



CURRICULUM FOR THE TRAINING AND CERTIFICATION OF PHOTOVOLTAIC PRACTITIONERS

BASIC PV TRAINING COURSES

SYLLABI AND REGULATIONS

Kenya renewable Energy Association
Kebs Centre, off Mombasa road
P.O. Box 15334-00100 GPO
Nairobi, Kenya

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Eng. Kiremu Magambo
Rencon Associates Ltd
Nairobi

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1. INTRODUCTION

Kenya has a very vibrant market driven solar PV business. Unfortunately this vibrant business sector does not have trained and experienced practitioners who can offer professionally designed and installed systems that perform well. Consequently, the design, installation and maintenance of solar PV systems is dominated by non-specialist technicians – the overwhelming majority of who have no solar PV training. As a result most solar systems installed in the country perform poorly and eventually fail leading to the widespread market perception that solar systems do not work and when they do, they perform poorly.

Performance problems, which are widespread, do not only reduce the utility of the systems for end users; but also limit the growth of the solar market by damaging the reputation of the capability of solar technology. Thus, efforts to increase the capacity of non-specialist technicians and to improve the awareness of solar end users will not only contribute to improving system performance, but will also enhance the long term growth and sustainability of the Kenya solar market.

The major obstacle to the development of expertise in the industry is lack of financing. In the year 2003, industry stakeholders approached the photovoltaic market transformation initiative (PVMTI), a GEF project being implemented in Kenya by IFC, to co-finance an industry wide local capacity building initiative. IFC accepted and approved the project in 2004.

There are few trainers and training institutions in the country that offer short courses in PV technology. However, there is no standard curriculum of instruction for the industry. This lack of a standard and structured curriculum of instruction has led to the production of PV technicians of varying and doubtful competencies.

This standard curriculum has been developed to provide for baseline training needs and certification of solar technicians for adoption by the industry. The curriculum also includes a syllabus for solar product knowledge training for entrepreneurs.

The technician course is designed specifically for school leavers who have acquired basic training in electrical, mechanical or electronics field. The entrepreneurs course is designed for individuals who have ventured into PV business to enhance their technology knowledge. The course is also open to individuals who intend to venture into the solar business.

The curriculum lays emphasis on developing basic practical and theoretical knowledge and skills in solar PV technology, products and systems.

2. General Objectives

The general objectives of the curriculum are: -

- i) To develop practical skills and attitudes among the participants to enable them to offer solar products and services that meet basic technical and performance standards to enhance the long term growth and sustainability of the solar market.

- ii) To impart basic technology knowledge and practical skills to the participant to enable them size, install, maintain, troubleshoot and repair basic PV systems generally referred to as solar home systems. The course for the training of technicians has been designed to meet this objective.
- iii) To impart basic technology and solar product knowledge to enable them to identify and market quality and functioning PV products and systems and offer satisfactory after sales service to their customers. The course for the training of entrepreneurs has been designed to meet this objective.
- iv) The curriculum provides for the entry-level technology knowledge and skills for those aspiring to pursue a technical or business career in the solar energy industry.

3. CURRICULUM STRUCTURE AND DURATION

3.1 Solar technicians course

3.1.1 Structure

The course comprises 18 topics covering technical aspects of PV products and systems and one topic covering business linkages and the basics of marketing. After each topic and where relevant, practical exercises are proposed.

3.1.2 Duration

The course duration is ninety six (96) hours.

The course may be delivered full time, Monday to Saturday for two weeks or part-time provided that the participants complete the whole course.

KEREA approved trainers and training institutions are at liberty to organize part-time or full time courses.

3.2 PV entrepreneurs course

3.2.1 Structure

The course comprises four topics covering technical aspects of PV systems and two topics covering business linkages and the basics of marketing.

3.2.2 Duration

The course duration is 16 hours. The course may be delivered full time for two days or part-time provided that the participants complete the whole course.

KEREA approved trainers and training institutions are at liberty to organize part-time or full time courses.

4. GENERAL REGULATIONS

4.1 Entry Requirements

4.1.1 Solar Technicians Course

Minimum entry requirements for this course are:

4.1.1.1 Education

Pass in Kenya Certificate of Primary Education or equivalent

4.1.1.2 Professional Training

- i) Basic qualification in the fields of electrical, mechanical, electronics qualification such as a trade test certificate or certificate from a technical training institution or
- ii) Other qualifications that demonstrate basic understanding of electrical, mechanical or electronics fundamentals.

4.1.2 PV entrepreneurs course

Participants must demonstrate that they have been in PV business for at least 1 year.

4.2 Evaluation

4.2.1 Solar technician

Evaluation shall comprise of course work, practicals and written examination at the end of the course. The following weights shall apply in determining the overall pass mark:

- i) Course work including design project - 20%
- ii) Practical - 30%
- iii) Written Exam - 50%.

The pass mark shall be 70%

4.2.2 PV entrepreneur

No evaluation is contemplated for this course.

4.3 Certification

4.3.1 Institutional certificates

4.3.1.1 Certificate in Basic Photovoltaic Technology

The training institutions shall issue **Certificate in Basic Photovoltaic Technology** to the technicians who have attended and successfully completed the solar technician course. A candidate shall be considered to have satisfactorily completed the course if he/she has attained the pass mark prescribed in 4.2.1

4.3.1.2 Certificate of Attendance

All participants who attend and complete the PV Entrepreneur course and those who fail to attain the requisite pass mark in the solar technician's course shall be awarded a Certificate of Attendance.

4.3.1.3 Wording of the Certificates

The trainer and institution awarding the certificates shall forward the wording of the certificates to KEREa for prior approval.

4.3.2 KEREa Certificate of Competency in Small stand-alone Photovoltaic Systems

A standard national **Certificate of Competency in Small Stand-alone Photovoltaic Systems** for solar technicians shall be issued to participants who meet the following conditions:

- i) Have satisfactorily completed the technician's training course at a KEREa recognized training institution. A KEREa recognized trainer must have conducted the course.
- iv) Have completed at least 6 months field attachment. The participant shall be required to submit a detailed field attachment report showing the PV activities undertaken and any projects they have been involved in and their role in the projects to qualify for the Kere a competency evaluation.
- iii) Have paid the requisite examination and other fees to be decided upon by KEREa.
- iv) Have sat and passed a KEREa solar technician competency evaluation criteria comprising:-
 - ◆ An examination comprising of 45 questions to be answered in 3 hours. At least 90% or all of the questions will be multiple choice type of questions.
 - ◆ Practical exercise

- v) The following weights shall apply in determining the overall pass mark:
 - ◆ Practical Exercise - 50%
 - ◆ Written Examination- 50%.

- vi) The pass mark shall be 75%

- vii) The examination shall be conducted twice a year. The examination schedule, venue and location to be decided upon by KEREAA.

5 SOLAR TECHNICIANS TRAINING COURSE CONTENT

5.1 ENERGY CONCEPTS (3 HOUR)

5.1.1 Objectives

This topic is a review of basic energy concepts that are essential for better understanding of photovoltaic systems. At the end of this topic, the participants should be able to:

- i) Define force, power, work and energy and their units of measurement
- ii) Describe forms of energy
- iii) Appreciate energy conversion
- iv) Describe traditional and renewable energy sources

5.1.2 Force, work, energy and power

5.1.2.1 Definition of force, work, energy and power and their units of measurement

5.1.2.2 Forms of Energy

- ◆ Heat energy
- ◆ Light energy
- ◆ Electrical energy
- ◆ Chemical energy
- ◆ Nuclear energy
- ◆ Kinetic energy
- ◆ Potential energy

5.1.3 Energy Conversion

- ◆ Electrical to heat
- ◆ Electrical to light
- ◆ Light to electrical
- ◆ Kinetic to electrical
- ◆ Chemical to Kinetic
- ◆ Potential to Kinetic Etc.

5.1.4 Energy Sources

5.1.4.1 Traditional energy sources

- ◆ Oils
- ◆ Coal
- ◆ Nuclear
- ◆ Etc.

