

36.3.0 POWER ELECTRONICS

36.3.01 Introduction

This module unit is designed to equip the trainee with appropriate knowledge, skills and attitudes necessary for the design, fabrication and maintenance of the power electronic systems and equipment.

36.3.02 General Objectives

At the end of the module unit, the trainee should be able to;

- a) Understand the operation and performance characteristics of power electronic devices.
- b) Explain the applications of power electronic devices
- c) Describe the operation of converters
- d) Understand the operation of Inverters
- e) Analyze the ac voltage controllers
- f) Apply the principles of power controls in electrical machines and equipment

36.3.03 Module Unit Summary and Time Allocation

Power Electronics

Code	Sub Module Unit	Content	Time Hours
36.3.1	Power semi-conductor devices	<ul style="list-style-type: none">• Construction and Operation, of special semi conductor devices• Analyses of semiconductor devices• Application of special semi conductor devices	10
36.3.2	Rectifier circuits	<ul style="list-style-type: none">• Rectifier circuits• Calculations related to rectifiers circuit• Controlled rectification techniques• Phase shift circuits• Calculations related to phase shift circuits for power control• Converter operation• Dc line commutation• Applications of controlled rectifier system	10
36.3.3	Cyclo-converters	<ul style="list-style-type: none">• Operation	12

		Principles of Cyclo-converters <ul style="list-style-type: none"> • Operation of Single phase to single phase circuit • Operation of Three phase half-wave Cyclo-converter • Operation of Load Commutated Cyclo converters • Envelope Cyclo-converter Operation • Applications of Cyclo-converters 	
36.3.4	Inverters	<ul style="list-style-type: none"> • Single phase inverters • Forced commutated thyristor inverters • Three phase bridge inverters • Pulse-width Modulated Inverters • Current source inverters • Series Inverters • Parallel inverters • Steady state inverter output voltage • Applications of inverters 	12
36.3.5	Electric drives	<ul style="list-style-type: none"> • Dc motor drives. • Dc motor control circuits • Dc motor speed controller • Ac machine drives • Ac motor controls • Motor control systems 	12
36.3.6	High frequency power sources and heating	<ul style="list-style-type: none"> • High frequency power source • Induction heating process • Di electric heating process • Operation of resistance heating process • Eddy current heating process • Solar heating systems 	10
Total time			66

36.3.1 POWER SEMI-CONDUCTOR DEVICES

Theory

36.3.1T0 Specific Objectives

By the end of this module unit the trainee should be able to;

- a) explain the construction, operation and characteristics of various types of special semi conductor devices
- b) analyze power electronic circuits
- c) describe the applications of power semiconductor devices.

Content

- 36.3.1T1** Construction, operation, characteristic and applications
- i) SCR
 - ii) Diac
 - iii) Triac
 - iv) power transistors
 - v) power MOSFET
 - vi) insulated gate bipolar transistor
 - vii) MOS controlled thyristors
 - viii) SCR
 - ix) GTO
 - x) other thyristor devices

Practice

36.3.1P0 Specific Objectives

By the end of the sub-module unit the trainee should be able to:

- a) classify the power electronic and special semiconductor devices
- b) design a voltage regulator
- c) analyze the characteristics of the power electronic devices
- d) apply power electronic devices in electrical and electronic circuits

Content

- 36.3.1P1** Power Electronic devices
- i) UJT
 - ii) SCR
 - iii) DIAC
 - iv) Power Transistors
- 36.3.1P2** The voltage regulator
- 36.3.1P3** Characteristics of power electronic devices
- 36.3.1P4** Applications of power electronic devices

36.3.1C Competence

The trainee should have the ability to:

- i) classify the electronic semiconductor devices
- ii) design and fabricate a Voltage regulator

Suggested teaching/Learning Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise
- Calculations
- Project work

Suggested Teaching and Learning Resources

- Relevant text books

- Assortment of power electronic devices
- Connecting leads
- Strip boards
- CRO
- Signal Analyzer

36.3.2T1

Content

- Rectifier circuits
- i) Single phase half wave rectifiers
 - Uncontrolled
 - Fully controlled
 - Half controlled
 - Bi-phase half wave rectifier
 - Single phase bridge rectifier
 - ii) Three phase half wave rectifier
 - iii) Twelve pulse circuits
 - iv) Choice of transformer in rectification
 - v) Single phase two pulse converters with discontinuous load current
 - vi) full converter
 - vii) semi-converter
 - viii) Dual converters
 - ix) Converters' Power Factor
 - x) Regulation of Converters
 - xi) Inversion
 - xii) P-pulse equation

