and Research, Writing, Drafting and Revising

1703PE012 SOLAR AND ENERGY STORAGE SYSTEM

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To understand the fundamentals of semiconductors and solar cells.
2. To analyze the power generation from solar energy.
3. To analyze the energy storage system for energy generated through solar.

UNIT I INTRODUCTION **9 Hours**

Characteristics of sunlight – semiconductors and P-N junctions –behavior of solar cells – cell properties – PV cell interconnection

UNIT II STAND ALONE PV SYSTEM **9 Hours**

Solar modules – storage systems – power conditioning and regulation - protection – stand alone PV systems design – sizing

UNIT III GRID CONNECTED PV SYSTEMS **9 Hours**

PV systems in buildings – design issues for central power stations – safety – Economic aspect – Efficiency and performance - International PV programs

UNIT IV ENERGY STORAGE SYSTEMS **9 Hours**

Impact of intermittent generation – Battery energy storage – solar thermal energy storage – pumped hydroelectric energy storage

UNIT V APPLICATIONS **9 Hours**

Water pumping – battery chargers – solar car – direct-drive applications –Space – Telecommunications.

TOTAL: 45 HOURS

FURTHER READING:

Applications of solar energy system in Indian satellites – A Case Study.

COURSE OUTCOMES:

On the successful completion of the course, students will be able to

CO1: Explain the fundamentals of solar energy system, semiconductors and solar cells.
CO2: Explain the energy generation from stand alone solar energy conversion system.
CO3: Explain the energy generation from grid integration solar energy conversion system.
CO4: Explain the energy storage system for solar energy conversion system.
CO5: Explain the applications of solar energy conversion system.

REFERENCES:

1. Eduardo Lorenzo G. Araujo, Solar electricity engineering of photovoltaic systems,Progensa,1994.
2. Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, Applied Photovoltaics, 2007,Earth scan, UK.
3. Frank S. Barnes & Jonah G. Levine, Large Energy storage Systems Handbook , CRC Press, 2011.
4. Solar & Wind energy Technologies – McNeils, Frenkel, Desai, Wiley Eastern, 1990
5. Solar Energy – S.P. Sukhatme, Tata McGraw Hill,1987.