5.1.4.2 Renewable energy sources

- ◆ Solar
- ◆ Wind
- ◆ Hydro power
- ◆ Geothermal
- ◆ Etc.

5.2 BASIC ELECTRICITY (4 HOURS)

5.2.1 Specific Objectives

This topic is a review of basic electricity that is essential for better understanding of photovoltaic systems. At the end of this topic, the participants should be able to:

- i) Define electricity
- ii) Define electrical quantities, symbols, units of measurement and measuring instruments
- iii) Describe electrical circuits, components and circuit conditions
- iv) Describe series and parallel electrical circuits and their characteristics
- v) State ohm's law and apply it to determine current, resistance, power and energy in D.C. circuits
- vi) Carry out simple electrical power and energy calculations
- vii) Differentiate direct current from alternating current
- viii) State measuring instruments for basic electrical quantities
- ix) Understand most common electrical symbols used in electrical wiring drawings

5.2.2 Electrical terminology and quantities

- 5.2.2.1 Qualitative definition of electricity as flow of electrons through conductors
- 5.2.2.2 Electrical quantities, units of measurements, and measuring instruments
 - ◆ Current and Ampere
 - ◆ Voltage and Volt
 - ◆ Resistance and Ohms
 - ◆ Power and Watts
 - ◆ Energy and Joules
 - ◆ Electrical instruments for measuring above quantities

5.2.3 Electrical Circuits

- 5.2.3.1 Components
 - ◆ Source of supply
 - ◆ Conductors
 - ◆ Control devices
 - ◆ Loads
- 5.2.3.2 Electric Circuit Conditions
 - ◆ Closed circuit
 - ◆ Open circuit
 - ◆ Short circuit
- 5.2.3.3 Series and Parallel circuits
 - ◆ Description and connections

- ◆ Characteristics in terms of resultant voltages, currents and resistance and their calculations

5.2.4 Ohms law and its applications

- ◆ Statement of ohms law
- ◆ Applying ohms law to determine current, voltage and resistance
- ◆ Simple energy and power calculations based on ohms law.

5.2.5 Common symbols used in domestic electrical wiring drawings

- ◆ Symbols for light fittings, switches, sockets, consumer units, circuit breakers, etc.

5.3 SOLAR ENERGY (3 HOUR)

5.3.1 Specific Objectives

At the end of this topic, the participants should be able to:

- i) Describe solar energy
- ii) Define common terms used in solar energy
- iii) Explain apparent motion of the sun and seasons
- iv) Explain solar radiation at the earth's surface and factors that affect it.
- v) Appreciate the concept of amount of solar energy received at the given location through a practical exercise.
- vi) State common applications of solar energy

5.3.2 Solar Energy

5.3.2.1 Sun as the source

5.3.2.2 Composition

- ◆ Infrared
- ◆ Visible Light
- ◆ Ultra Violet

5.3.2.3 Basic data about the sun

- ◆ Distance from the earth
- ◆ Surface temperature
- ◆ Mass
- ◆ Diameter
- ◆ Amount of energy it radiates

5.3.3 Solar energy terminology

- ◆ Solar constant
- ◆ Direct and diffuse radiation
- ◆ Insolation or irradiation
- ◆ Irradiance
- ◆ Peak sun hours

5.3.4 Apparent motion of the sun

- ◆ Rotation of the earth on its axis - cause of day and night
- ◆ Movement of the earth round the sun - cause of seasons
- ◆ Sun tracking

5.3.5 Solar radiation on the Earth's surface

5.3.5.1 Solar constant

5.3.5.2 Radiation reaching earth's surface

- ◆ Loss in atmosphere
- ◆ Effect of cloud cover
- ◆ Effect of seasons

5.3.6 Common solar energy applications

- ◆ Drying
- ◆ Heating
- ◆ Electricity generation

5.3.7 Practical exercise

To demonstrate the hourly amount of solar energy received at the training centre

- ◆ Set up to measure half-hourly irradiance (a pyranometer and meter) at the training centre for the day between 8.30 a.m. and 4.30 p.m.
- ◆ Plot a graph of half-hourly irradiance against time of day.
- ◆ Use the graph to estimate the total amount of energy received that day at the training centre.

5.4 SOLAR PHOTOVOLTAIC SYSTEMS (5 HOURS)

5.4.1 Specific objectives

At the end of this topic, the participants should be able to:

- i) Describe solar photovoltaic system and how it works
- ii) State basic components of a simple PV system and their functions
- iii) Configure simple PV systems
- iv) State applications of PV systems
- v) State benefits and limitations of solar PV systems

5.4.2 PV Technology and PV systems

5.4.2.1 PV technology

- ◆ Define the Photovoltaic (PV) effect
- ◆ Brief historical development of the technology
- ◆ Current status of the technology

5.4.2.2 PV systems

- ◆ Description of a PV system

5.4.3 PV System Components and their functions

5.4.3.1 Basic components

- ◆ Solar module
- ◆ Charge Controller
- ◆ Battery
- ◆ Inverter
- ◆ Cables
- ◆ Loads

5.4.3.2 Other components

- ◆ Mounting structures for modules
- ◆ Electrical Installation accessories and fittings

5.4.4 How a PV System Works

- ◆ Electricity generation
- ◆ Transportation through cables
- ◆ Storage in batteries
- ◆ Controls (charge controller)
- ◆ Utilisation
- ◆ The house roof rain water collection analogy

5.4.5 PV Systems configurations

- ◆ Systems without batteries

- ◆ DC system with battery
- ◆ AC system with battery storage
- ◆ Combined AC and DC system

5.4.6 PV systems applications

- ◆ Lighting
- ◆ Powering domestic electrical and electronic appliances
- ◆ Refrigeration
- ◆ Powering basic office/business equipment
- ◆ Water pumping
- ◆ Technically no limitation

5.4.7 Benefits and Limitations

5.4.7.1 Benefits

- ◆ Free fuel - sunlight
- ◆ Sunlight readily available in good quantities in Kenya
- ◆ Eliminates use of Kerosene for lighting
- ◆ Provides immediate access to electricity in rural areas
- ◆ Modularity
- ◆ Raises standards of living in rural communities
- ◆ Environmentally friendly
- ◆ Etc -

5.4.7.2 Limitations

- ◆ Cost
- ◆ Specialist technology - specialised training needed
- ◆ Suited to low power and energy needs
- ◆ Etc.

5.4.8 Practical Exercises

5.4.8.1 Demonstration of PV components and

- ◆ Silicon wafers
- ◆ Solar cells
- ◆ Module Laminates
- ◆ Batteries
- ◆ Charge controllers
- ◆ etc

5.4.8.2 PV systems configuration -Demonstration of basic PV systems configurations on a pre-wired practice board

- ◆ Systems without batteries
- ◆ DC system with battery
- ◆ AC system with battery storage
- ◆ Combined AC and DC system

5.5 SOLAR CELLS AND MODULES (6 HOURS)

5.5.1 Specific Objectives

At the end of this topic, the participants should be able to:

- i) Define various terms used with cells and modules
- ii) Explain semiconductor materials
- iii) Explain the photovoltaic effect and solar cells formation
- iv) Describe IV curves and solar cell characteristics
- v) Explain how a module is made from solar cells and why
- vi) Describe the characteristics and performance of solar modules
- vii) Describe series, parallel and series/parallel connections of modules and resultant output characteristics and state suitable conditions for connecting modules in series or parallel.
- viii) Describe the silicon solar module technologies, characteristics and performance
- ix) State few other PV technologies
- x) Verify experimentally the effects of temperature, shading, dust, tilt angle, and series and parallel connections on the output performance of modules.