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests
- Project

36.3.2 RECTIFIER CIRCUITS

Theory

36.3.2 T0 Specific Objectives

By the end of the sub-module, the trainee should be able to;

- a) describe operation of rectifier circuits.
- b) solve problems related to rectifier circuits.
- c) explain controlled rectification techniques.
- d) describe phase shift circuits for power control
- e) solve problems on phase shift circuits for power controls.
- f) explain converter operation.
- g) solve problems on converter operation.
- h) explain dc line commutation.
- i) illustrate the applications of controlled rectifier system.

36.3.2T2

Calculations related to rectifiers circuit

36.3.2T3

Controlled rectification

36.3.2T4

Phase shift circuits

36.3.2T5

Calculations related to phase shift circuits for power control

36.3.2T6

Converter operation

36.3.2T7

Dc line commutation

36.3.2T8

Applications of controlled rectifier system

Practice

- 36.3.2P0 *Specific Objectives*
By the end of the module unit the trainee should be able to:
- test the outputs from converters
 - design a converter system
 - fabricate a converter system

Content

- 36.3.2P2 Single phase half wave rectifiers
- Uncontrolled
 - Fully controlled
 - Half controlled
- 36.3.2P3 Bi-phase half wave rectifier
- 36.3.2P4 Single phase bridge rectifier
- 36.3.2P5 Three phase half wave rectifier

36.3.2C Competence

The trainee should have the ability to:

- test the converter circuits
- fabricate converter circuits

Suggested teaching/Learning

Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise
- Project work

Suggested Teaching and Learning Resources

- Relevant text Books
- Assorted rectifier devices
- Strip boards
- Assorted Fabrication Accessories
- CRO
- Signal Analyzers

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests
- Project

36.3.3 CYCLO-CONVERTERS

Theory

- 36.3.3T0 *Specific Objectives*
By the end of the sub-module, the trainee should be able to:
- describe the operation of the Cyclo-converter.
 - solve problems on single phase to single phase rectifier circuits.
 - Explain the operation of three phase –half wave cyclo converters
 - Explain the operation of load commutated cyclo converters
 - Explain the operation of envelop cyclo converter operation
 - Identify applications of cyclo converters

Content

- 36.3.3T1 Operation

	principles of Cyclo-converters		a) analyze the outputs of cyclo-converter signals
	i) Block to group operation		b) design and fabricate a cyclo-converter system
	ii) Circulating current mode		c) install a cyclo-converter system
	iii) Cyclo-converters in Control		
36.3.3T2	Operation of Single phase to single phase circuit		
	i) Step down Cyclo-converter operation		
	ii) Midpoint Cyclo-converter		
	iii) Bridge type Cyclo-converter		
	iv) Output voltage equations		
36.3.3T3	Operation of Three phase half-wave Cyclo-converter		
	i) Three-phase to Single-phase Cyclo-converters		
	ii) Three-phase to Three-phase Cyclo-converters		
	iii) Output Voltage equation		
36.3.3T4	Operation of Load Commutated Cyclo-converters		
36.3.3T5	Envelope Cyclo-converter Operation		
36.3.3T6	The Applications of Cyclo-converters		
	Practice		
36.3.3P0	<i>Specific Objectives</i> By the end of the module unit the trainee should be able to:		
		36.3.3P7	<i>Content</i> Single phase to single phase – step up i) Midpoint Cyclo-converter ii) Bridge type Cyclo-converter iii) Output voltage equations
		36.3.3T8	Three phase half-wave Cyclo-converter i) Three-phase to Single-phase Cyclo-converters ii) Three-phase to Three-phase Cyclo-converters iii) Output Voltage equation
			<i>Suggested teaching/Learning Activities</i> - Discussion - Illustration - Demonstration - Note taking - Practical exercise - Project work
			<i>Suggested Teaching/Learning Resources</i> - Relevant Text Books - Assorted Power Electronic Devices - Signal analyzer - Strip boards - Assorted materials ,tools and equipment
		36.3.3C	Competence

