

## CONTENT OF THE TRAINING MANUAL

### The Design and Installation of Off-Grid Photovoltaic (PV) Systems Training

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#### b. Contents

##### **Chapter 1 Introduction to Off-Grid PV Power System**

Course Overview. Types of off-grid PV power systems: stand-alone and hybrid PV system. Framework of system components.

##### **Chapter 2 Occupational, Safety and Health (OSH) Related Issues**

Safety requirements at workplace. Good work habits. On-site risk assessment. Safety requirements relating to handling PV modules, batteries, generator set. Hazards: physical hazards, electrical hazards, chemical hazards. Safety equipment. Site safety. Electrical shock.

##### **Chapter 3 Introduction to Solar Energy**

Sun-Earth physical geometry. Physical geography of Earth. Sun-Earth-Collector geometry. Solar time and civil time. Solar irradiance and geometric effect. Altitude and azimuth. Sunpath diagram. Magnetic and true north. Atmospheric effect on solar irradiation. Irradiance, irradiation and peak sun hour.

##### **Chapter 4 Fundamentals of Electricity**

Ohm's law. DC circuit: power and energy. Series and parallel circuits. AC circuit: Apparent power, real power, power factor.

### **Chapter 5 Photovoltaic Cells, Modules and Arrays**

Overview and Technology content. Solar cells and p-n junction. Types of solar cells: Monocrystalline, polycrystalline, amorphous. Performance of solar cells: Efficiency and fill factor, PV Modules. Standard Test Condition. PV module Datasheet. Open circuit test. Short circuit test. The IV curve characteristics. Maximum power. Factors that affect the performance of solar cells: Temperature, Irradiance, manufacturer tolerance. PV Array: Series, parallel and series-parallel modules: voltage, current and power. Module reliability.

### **Chapter 6 Mounting Structures**

Basics of structures and strength: Static and dynamic loadings. Types of PV mounting structures: Static and tracking. Examples of mounting structures.

### **Chapter 7 Batteries**

Types of batteries: Flooded lead acid batteries, Valve regulated lead acid (VRLA), Nickel Cadmium etc. Characteristics of batteries. Battery Datasheet. Energy storage in batteries. Battery capacity. Charging rate. Cut-off voltage. Depth of discharge (DOD). Discharge rate. Equalisation. Gassing. Self discharge rate. State of charge (SOC). Specific gravity. Sulphation. Battery voltage. Charging after deep discharge. Determining state of charge. Maintenance of batteries. Effect of temperature. Combining batteries. Battery selection criteria. Installation requirements. Life expectancy of batteries. Factors that affect the life of batteries. Cost of batteries. Battery isolation. Battery room layout.

### **Chapter 8 System Controllers**

Introduction: Purpose of controller. The charge/discharge cycle. Overcurrent protection. Types of controllers: linear and switching regulator (shunt or series). Types of switching controllers: single stage voltage sensing regulator. Monitoring features. Signaling for genset start-up.

### **Chapter 9 Inverters**

Introduction: Purpose of inverter. AC system: frequency, rms, peak value, voltage, current, harmonic distortion. Power factor. Types of inverters: pure sine wave and modified sine wave. Bi-directional inverter. Protection circuit: reverse polarity, overload, over temperature, high and low battery voltage. Inverter power. Surge capacity. Rating of inverter. Autostart/demand start features. Isolation. Selection of inverter. Radio frequency interference (RFI).

### **Chapter 10 Back-up Fuel Generators**

Introduction: Requirement for fuel generator set. Different positions of generator set in off-grid PV system. Generator set components: Engine, engine de-rating for operating conditions, alternator, automatic voltage regulator (AVR), base, fuel tank, battery, and silencer. Alternator parameters: power, voltage, full load current, instantaneous current, speed, derating for ambient temperature. Genset derating factor. Petrol versus diesel genset. Genset control system. Siting of genset. Steam genset.

### **Chapter 11 Energy Efficiency and Load Assessment**

Introduction. Passive solar design principle: orientation, thermal mass, insulation, windows, sun control, ventilation and placement of tree. Active solar design: Load assessment. Improving energy efficiency: heating, cooling, lighting, and other services. Estimating the electrical energy load. DC load assessment form. AC load assessment form.

### **Chapter 12 System Sizing – Part 1**

Introduction. Resource assessment. Average daily energy usage. Total Ah demand per day. Determination of system voltage. Sizing the solar batteries. Maximum and surge demand. Maximum charging current, daily depth of discharge, allowing for future load growth, specifying inverter: unidirectional inverter, inverter-charger and interactive inverter. System losses. Sizing the PV array: with standard regulator, with maximum power point tracker. Sizing the controller. Sizing the battery charger. Sizing the fuel generator set. Generator set run time.

### **Chapter 13 System Sizing – Part 2**

Sizing of bypass and blocking diodes. Sizing of DC and AC cables: permissible voltage drop, current carrying capacity (CCC). Sizing of fuses: main battery fuse, inverter, charge controller, generator set, Protection system: DC and AC fuses, DC and AC circuit breaker. Radial and ring circuit and AC load. Earthing and lightning protection.

### **Chapter 14 System Installation, Testing & Commissioning, Acceptance**

Installation preparation. Installation check list. Equipment installation: solar array, battery bank, ventilation of battery bank, inverter, fuel generator set. Safety equipment. Testing & commissioning: test required, checklist and procedure. System acceptance: test required, checklist and procedure. System documentation.

### **Chapter 15 System Maintenance**

Introduction. Maintenance schedule and log books: fuel generator, batteries, PV array, inverter, regulator and system integrity.

### **Chapter 16 Fault Finding and Troubleshooting**

Introduction. General guideline to fault finding: fuel generator, batteries, PV array, Inverter, regulators and system integrity.

### **Chapter 17 Economics**

Introduction. Basic economics: simple payback period, Life Cycle Costing.