5.5.2 Solar cells and module terminology definitions

- ◆ Solar cell
- ◆ Solar module
- ◆ Solar panel
- ◆ Solar array
- ◆ Short circuit Current (I_{sc})
- ◆ Open Circuit Voltage (V_{oc})
- ◆ Current at Maximum Power (I_{pmax})
- ◆ Voltage at maximum Power (V_{pmax})
- ◆ Maximum power (P_{max})
- ◆ Module rating (standard test conditions)

5.5.3 Semi-conductor materials

- ◆ Definition
- ◆ Basic Characteristics
- ◆ Examples
- ◆ The P and N materials formation

5.5.4 The photovoltaic effect and the solar cell

- ◆ Solar radiation - photons
- ◆ The P-N junction
- ◆ P-N junction characteristics
- ◆ The solar cell formation

5.5.4 IV (current, voltage) Curves

- ◆ Description of IV curves
- ◆ Determination of IV curves

- ◆ Use of IV curves

5.5.5 Solar cell characteristics and performance

- ◆ Voltage output
- ◆ Current output
- ◆ Effect of temperature on current output
- ◆ Effect of temperature on voltage output
- ◆ Effect of sunshine intensity (irradiance) on current output
- ◆ Effect of sunshine intensity (irradiance) on voltage output

5.5.6 Solar Module construction, characteristics and performance

5.5.6.1 From solar cell to solar module

- ◆ Solar cells interconnection to build voltage
- ◆ Module construction -
 - encapsulation and sealing for environment protection
 - Mechanical strength (glass etc)
 - Mounting frame
- ◆ Module laminate

5.5.6.2 Solar module characteristics

- ◆ Voltage output
- ◆ Current output
- ◆ Effect of temperature on current output
- ◆ Effect of temperature on voltage output
- ◆ Effect of sunshine intensity (irradiance) on current output
- ◆ Effect of sunshine intensity (irradiance) on voltage output
- ◆ Illustrations using IV curves

5.5.6.3 Module performance in the field determining factors

- ◆ Power rating of the module
- ◆ Type of module - some technologies degrade with time
- ◆ Location of the site and season
- ◆ Intensity of sunshine
- ◆ Cloud cover and dust on module
- ◆ Proper installation

5.5.7 Module connections

5.5.7.1 Series connections

- ◆ The need for interconnecting modules
- ◆ Description and connections
- ◆ Characteristics in terms of resultant voltages, currents and their calculations

5.5.7.2 Parallel connections

- ◆ Description and connections

- ◆ Characteristics in terms of resultant voltages, currents and their calculations
- 5.5.7.3 Series/Parallel connections
 - ◆ Description and connections
 - ◆ Characteristics in terms of resultant voltages, currents and their calculation
 - ◆ Conditions for connecting modules in series or parallel.
- 5.5.8 Silicon solar module technologies, characteristics and performance (Silicon technology fully commercialized)
 - 5.5.8.1 Polycrystalline modules
 - ◆ Description
 - ◆ Performance
 - Output voltage and current
 - efficiency
 - temperature effects
 - power output degradation with time
 - 5.5.8.2 Monocrystalline modules
 - ◆ Description
 - ◆ Performance
 - Output voltage and current
 - efficiency
 - temperature effects
 - power output degradation with time
 - 5.5.8.3 Amorphous silicon modules
 - ◆ Description
 - ◆ Performance
 - Output voltage and current
 - efficiency
 - temperature effects
 - power output degradation with time
 - 5.5.9 Other PV technologies (not fully commercialised)
 - ◆ Cadmium Telluride
 - ◆ Gallium Indium disalanide
 - ◆ Gallium Asernide
 - ◆ Etc
 - 5.5.10 Practical Exercises
 - 5.5.10.1 Module testing
 - ◆ Open circuit tests
 - ◆ Short circuit tests
 - ◆ Interpretation of results - module status

5.5.10.2

Tests on modules to verify:-

- ◆ The effects of temperature on module output voltage and current and implication on energy output and battery charging.
- ◆ The effect of shading on module output voltage and current and implication on energy output and system performance.
- ◆ The effect of dust on module output voltage and current and implication on energy output and overall system performance
- ◆ The effect of connecting modules of same rating in series and parallel on resultant voltage and current
- ◆ The effect of connecting modules of different power rating in series and parallel on resultant voltage and current.

5.6 BATTERIES (6 HOURS)

5.6.1 Specific Objectives

At the end of this topic, the participants should be able to:

- i) Define various terms used with batteries
- ii) Explain the need for rechargeable storage batteries in some PV systems
- iii) State two most common battery technologies in the market and major differences
- iv) Explain battery classification based on application and performance characteristics
- v) Describe lead acid battery construction and packaging
- vi) Describe qualitatively the theory of lead acid battery operation
- vii) Explain effects of various factors on lead acid battery performance
- viii) Battery testing
- ix) Selecting batteries for solar applications

5.6.2 Battery terminology definitions

- ◆ Cell
- ◆ Battery
- ◆ Capacity - ampere hours
- ◆ Discharge rate
- ◆ Depth of discharge
- ◆ Cycle life
- ◆ Deep cycle battery
- ◆ Self discharge
- ◆ Electrolyte and Specific gravity

5.6.3 Energy Storage in PV systems

5.6.3.1 Need for energy storage

- ◆ Intermittent nature of the solar energy
- ◆ Need for energy at night and during poor weather
- ◆ System failure

5.6.3.2 Electrical energy storage

- ◆ Battery storage systems
- ◆ Battery storage and effect on system performance and cost
- ◆ Other storage systems e.g. capacitors.

5.6.4 Common storage battery Technologies

5.6.4.1 Alkaline

- ◆ Alkali (usually potassium hydroxide) used as the electrolyte
- ◆ Example - Nickel Cadmium

- ◆ Performance
 - cycle life
 - self discharge
 - maintenance
- ◆ Limitation
 - cost
 - common application

5.6.4.2 Lead Acid

- ◆ Acid (usually sulphuric acid) used as the electrolyte
- ◆ Examples - normal car battery
- ◆ Performance
 - cycle life
 - self discharge
 - maintenance
- ◆ Limitation
 - Cost
 - common application

5.6.5 Battery Classification

5.6.5.1 Starter Batteries (SLI)

- ◆ Application
- ◆ Performance
 - cycle life
 - self discharge
 - maintenance

5.6.5.2 Standby Batteries

- ◆ Application
- ◆ Performance
 - cycle life
 - self discharge
 - maintenance

5.6.5.3 Traction Batteries

- ◆ Application
- ◆ Performance
 - cycle life
 - self discharge
 - maintenance

5.6.5.4 Solar Batteries

- ◆ Application
- ◆ Performance
 - cycle life
 - self discharge
 - maintenance

5.6.6 Lead acid Battery construction

5.6.6.1 Active material

- ◆ +ve plate
- ◆ -Ve plate
- ◆ Electrolyte
- ◆ Tubular and Flat plates
- ◆ AGM

5.6.6.2 Other materials

- ◆ Separators
- ◆ Casing

5.6.6.3 Packaging

- ◆ Vented or flooded
- ◆ Sealed/immobilized electrolyte
- ◆ Advantages and disadvantages of both types of packaging

5.6.7 Lead acid battery operation

5.6.7.1 Discharging process

- ◆ Active material utilisation
 - +ve plate
 - -Ve plate
 - sulphuric acid
 - Over-discharging effects such as sulphation

5.6.7.2 Charging process

- ◆ Active material reconstitution
 - +Ve plate
 - -Ve plate
 - Sulphuric acid
 - Over-charging effects such as water loss

5.6.7.3 Chemical reaction equation

- ◆ To use the equation to explain performance characteristics of lead acid battery.