The trainee should have the ability to:		<i>Content</i>
i) Analyze Cyclo-converter outputs ii) Design and construct a Cyclo-converter system	36.3.4T1	Operation principles of Single-phase Inverters i) Single-phase Bridge Inverters ii) Steady-state analysis of single-Phase Inverters iii) Fourier Analysis of Single-phase Inverters iv) Voltage control in single phase inverters
<i>Suggested Evaluation Methods</i>	36.3.4T2	Operation of Forced – commutated Thyristor Inverters i) Half-Bridge Inverters ii) Full-Bridge inverters
- Oral tests - Timed written tests - Assignments - Timed practical tests - Project	36.3.4T3	Operation of three phase Bridge inverters i) Three phase 180 degree mode ii) Three phase 120degree mode
36.3.4 INVERTERS	36.3.4T4	Operation of pulse width modulated inverters i) Single-pulse modulation ii) Multiple-pulse modulation iii) Sinusoidal-pulse modulation
Theory	36.3.4T5	Operation of current Source inverters i) Single phase CSI with ideal switches ii) Single phase-capacitor commutated CSI with R load iii) Single phase Auto-sequential commutated inverters
36.3.4T0 <i>Specific Objectives</i> By the end of the sub-module unit, the trainee should be able to:	36.3.4T6	Operation of Series inverters i) Basic Series inverters
a) describe the operation of single phase inverters b) explain the operation of forced commutated thyristor inverters c) describe the operation of three phase bridge inverters d) describe the operation of pulse-width modulated inverters e) explain the operation series inverters f) describe the operation of parallel inverters g) analyze the steady state-state inverter output voltage h) explain the applications of inverters		

- ii) Analysis of Series Inverters
- 36.3.4T7 Operation of Parallel inverters
 - Analysis of Parallel Inverters
- 36.3.4T8 steady state inverter output voltage
 - Reduction of Harmonics in the Inverters Voltage Output
- 36.3.4T9 Applications of inverters

- i) Single-pulse modulation
- ii) Multiple-pulse modulation
- iii) Sinusoidal-pulse modulation
- 36.3.4P13 Current Source Inverters
 - i) Single phase CSI with ideal switches
 - ii) Single phase-capacitor commutated CSI with R load
 - iii) Project work

Practice

- 36.3.4P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
 - a) analyze the inverter output voltage
 - b) design and construct an inverter system
 - c) service and maintain an inverter system

Suggested teaching/Learning Activities

- Discussion
- Illustration
- Demonstration
- Note taking
- Practical exercise
- Visits to industries

Content

- 36.3.4P1 Single-phase Bridge Inverters
 - i) Steady-state analysis of single-Phase Inverters
 - ii) Fourier Analysis of Single-phase Inverters
 - iii) Voltage control in single phase inverters
- 36.3.4P10 Forced –commutated Thyristor Inverters
 - i) Half-Bridge Inverters
 - ii) Full-Bridge inverters
- 36.3.4P11 Three phase Bridge inverters mode
- 36.3.4P12 Pulse-width modulated inverters

Suggested Teaching and Learning Resources

- Relevant Text books
- Assorted Power Electronic Devices
- Assorted tools and accessories
- Signal Analyzers

36.3.4C

Competence

- The trainee should have the ability to:
- i) Design and construct an inverter
 - ii) Service and maintain an Inverter system

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments

	- Timed practical tests		viii) three-phase dual-converter drives
	- Project		
36.3.5 ELECTRIC DRIVES		36.3.5T2	A.c electric drive
	Theory		i) Operation and performance
36.3.5	<i>Specific Objectives</i>		ii) Synchronous Machines
	By the end of the sub-module unit, the trainee should be able to:		iii) Cage Induction Motors
	a) explain the operation of dc motor drives		iv) Slip-ring Induction Motors
	b) describe dc motor control systems	36.3.5T3	DC motor speed controls
	c) analyze dc motor speed control circuits		i) traction drives
	d) describe the operation of ac machine drives		ii) control feedbacks\
	e) analyze the ac motor controls		iii) chopper drive controls
	f) explain the applications of ac motor control systems	36.3.5T4	Ac machines speed controls
			i) Motor speed control by voltage regulation
			ii) Transformer tap changers
			iii) Cyclo-converter control
			iv) Reluctance and stepper motor drives
			v) Constant voltage inverters control
			vi) Constant current controls
			vii) Transistorized inverter controls
	<i>Content</i>		Practice
36.3.5T1	Dc motor drive		
	i) Operation and performance equations		
	ii) single-phase half-wave converter drives		
	iii) single-phase semi-converter drives		
	iv) single-phase full-wave converter drives		
	v) three-phase half-wave converter drives		
	vi) three-phase semi-converter drives		
	vii) three-phase full-wave converter drives	36.3.5P0	<i>Specific Objectives</i>
			By the end of the sub-module unit, the trainee should be able to:
			a) operate motor controls
			b) service motor control system
			c) install motor control system

- d) design a motor control system

Content

- 36.3.5P5 Dc Electric Drives
- 36.3.5P6 Ac Electric Drives
- 36.3.5P7 Dc Motor Speed Controls
- 36.3.5P8 Ac motor Speed Controls

- 36.3.5C Competence**
The trainee should have the ability to:
- i) Operate a motor control system
 - ii) Design a motor control system
 - iii) Install and maintain motor control system

Suggested Teaching and Learning Resources

- Relevant text books
- Motor Control Equipment
- Simulation Equipment
- Assorted Components, tools and equipment

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests
- Project

36.3.6 HIGH FREQUENCY POWER SOURCES AND HEATING

Theory

- 36.3.6 *Specific Objectives*

By the end of the sub-module unit, the trainee should be able to:

- a) explain the operation of high frequency power source.
- b) describe induction heating process.
- c) analyze dielectric heating process.
- d) explain the operation of resistance heating process
- e) describe eddy current heating process.
- f) explain the solar heating system

Content

- 36.3.6T1 Operation of high frequency power sources
 - i) Thyatron
 - ii) Magnetrón
 - iii) Klystron
- 36.3.6T2 Operation and design of Uninterruptable power sources
 - i) UPS
 - ii) PWM power supply
 - iii) Transformer isolated switching mode power supply
- 36.3.6T3 Operation of high frequency heating systems
 - i) Induction heating
 - ii) Resistance heating
 - iii) Eddy current heating
 - iv) Dielectric heating
- 36.3.6T4 Solar Heating

Practice

- 36.3.6P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:

- a) Maintain a High frequency heating device
- b) Design solar heater system
- c) Install and maintain solar heater system

- ii) Maintain high frequency heating system
- iii) Design and install UPS

Suggested Teaching and Learning Resources

- Relevant text books
- Solar Concentrators and accessories
- Assorted Power electronic components and devices

Content

36.3.6P7 High Frequency power sources

36.3.6P8 Uninterruptable Power Sources

36.3.6P9 High Frequency heating

36.3.6P10 Solar Heating

36.3.6C Competence

The trainee should have the ability to:

- i) Install and maintain a Solar Heating system

Suggested Evaluation Methods

- Oral tests
- Timed written tests
- Assignments
- Timed practical tests
- Project

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TOOLS AND EQUIPMENT FOR THE COURSE

FOR 20 TRAINEES

A	Measuring Instruments	QTY
	1. Ac Ammeters Multirange	15
	2. Ac Voltmeter	15
	3. Cathode Ray Oscilloscope	5
	4. Clip On Meters	5
	5. Dc Ammeters	15
	6. Dc Millimetres	15
	7. Dc Voltmeters	10
	8. Electrodynamics Wattmeter- Three Phase	5
	9. Electrodynamics Wattmeter- Single Phase	15
	10. Frequency meter	5
	11. Galvanometers (Central Zero)	10
	12. High Temperatures Thermometers	5
	13. Insulation Resistance Tester	5
	14. Line Earth Loop Impedance Tester	5
	15. Multi Meters (Multirange)	5
	16. Tachometers	5
	17. Transformer Tester	5
B	Tools	
	1. Allan Screw Set	5
	2. Assorted Sizes And Types Of Pliers	5 of each type/size
	3. Assorted Types And Sizes Of Screw Drivers	5 of each type/size
	4. Bradawl	10
	5. Brass Wood Mallet	5
	6. Centre Punch	5
	7. Chisels	5
	8. Claw And Ball Type Hammers	5