5.6.8 Lead acid battery performance

5.6.8.1 Battery Capacity

- ◆ Effect of temperature
- ◆ Effect of rate of discharge current

5.6.8.2 Service life

- ◆ Effect of depth of discharge
- ◆ Effect of rate of discharge
- ◆ Effect of overcharging

- ◆ Effect of over discharging
- 5.6.8.3 Other factors that affect battery performance
 - ◆ Maintenance
 - ◆ storage
- 5.6.9 Battery Testing
- 5.6.9.1 State of charge tests
 - ◆ Voltage tests
 - ◆ Specific gravity tests using hydrometer
 - ◆ Interpretation of results
- 5.6.9.2 Capacity test
 - ◆ Discharge test
 - ◆ Needs special equipment to carry out
- 5.6.10 Specifying and selecting solar batteries for solar applications
- 5.6.10.1 Standard features
 - ◆ cycle life
 - ◆ low self discharge
 - ◆ large electrolyte volume
- 5.6.10.2 Selecting solar batteries
 - ◆ Standard features above have to be considered
 - ◆ Vented flooded preferable over sealed
 - ◆ Shallow cycle (SLI) reasonable for small systems
 - ◆ Medium cycle for larger systems - Modified car batteries for solar use.
 - ◆ Deep cycle for critical applications
 - ◆ Deep cycle for large expensive systems
 - ◆ Price
- 5.6.11 Practical Exercises
- 5.6.11.1 Use of battery testing instruments
 - ◆ Voltmeter
 - ◆ Hydrometer
- 5.6.11.2 State of charge tests
 - ◆ Voltage tests
 - ◆ Electrolyte specific gravity tests using hydrometer
 - ◆ Interpretation of results

5.7 CHARGE CONTROLLERS (3 HOURS)

5.7.1 Specific Objectives

At the end of this topic, the participants should be able to:

- i) Describe the functions of a charge controller
- ii) Describe the two common types of charge controllers and their performance differences
- iii) Specify and select appropriate charge controllers

5.7.2 Functions of Charge Controllers

5.7.2.1 Control and Supervisory functions

- ◆ Why charge control?
- ◆ Overcharge
- ◆ Over-discharge
- ◆ Charging algorithms - hysteresis, dual voltage, three stage
- ◆ Status indicators
- ◆ Alarms
- ◆ Metering

5.7.2.2 Protection functions

- ◆ Battery
- ◆ Equipment
- ◆ Overload
- ◆ Short circuit
- ◆ Reverse polarity
- ◆ Lightning and voltage surges

5.7.2.3 Other functions

- ◆ Convenient point for interconnecting other components

5.7.3 Types of charge controllers

5.7.3.1 Series Controller

- ◆ Description
- ◆ Performance
 - Accuracy in regulation
 - efficiency

5.7.3.2 Shunt Controller

- ◆ Description
- ◆ Performance
 - Accuracy in regulation
 - Efficiency

5.7.4 Specifying and selecting charge controllers

5.7.4.1 Standard features of charge controllers

- ◆ Low battery voltage disconnect (LVD)
- ◆ Reversed polarity protection
- ◆ Low battery disconnect alarm
- ◆ Proper settings for batteries to be used in the system
- ◆ Voltage and current ratings

5.7.4.2 Other features

- ◆ Type - series or shunt
- ◆ Short circuit protection
- ◆ Overload protection
- ◆ High battery voltage disconnect (HVD)
- ◆ Metering (Voltage, Current, energy)
- ◆ Alarms (HVD,LVD)
- ◆ Lightning and surge protection

5.7.4.3 Other considerations

- Environment of use - outdoor or indoor, humidity, temperature etc.

5.7.4.4 Selecting charge controllers

- ◆ Standard features should be incorporated
- ◆ Application - high specs for critical applications
- ◆ Cost of the PV system - high specs for expensive systems justifiable
- ◆ Price of Controller

5.8 POWER CONVERTERS AND THE INVERTER (3 HOURS)

5.8.1 Specific objectives

At the end of the topic, the participant should be able to:

- i) Explain the need for power converters and state the four common power converters
- ii) Describe an Inverter and explain the need for an inverter in a PV system
- iii) State the types of inverters and performance differences
- iv) Select appropriate inverters for PV systems

5.8.2 Power Conversion

5.8.2.1 Need for power conversion

- ◆ Matching to appliances to form of power available

5.8.2.2 Power converters

- ◆ Transformer
- ◆ Inverters
- ◆ Rectifiers
- ◆ DC-DC converters

5.8.3 Inverters

5.8.3.1 Description

- ◆ Need for Inverters in PV systems
- ◆ Description of an Inverter

5.8.3.2 Types of Inverters and their performance

- ◆ Square Wave
 - Efficiency
 - Harmonics
 - output voltage regulation
 - Problem loads/appliances
- ◆ Modified Square Wave
 - Efficiency
 - Harmonics
 - output voltage regulation
 - Problem loads/appliances
- ◆ Sine Wave
 - Efficiency
 - Harmonics
 - output voltage regulation
 - Problem loads/appliances

5.8.3.3

Selecting Inverters

- ◆ Effect of Inverter on system capacity and cost
- ◆ Standard features
 - Efficiency
 - Battery over-discharge protection
 - Short circuit protection
 - Overload protection
- ◆ Load considerations
 - resistive loads
 - reactive loads
- ◆ Type of Inverter
- ◆ Price

5.9 APPROPRIATE LOADS OR APPLIANCES (5 HOURS)

5.9.1 At the end of the topic, the participant should be able to:

- i) Determine situations where PV is a viable electrical power source.
- ii) Select appropriate appliances for use in PV systems
- iii) Design basic lighting system for domestic dwellings

5.9.2 PV Power Viability

- ◆ Remote areas
- ◆ Lighting
- ◆ Low power appliances
- ◆ Short duration loads or appliances
- ◆ High efficiency loads or appliances

5.9.3 Selecting Appropriate Loads/appliances for PV

5.9.3.1 Lights

- ◆ Fluorescent lights
- ◆ Incandescent lights - avoid!
- ◆ Other lights like white light emitting diodes (WLED) and High Discharge (HID) Lamps

5.9.3.2 Other loads appliances

- ◆ Radios
- ◆ TV, VCRs, VCDs, DVDs
- ◆ Computers
- ◆ Printers
- ◆ UHF/VHF radios
- ◆ Repeater stations
- ◆ Etc.

5.9.3.3 Special complete PV Packages

- ◆ Need and benefits of complete packages
- ◆ Medical Refrigeration
- ◆ Water pumps

5.9.3.4 Power consumption of common household appliances.

- Common appliances table and power consumption developed in an interactive session

5.9.4 Domestic Lighting Basics and Guideline

5.9.4.1 Lighting terminology

- ◆ Lumen
- ◆ Illuminance
- ◆ Luminous efficacy (efficiency) of lamps
- ◆ Efficacy of common lamps

- ◆ Electronic and electromagnetic ballasts

5.9.4.2 Household lighting guide

- ◆ Recommended illuminance levels
 - General area lighting
 - Kitchen
 - Reading/study
 - Bedrooms
 - Toilets
 - Corridors
 - External
- ◆ Factors determining number of lamps per room
 - Illuminance level needed
 - Room color surfaces of ceilings, walls and floors
 - Room area
 - Mounting heights if ceiling
 - Luminous efficacy of lamps
- ◆ Guidelines/rules of thumb.
 - Number of lamps per room area based on standard locally available lamp types and common house design in rural setting to be developed in an interactive session.

5.10 PV SYSTEM SIZING (10 HOURS)

5.10.1 Specific Objectives

At the end of the topic, the participants should be able to:

- i) Define system sizing and describe its importance in system performance integrity
- ii) Collect appropriate data for system sizing
- iii) Determine the appropriate ratings/capacities/sizes of modules, batteries, charge regulators, inverter, cables and fuses for simple PV system
- iv) Size a PV system
- v) Use rules of thumb for sizing of simple PV systems in Kenya.
- vi) Select appropriate electrical installation accessories and fittings to complete a PV system

5.10.2 System Sizing

- ◆ Definition
- ◆ Importance of system sizing on system performance integrity

5.10.3 System Sizing Procedure

5.10.3.1 Data gathering

- ◆ Load/Appliances data
 - power rating
 - voltage rating
 - daily duration of usage
- ◆ Site data
 - location
 - Insolation (monthly and annual average)
 - Temperature
 - Lightning prevalence
- ◆ Other data/information
 - System autonomy
 - Array tilt angle
 - Inverter efficiency (where applicable)
 - Overall system efficiency
 - Maximum voltage drop allowed
 - Other assumptions

5.10.3.2 Sizing process

- ◆ Calculation of total daily energy demand
- ◆ Calculation of maximum power demand
- ◆ Calculation of maximum load current
- ◆ Determination of system voltage
- ◆ Calculation of battery capacity