9. Drill Gauge	5
10. Electric Soldering Iron (various sizes)	5 of each size
11. Electrician Knife	5
12. Electrician Tool Kit	5
13. Fish Tape	5
14. Framing Square	5
15. Gripping Tool	5
16. Hacksaw Frames and Blades	10
17. Hand Reamers	10
18. Knock Out Punches	10
19. Micrometer	5
20. MIMS Cable Terminating Tools	5
21. Nuts Driver Sets	5
22. Phase Tester	10
23. Pipe Bending Springs	10
24. Pipe Cutter	5
25. Pipe Pliers	5
26. Pipe Stocks And Die	10 sets
27. Pipe Wrench	10
28. Plumb Bobs	5
29. Precision Screw Drivers (set)	5
30. Prick Punches	5
31. Scribes	10
32. Side Cutting Tool	10
33. Spirit Level	10
34. Standard Wire Gauge	5
35. Steel Measuring Tape -3m	10
36. Tin Snips	10
37. Try Square	10
38. Various Type And Sizes Of Files	10 each
39. Vervier Callipers	5

40. Vice Grip Pliers	5
41. Wire Strippers	10

C Equipment

1. Air conditioning units	5
2. Audio Function generators	5
3. Battery Charger	1set
4. Bells 240 volts	15
5. Bells 12 volts	15
6. Bench Vices	6
7. Blow Out Lamp	5
8. Bread Boards	21
9. Charge Controllers For Solar Systems	5
10. Circuit breakers (various sizes)	5 each
11. Computers and computer peripherals(workstation)	21
12. Conduit Benders	5
13. Dc Power Supply Units	6
14. Digital Counter	5
15. Digital Function Generators	5
16. Digital Trainer Kit	6
17. Dish Reflectors - for Solar Harvesting	1
18. Drawing Equipment	21
19. Drill Press	4
20. Electrical Consumer Control Unit	5
21. Electrical Distribution Boards	5
22. Electro traction simulators	5
23. Electronic /Electrical Bell Indicator Boards	5 each
24. Electronic Tool Kit	5
25. Fire Extinguishers	5
26. First Aid Kit	2
27. Flat Plate Collector	1

28. Fluorescent Fitting (various sizes	10 Of each
29. Folding Vices(Both Portable And Bench Vices)	10
30. Function/Arbitrary waveform generators	5
31. Grinder	2
32. Hand Drill	5
33. HRC fuses (various sizes)	10 of each
34. KVA meter	5
35. Lead acid cells	5
36. Line insulators	5
37. Microcontrollers trainer kit	10
38. Microprocessor units	10
39. Model Power Station	2
40. Motor simulators	10
41. Oxy acetylene gas equipment	1
42. Panel mounted digital multimeter and calibrator	5
43. Parabolic reflectors for solar harvesting	2
44. PID process control trainer	10
45. Pipe Vices	5
46. PLC control interface panel for measurement of level	5
47. Power Cut Out	5
48. Power Transformers(Variacs)	5
49. Programmable DC Electronic Loads	5
50. Programmable DC Power Supplies	5
51. Refrigerators	2
52. Relays (various rating)	20 each
53. Shearing machines	2
54. Solar batteries	5
55. Solar concentrators	5
56. Solar energy inverter	5
57. Solar module	5
58. Solar systems service kit	5

59. Solder sucker	10
60. Surge diverters	5
61. Synroscope	5
62. Used Electrical Appliances (enough)	
63. Ward Leonard dc/ac motors	5
64. X-Y Plotter	5

D-1 Electrical Machines – Transformers

1. Auto Transformers	5
2. Bell Transformers (12v/240v)	10
3. Current Transformers	5
4. Power Transformers	5
5. Variable Transformers	5

D-2 Electrical Machines – Motors

1. Capacitor Start – Run Motor	5
2. Dc Compound Motor	5
3. Dc Shunt Motor	5
4. Repulsion Induction Motor	5
5. Shaded Pole Motor	5
6. Split Phase Motor	5
7. Three Phase Induction Motor	5
8. Three Phase Synchronous Motor	5
9. Three Phase Wound Rotor Motor	5
10. Universal Motor	5

D-3 Electrical Machines – Generators

1. Ac Single Phase Generator	5
2. Ac Three Phase Generator	5
3. Dc Compound Generator	5
4. Dc Series Generator	5
5. Dc Shunt Generator	5

6. Diesel Generator 2

D-4 Motor Control Devices

- | | |
|-----------------------------------|---------|
| 1. Auxiliary Hold On Devices | Enough |
| 2. Direct On Line Starter | 5 |
| 3. Face Plate Starter | 5 |
| 4. Magnetic Relays (240/415V) | 15 Each |
| 5. SCR Speed Controller | 5 |
| 6. Star Delta Starter | 5 |
| 7. Start –Stop Push Buttons | 5 |
| 8. Magnetic Contactors (240/415V) | 15 Each |

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