- ◆ Calculation of module/array capacity
- ◆ Calculation of total module/array current
- ◆ Determination of charge controller rating
- ◆ Determination of Inverter rating
- ◆ Determination of cable sizes for interconnection
- ◆ Determination of the rating of fuses/circuit breakers
- ◆ Selection of batteries, modules, charge controllers, Inverters, and cables

5.10.3.3 Sizing example and exercise

- ◆ Complete example (DC) by facilitator on the board
- ◆ Complete example (AC) by facilitator on the board
- ◆ Individual sizing exercise for the participants

5.10.3.4 Rules of Thumb for sizing ordinary systems in Kenya

- ◆ Average Insolation:- 5 peak sun hours
- ◆ Tilt angle - Ignore. Assume array plane insolation equals site global insolation above
- ◆ Battery autonomy - 3 days
- ◆ Overall system losses - 10 -20%

5.10.4 Other Installation accessories and fittings

5.10.4.1 Other required accessories and fitting

- ◆ Module/Array Mounting structures
- ◆ Battery Box or rack
- ◆ Fuses or circuit breakers
- ◆ Switches
- ◆ Sockets
- ◆ Normal wiring accessories

5.10.4.2 Selecting electrical wiring accessories and fittings

- ◆ Fuses
 - AC rated
 - DC rated
 - Conditions for using AC fuses in DC circuits
- ◆ Circuit Breakers
 - AC rated
 - DC rated
 - Conditions for using AC breakers in DC circuits
- ◆ Switches
 - AC rated
 - DC rated
 - Conditions for using AC switches in DC circuits
- ◆ Sockets

- AC rated
 - DC rated
 - Conditions for using AC sockets in DC circuits
- ◆ Other accessories
- In general, normal AC accessories and fittings can be used in DC wiring

5.11 PV SYSTEM SIZING AND DESIGN PROJECT (6 Hours)

5.11.1 Specific Objective

At the end of the project, the participants should be able to:

- i) design and specify a PV system based on data and information gathered from clients and other sources
- ii) Select appropriate equipment and components for the designed system
- iii) Prepare bills of quantities covering major system equipment and components

5.11.2 Project description

Participants will be provided with the following data and information

- i) Site location for the system
- ii) Weather data at site
- iii) Load details including ratings and operating hours
- iv) System autonomy
- v) A PV products catalogue or list containing various types and specifications of PV and balance of systems components
- vi) A list or catalogue containing major PV installation and electrical and hardwiring accessories and fittings, including their specifications.
- vii) Plan of the building
- viii) Distances between the array and charge controller and charge controller to battery
- ix) Distance between battery and Inverter
- x) Allowed voltage drops for various cable runs
- xi) Any other data deemed relevant for the exercise

5.11.2 Design Tasks

The participant will be required to: -

- i) Determine the most appropriate DC system voltage
- ii) Calculate the total energy needs of the system
- iii) Determine the array (Wpk) and battery capacity (Ah) of the system
- iv) Determine the current and voltage ratings of the appropriate Charge Regulator and Inverter for the system.
- v) Determine the appropriate cable sizes necessary to ensure that the voltage drop between the array and charge controller, controller and battery and battery to Inverter not exceed 5% of the nominal system voltage
- vi) Determine the ratings and specify the necessary Inverter for running the AC loads
- vii) Determine the ratings and specify the necessary fuses or circuit breakers for battery line and inverter input protection.
- viii) Select appropriate equipment and components from the products catalogues

- ix) Prepare bills of quantities for the major equipment and components of the system
- x) Draw a wiring schematic diagram for the PV system up to the distribution board.

NB: The design project should be evaluated as part of course work and contribute towards the overall pass mark.

5.12 PV SYSTEM INSTALLATION (7 HOURS)

5.12.1 Specific Objective

At the end of the topic, the participants should be able to:

- i) Planning PV installation work
- ii) List the main tools used in PV system installation and testing
- iii) Choose an appropriate module/array mounting structure
- iv) Properly locate and mount PV components - module, battery, Inverter, Charge Controller
- v) Interconnect PV components to complete a PV system installation

5.12.2 Planning PV installation work

- ◆ Importance of planning the work
- ◆ System completeness
- ◆ PV components working condition
- ◆ Tools and instruments
- ◆ Documents and manuals
- ◆ Scheduling
- ◆ PV system installation check list

5.12.3. Key Tools and Instruments for PV installation

- ◆ Multimeter (with at least 10A DC current rating)
- ◆ Compass
- ◆ Hydrometer
- ◆ Inclinator (or angle of tilt template and spirit level)
- ◆ Set of Spanners
- ◆ Set of Screw drivers
- ◆ Claw hammer
- ◆ Drill/wall punch
- ◆ Cable Stripper
- ◆ Measuring Tape

5.12.4 Installation of PV components -Theory

5.12.4.1 PV module or array

- ◆ Choice of mounting structure
 - Roof
 - Ground
 - pole
- ◆ Orientation
- ◆ Tilt
- ◆ Fixing
- ◆ Module interconnection - for more than one module

- 5.12.4.2 Charge Controller
 - ◆ Location
 - ◆ fixing
- 5.12.4.3 Charge Controller
 - ◆ Location
 - ◆ Fixing
- 5.12.4.4 Inverter
 - ◆ Location
 - ◆ Fixing
- 5.12.4.5 Battery
 - ◆ Location
 - ◆ Battery box
 - ◆ Safe handling
- 5.12.4.6 Fuses and Circuit breakers
 - ◆ Battery line fuse
 - ◆ Inverter fuse
- 5.12.4.7 Lamps and other appliances
 - ◆ Lamps
 - Location
 - Fixing
 - ◆ Other appliances
- 5.12.4.8 Electrical wiring accessories
 - ◆ Location and fixing of:
 - switches
 - Sockets
 - distribution board/consumer unit
 - ◆ internal wiring
- 5.12.4.9 System interconnection
 - ◆ Cable terminations
 - ◆ Module / array to charge controller
 - safety
 - sequence
 - ◆ charge controller to battery through the battery fuse
 - ◆ Battery to Inverter through the Inverter fuse
 - ◆ Connection to consumer unit or distribution board
 - dc loads
 - ac loads
 - mixed ac and dc loads

5.12.5 Practical - PV system installation on practice board

- ◆ Mounting basic PV components practice board based on a provided circuit diagram
- ◆ Installing the fittings and associated accessories and loads
- ◆ Interconnecting the system

5.13 PV SYSTEM INSPECTION, TESTING AND COMMISSIONING (5 HOURS)

5.13.1 Specific objective.

At the end of the topic, the participant should be able to:

- i) Carry out visual and mechanical inspection of a PV system
- ii) Carry out testing and commission a PV system
- iii) Carry out user training

5.13.2 Visual and mechanical inspection

- ◆ Completeness of the installation
 - all necessary PV components
 - Protection fuses/circuit breakers
- ◆ Module or array orientation
- ◆ Module or array tilt
- ◆ Battery location for ventilation and safety
- ◆ Battery electrolyte levels (if flooded)
- ◆ Firmness of cable terminations and connections
- ◆ Firmness of components and equipment mounting
- ◆ Neatness

5.13.2 System testing and commissioning

5.13.2.1 Electrical wiring tests

- ◆ Purpose and instruments
- ◆ Continuity tests
- ◆ Polarity tests with special emphasis on DC systems
- ◆ Insulation resistance tests

5.13.2.2 Module or array tests

- ◆ Purpose and instrument selection and settings
- ◆ Weather condition
- ◆ Current tests (short circuit) test
- ◆ Voltage (open circuit) test
- ◆ Interpreting the results

5.13.2.3 Battery Tests

- ◆ Purpose and instruments selection and settings
- ◆ Voltage tests
- ◆ Electrolyte specific gravity tests
- ◆ Interpreting the results

5.13.2.4 Charge Regulator tests

- ◆ Purpose and instruments selection and settings
- ◆ Voltage tests

- 5.13.2.5 Inverter tests
 - ◆ Interpreting the results
 - ◆ Purpose and instruments selection and settings
 - ◆ Input Voltage test
 - ◆ Output voltage test
 - ◆ Interpreting the results
- 5.13.2.6 Loads and other appliances tests
 - ◆ As prescribed by the manufacturer
- 5.13.2.7 System commissioning
 - ◆ Definition and purpose of system commissioning
 - ◆ Step-by-step commissioning procedure
- 5.13.3 User Training
- 5.13.3.1 Importance of user training
- 5.13.3.2 User training topics
 - ◆ System design and performance expectations review
 - ◆ Purpose of each installed component
 - ◆ Status indicators and their purpose
 - ◆ How to operate each component and equipment
 - ◆ User maintenance functions
 - ◆ The use of provided manuals and forms
 - ◆ How to deal with breakdowns
 - ◆ Load management and energy conservation
- 5.13.4 Practical - PV system testing and commissioning and user training
- 5.13.4.1 Testing and commissioning of PV system
 - ◆ System mounted on the practice board carried outside, in the sun.
 - ◆ Modules and batteries connected
 - ◆ Commissioning tests described in 5.13.2 carried out
- 5.13.4.2 User training
 - ◆ User training as per 5.13.3 practice
 - ◆ Role play method

5.14 PV SYSTEM INSTALLATION, TESTING AND COMMISSIONING - FIELD PRACTICE (9 HOURS)

5.14.1 Specific Objectives

At the end of the exercise, the participants should be able to:

- i) Install, test and commission a PV system and carry out user training

5.14.2 PV system installation in the field

- ◆ Real life PV system installation, testing and commissioning in accordance with section 5.12 and 5.13
- ◆ User training as per section 5.13.3

5.15 PV SYSTEM MAINTENANCE (4 HOURS)

5.15.1 Specific Objectives

At the end of the topic, the participant should be able to:

- i) Carry out electrical wiring maintenance tasks
- ii) Carry out PV system components maintenance tasks
- iii) Plan maintenance work

5.15.1 Electrical wiring maintenance Tasks

- ◆ Neatness
- ◆ Firmness of installed accessories and fittings
- ◆ Cables and conduits condition

5.15.2 PV system Components maintenance tasks

5.15.2.1 Array maintenance

- ◆ Cleaning
- ◆ Mechanical checks
- ◆ Integrity of cable terminations
- ◆ Electrical tests

5.15.2.2 Battery Maintenance

- ◆ Cleaning
- ◆ Integrity of cable terminations and corrosion protection
- ◆ Topping up (if flooded)
- ◆ Specific gravity checks
- ◆ Voltage test

5.15.2.3 Charge Regulator test

- ◆ Dusting
- ◆ Integrity of cable terminations
- ◆ Status indicators checks
- ◆ Voltage tests

5.15.2.4 Inverters

- ◆ Dusting
- ◆ Integrity of cable terminations
- ◆ Status indicators checks
- ◆ Voltage tests

5.15.2.5 Loads and installed equipment

- ◆ As per manufacturers recommendations

5.15.3 Maintenance planning

- ◆ Planning and scheduling maintenance work.

5.15.4 **Practical Exercise**

- ◆ PV components maintenance practice in accordance with 5.15.2

5.16 SYSTEM TROUBLESHOOTING AND REPAIRS (5 HOURS)

5.16.1 Specific Objectives

At the end of the topic, the participant should be able to

- i) Carry out a step by step system trouble shooting
- ii) Identify faulty PV components and take appropriate action
- iii) Identify common faults and carry out simple repairs

5.16.2 System troubleshooting

5.16.2.1 Step-by-step troubleshooting

- ◆ User Interview
- ◆ System components status indicators
- ◆ Protective devices condition
- ◆ System commissioning tests
- ◆ Components test

5.16.2.2 Identifying faulty PV components

- ◆ Single Modules
- ◆ Single module in an array
- ◆ Single Battery
- ◆ Single battery in battery bank
- ◆ Charge controller
- ◆ Inverter
- ◆ Fuses/circuit breakers
- ◆ Broken wire or bad connections
- ◆ Fluorescent lamps

5.16.3 Common faults and simple Repairs

5.16.3.1 Common faults

- ◆ Wiring faults such as broken wire, loose connection etc.
- ◆ Excessive system use
- ◆ Component failure
- ◆ Operation of wiring protective devices
- ◆ Operation of component/equipment protective devices

5.16.3.2 Simple repairs

- ◆ Components repairs
- ◆ Components replacement
- ◆ System wiring protective devices failure
- ◆ Resetting of component/equipment protective devices

5.16.4 Practical Exercise

Working in groups and using practice boards in open sunshine, each group simulates a fault or a series of faults and asks the other group to troubleshoot the system.

5.17 HEALTH, SAFETY AND ENVIRONMENT (2 HOUR)

5.17.1 Specific Objectives

At the end of the topic, the participants should be able to:

- i) Identify health and safety hazards in handling PV systems and Components and take precautionary measures to minimise them
- ii) Identify environmental hazards in handling PV systems and components and take precautionary measures

5.17.2 Health and safety hazards

5.17.2.1 Identification

- ◆ Battery acid
- ◆ Acidic fumes from batteries on charge
- ◆ Electric shocks
- ◆ Electrocutation
- ◆ Fires and explosion risks
- ◆ Safety at work and site

5.17.2.2 Risk mitigation

- ◆ Protective wear
- ◆ Use of appropriate tools and instruments
- ◆ Restrictions
- ◆ Danger and warning notices
- ◆ User training
- ◆ Proper designs and professional installations

5.17.2 Environmental hazards and mitigation

- ◆ The battery lead hazard
- ◆ Lead hazard risk mitigation

5.18 PV STANDARDS AND CODES OF PRACTICES (2 HOUR)

5.18.1 Specific Objective

At the end of the topic, the participants should be able to: -

- i) State and adopt national PV standards and codes of practice
- ii) Appreciate existence of international PV standards and codes of practice.

5.18.2 National standards and codes of practice

The Kenya Bureau of Standards has developed the following PV standards and codes of practice. The standards are legally binding and enforceable. The industry should strive to study them and adhere to them. KEREAS has summarized all of them for its members. Copies are available from the KEREAS secretariat free of charge for members and at a fee for non-members. The more relevant standards are listed hereunder.

| Code | Subject |
|-------------|--|
| KS 1673-1 | Generic specifications for solar photovoltaic systems - system design, installation, operation, monitoring and maintenance. Part1: General PV system requirements |
| KS 1673-2-1 | Generic specifications for solar Photovoltaic systems - system design, installation, operation, monitoring and maintenance. Part 2: Test Procedure for Main components. Section 1- Test Procedure for PV Modules |
| KS 1673-2-2 | Generic specifications for solar Photovoltaic systems - system design, installation, operation, monitoring and maintenance. Part 2: Test Procedure for Main components. Section 2- Recommended practices for installation, maintenance, testing and replacement of secondary batteries for use with standalone power systems |
| KS 1673-2-3 | Generic specifications for solar Photovoltaic systems - system design, installation, operation, monitoring and maintenance. Part 2: Test Procedure for Main components. Section 3- Test Procedure for Charge Regulators |
| KS 1673-2-4 | Generic specifications for solar Photovoltaic systems - system design, installation, operation, monitoring and maintenance. Part 2: Test Procedure for Main components. Section 4- Test Procedure for Inverters |
| KS 1673-2-5 | Generic specifications for solar Photovoltaic systems - system design, installation, operation, monitoring and maintenance. Part 2: Test Procedure for Main components. Section 5- Test Procedure for Luminaries |
| KS 1674 | Crystalline Silicon terrestrial photovoltaic modules - design qualification and type approval |

| | |
|--------------|---|
| KS 1675 | Thin-film terrestrial photovoltaic modules - design qualification and type approval |
| KS 1676 | Terrestrial photovoltaic power generating systems - General and guide |
| KS 1677 | Procedures for temperature and irradiance corrections to measured I-V characteristics of silicon photovoltaic devices |
| KS 1678-1 | Photovoltaic Devices - Part 1: Measurement of photovoltaic current-voltage characteristics |
| KS 1685 | photovoltaic system performance monitoring - guidance for measurement, data exchange and analysis |
| KS 1688 | Crystalline Silicon photovoltaic array-on-site measurement of I-V characteristics |
| KS 1709:2001 | Specification for batteries for use in photovoltaic systems |
| KS 662 | Kenya Wiring Regulations |

5.18.3 International Standards

The International Electrotechnical Commission (IEC) has developed many PV standards and codes of practice. The standards are not legally binding and enforceable UNLESS the country adopts them. Kenya is a member of the IEC and normally uses the IEC standards where there are no national standards. Most of the national standards referred to in 5.18.2 have been adapted from IEC standards.

International standards are very useful particularly when buying PV products from other countries. A product that meets IEC standard is generally of good quality.

5.19 BUSINESS LINKAGES AND BASICS OF MARKETING (7HOURS)

5.19.1 At the end of the course, the participants should be able to:

- i) Understand local and international PV market development and trends
- ii) Source products from major manufacturers and importers
- iii) Explore subcontracting and other business opportunities
- iv) Apply the basics of sales and marketing in the conduct of their businesses
- v) Apply the concepts of life cycle cost in the marketing of PV products
- vi) Adopt attitudes and business practices that enhance customer relationships

5.19.2 PV market development and trends

- ◆ International
- ◆ Local

5.19.2.1 Major manufacturers and dealers

- ◆ International
- ◆ Local
- ◆ Local and international product sourcing

5.19.3 Basics of Marketing

5.19.3.1 Definition of marketing - satisfying customer's needs profitably

5.19.3.2 Marketing activities - the 4P

- ◆ Product (1st P)
 - product or service identification process
 - Product or service packaging, branding etc
- ◆ Place (2nd P)
 - Ensuring customer has easy access to the product or service.
 - Distribution channels
- ◆ Promotion (3rd P)
 - Making the market aware of the product or service through appropriate communication
 - Marketing communication channels such as advertising, exhibitions etc.
- ◆ Pricing (4th P)
 - Pricing competitively and profitably
 - Common pricing strategies i.e. cost-plus and value-in-use
 -

5.19.3.3 Professional selling

- ◆ Selling activities
 - identifying potential clients

- identifying the needs of clients
- identifying clients financial position
- contacting the client
- Selling the products or service benefits
- Closing the sale

◆ Selling skills

- Good planning and self organisation
- Effective verbal and written communication
- Good human relationships

◆ What clients dislike in salespeople

- Lack of knowledge or information on the product or service or company
- Unacceptable manners
- Time wasting
- Being pushy or aggressive
- Poor sales presentation

5.19.4 Marketing Solar PV systems

5.19.4.1 Packaging

- Components
- Do it yourself (DIY) Kits
- Customized systems

4.19.4.2 Selling PV Benefits

- ◆ Free fuel - sunlight
- ◆ Eliminates use of Kerosene for lighting - saves money
- ◆ No smoke - removes health hazards of smoke
- ◆ Immediate access to electricity for radios (no more dry cells) and TV (no more carrying car battery for charging in market) and saves money
- ◆ Low maintenance
- ◆ Long life > 20 years
- ◆ Easily expanded (modular) should needs increase
- ◆ Environmentally friendly
- ◆ Etc

5.19.4.3 Handling the PV price issue

- ◆ PV competing and cheap to acquire alternatives
 - Kerosine lamps for lighting
 - Dry cells for radios/electronics
 - Rechargeable car battery for TV, recharged at local markets usually once a week.
 - All these cheap to buy but expensive to operate

- ◆ The cycle life cost concept (qualitative)
Full cost of owning product over its lifetime includes
 - buying price
 - fuel cost
 - repair costs
 - spares

- ◆ PV price comparison with alternatives should be on total cost of buying and operating them over their service life.

5.19.5 Business opportunities in PV

- ◆ Retailing
- ◆ Dealerships
- ◆ Franchises
- ◆ Sub-contracting

5.19.6 Good business practices

- ◆ Quality products and services
- ◆ Fair pricing
- ◆ Customer care
- ◆ The KEREAA code of Conduct

6. PV ENTREPRENEURS TRAINING COURSE CONTENT (16 HOURS)

6.1 Basic Electricity and simple energy calculations

6.1.1 Specific Objectives

This topic is a review of basic electricity that is essential for better understanding of photovoltaic systems. At the end of this topic, the participants should be able to:

- i) Define electricity
- ii) Define electrical quantities, symbols and their units of measurement
- iii) Carry out simple electrical power and energy calculations

6.1.2 Qualitative definition of electricity as flow of electrons through conductors

6.1.3 Electrical quantities, units of measurements and symbols

- ◆ Current and Ampere
- ◆ Voltage and Volt
- ◆ Resistance and Ohms
- ◆ Power and Watts
- ◆ Energy and Joules
- ◆ Ampere hours
- ◆ Watt hours
- ◆ Relationships formulae between quantities above

6.1.4 Simple electrical energy calculations

- ◆ Power
- ◆ Energy
- ◆ Ampere hours
- ◆ Watt hours

6.2 Solar Energy

6.2.1 Specific Objectives

At the end of this topic, the participants should be able to:

- i) Describe solar energy
- ii) Define common terms used in solar energy
- iii) Explain apparent motion of the sun and seasons
- iv) Explain solar radiation at the earth's surface and factors that affect it.
- v) State common applications of solar energy

6.2.2 Solar Energy

6.2.2.1 Sun as the source

6.2.2.2 Basic data about the sun

- ◆ Distance from the earth
- ◆ Surface temperature

- ◆ Amount of energy it radiates

- 6.2.2.3 Solar energy terminology
- ◆ Solar constant
 - ◆ Insolation or irradiation
 - ◆ Irradiance
 - ◆ Peak sun hours

- 6.2.3 Apparent motion of the sun
- ◆ Rotation of the earth on its axis - cause of day and night
 - ◆ Movement of the earth round the sun - cause of seasons

6.2.4 Solar radiation on the Earth's surface

- 6.2.4.1 Solar constant

- 6.2.4.2 Radiation reaching earth's surface
- ◆ Loss in atmosphere
 - ◆ Effect of cloud cover
 - ◆ Effect of seasons

- 6.2.5 Common solar energy applications
- ◆ Drying
 - ◆ Heating
 - ◆ Electricity generation

6.3 Solar Photovoltaic Systems

6.3.1 Specific objectives

At the end of this topic, the participants should be able to:

- Describe solar photovoltaic system and how it works
- State basic components of a simple PV system and their functions
- State benefits and limitations of solar PV systems

6.3.2 PV Technology and PV systems

- 6.3.2.1 PV technology
- ◆ Define the Photovoltaic (PV) effect
 - ◆ Brief historical development of the technology

- 6.3.2.2 PV Systems
- ◆ Description of a PV system

6.3.3 PV System Components and their functions

- 6.3.3.1 Basic components and their functions

- ◆ Solar module
- ◆ Charge Controller
- ◆ Battery
- ◆ Inverter
- ◆ Cables
- ◆ Loads

6.3.3.2 Other components

- ◆ Mounting structures for modules
- ◆ Electrical Installation accessories and fittings

6.3.4 How a PV System Works

- ◆ Electricity generation
- ◆ Transportation through cables
- ◆ Storage in batteries
- ◆ Controls (charge controller)
- ◆ Utilisation
- ◆ The house roof rain water collection analogy

6.3.5 PV systems applications

- ◆ Lighting
- ◆ Powering domestic electrical and electronic appliances
- ◆ Refrigeration
- ◆ Powering basic office/business equipment
- ◆ Water pumping
- ◆ Technically no limitation

6.3.6 Benefits and Limitations

6.3.6.1 Benefits

- ◆ Free fuel - sunlight
- ◆ Sunlight readily available in good quantities in Kenya
- ◆ Eliminates use of Kerosene for lighting
- ◆ Provides immediate access to electricity in rural areas
- ◆ Modularity
- ◆ Raises standards of living in rural communities
- ◆ Environmentally friendly
- ◆ Etc -

6.2.6.2 Limitations

- ◆ Cost
- ◆ Specialist technology - specialised training needed
- ◆ Suited to low power and energy needs

6.4 PV System Sizing

6.4.1 Specific Objectives

At the end of the topic, the participants should be able to:

- i) Define system sizing and describe its importance in system performance integrity
- ii) Collect appropriate data for system sizing
- iii) Determine the appropriate ratings/capacities/sizes of modules, batteries, charge regulators and inverter for simple PV system
- iv) Size a 12V PV system
- v) Use rules of thumb for sizing of simple PV systems in Kenya.

6.4.2 System Sizing

- ◆ Definition
- ◆ Importance of system sizing on system performance integrity

6.4.3 System Sizing Procedure

6.4.3.1 Data gathering

- ◆ Load/Appliances data
 - power rating
 - voltage rating
 - daily duration of usage
- ◆ Site data
 - location
 - Insolation (monthly and annual average)
- ◆ Other data/information
 - System autonomy
 - Overall system efficiency

6.4.3.2 Sizing process

- ◆ Calculation of total daily energy demand
- ◆ Determination of system voltage
- ◆ Calculation of battery capacity
- ◆ Calculation of module/array capacity
- ◆ Determination of charge controller rating
- ◆ Determination of Inverter rating
- ◆ Selection of batteries, modules, charge controllers, Inverters

6.4.3.3 Hand Sizing example and exercise

- ◆ 12V DC by facilitator on the board
- ◆ System with Inverter by facilitator on the board
- ◆ Individual sizing exercise for the participants

- 6.4.3.4 Rules of Thumb for sizing ordinary systems in Kenya
- ◆ Average Insolation:- 5 peak sun hours
 - ◆ Tilt angle - Ignore. Assume array plane insolation equals site global insolation above
 - ◆ Battery autonomy - 3 days
 - ◆ Overall system losses - 10 -20%

6.5 Frequently Asked Questions

6.5.1 Specific Objectives

At the end of the topic, the participants should be able to:-

- i) Answer at least ten of the most frequently asked questions on solar photovoltaics.

6.5.2 Frequently asked questions

At least 10 frequently asked questions on PV should be identified and answered in an interactive session.

6.6 Business Linkages

6.6.1 At the end of the course, the participants should be able to:

- i) Appreciate local and international PV market development and trends
- ii) Source products from major manufacturers and importers
- iii) Explore subcontracting and other business opportunities

6.6.2 PV market development and trends

- ◆ International
- ◆ Local

6.6.3 Major manufacturers and dealers

- ◆ International
- ◆ Local
- ◆ Local and international product sourcing

6.6.4 Business opportunities in PV

- ◆ Retailing
- ◆ Dealerships
- ◆ Franchises
- ◆ Sub-contracting

6.7 Basics of Marketing

6.7.1 Specific Objectives

At the end of the topic, the participants should be able to:

- i) Apply the basics of sales and marketing in the conduct of PV marketing function
- ii) Apply the concepts of life cycle cost in the marketing of PV products
- iii) Adopt attitudes that enhance customer relationships

6.7.2 Definition of marketing - satisfying customer's needs profitably

6.7.3 Marketing activities - the 4P

- ◆ Product (1st P)
 - product or service identification process
 - Product or service packaging, branding etc
- ◆ Place (2nd P)
 - Ensuring customer has easy access to the product or service.
 - Distribution channels
- ◆ Promotion (3rd P)
 - Making the market aware of the product or service through appropriate communication
 - Marketing communication channels such as advertising, exhibitions etc.
- ◆ Pricing (4th P)
 - Pricing competitively and profitably
 - Common pricing strategies i.e. cost-plus and value-in-use

6.7.4 Professional selling

- ◆ Selling activities
 - identifying potential clients
 - identifying the needs of clients
 - identifying clients financial position
 - contacting the client
 - Selling the products or service benefits
 - Closing the sale
- ◆ Selling skills
 - Good planning and self organisation
 - Effective verbal and written communication
 - Good human relationships
- ◆ What clients dislike in salespeople
 - Lack of knowledge or information on the product or service or company

- Unacceptable manners
- Time wasting
- Being pushy or aggressive
- Appearance
- Poor sales presentations

6.7.5 Marketing Solar PV systems

5.19.3.3 Packaging

- Components
- Do it yourself (DIY) Kits
- Customised systems

6.7.5.2 Sell PV Benefits

- ◆ Free fuel - sunlight
- ◆ Eliminates use of Kerosene for lighting - saves money
- ◆ No smoke - removes health hazards of smoke
- ◆ Immediate access to electricity for radios (no more dry cells) and TV (no more carrying car battery for charging in market) and saves money
- ◆ Low maintenance
- ◆ Long life > 20 years
- ◆ Easily expanded (modular) should needs increase
- ◆ Environmentally friendly
- ◆ etc

6.7.5.3 Handling the PV price issue

- ◆ PV competing and cheap to acquire alternatives
 - Kerosene lamps for lighting
 - Dry cells for radios/electronics
 - Rechargeable car battery for TV, recharged at local markets
 - All these cheap to buy but expensive to operate
- ◆ The cycle life cost concept (qualitative)
Full cost of owning product over its lifetime includes
 - buying price
 - fuel cost
 - repair costs
 - spares
- ◆ PV price comparison with alternatives should be on total cost of buying and operating them over their service life.

7.0 APPENDIXES

7.1 BASIC TOOLS AND EQUIPMENT REQUIREMENTS FOR BASIC PV TRAINING COURSES

The suggested quantities are recommended minimum meant for every 6 participants.

| Item No. | Quantity | Description |
|----------|----------|--|
| 1 | 4 | PV Modules assorted sizes and ratings |
| 2 | 1 each | Mounting Structures – roof, pole, ground |
| 3 | 2 | Charge Controller 12V c/w indicators |
| 4 | 2 | Multimeter – digital 10A |
| 5 | 2 | Batteries |
| 6 | 2 sets | Battery terminals |
| 7 | 2 litres | Battery water |
| 8 | 1 packet | Cable Lugs and crimps 2.5mm to 6mm |
| 9 | 2 each | Various Lamp fittings and accessories -Tube, CFL, incandescent, external |
| 10 | 4 | Fuse and Holder of various ratings |
| 11 | 1 roll | Wiring cable 2.5 mm twin |
| 12 | 10m | 4 to 10 sq.mm. cable lengths each |
| 13 | 4 | Mini trunks |
| 14 | 2 | Isolator double pole |
| 15 | 1 packet | Rawl Plugs |
| 16 | 1 | Drill or Chisel |
| 17 | 1 | Drill Bits set (both masonry and steel) |
| 18 | 1 | Tool box |
| 19 | 2 | Hydrometer |
| 20 | 2 | Splitter Switch |
| 21 | 1 packet | Junction Boxes |
| 22 | 1 | Nuts and Bolts sets |
| 23 | 2 | Hammer |
| 24 | 1 | Hand Saw |
| 25 | 2 | Hacksaw and blades |
| 26 | 2 | Crimping tool set |
| 27 | 2 | Stripping tool set |
| 28 | 1 | Electrician knife |
| 29 | 2 | Screw Driver set |
| 30 | 2 | Spanner set |
| 31 | 2 | Allen Keys set |
| 32 | 1 | Ratchet Spanner Set |
| 33 | 0.5m | Cable samples - 6 to 70 sq.mm mounted on demo board |
| 34 | 1 | Compass |
| 35 | 1 | Inclinometer or equivalent |
| 36 | 1 packet | Switches |
| 37 | 2 | Inverter 200W - 1000W, 12V |
| 38 | 2 | Practice boards |

| | | |
|----|---|---|
| 39 | 2 | Earth rods and clamps |
| 40 | 1 | MCB consumer unit - 4 way with 4 mcbs of 5-30A rating |

7.2 Suggested reference materials.

- i) The solar entrepreneur's hand book by Geoff Stapleton, Larith Gunaratne and Peter JM Konics
- ii) Solar electric systems for Africa by Mark Hankins, revised edition
- iii) How to Start and run your own small business by Pete Odeng
- iv) Rural lighting by IT Power Ltd