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GUIDELINES ON DESIGN, INSTALLATION, OPERATION AND MAINTENANCE OF STAND-ALONE POWER SYSTEMS AND POWER BACKUP SYSTEMS

VERSION I

CONTENTS

PREFACE

This document provides a general guideline and best practices guide for design, installation, operation and maintenance of Stand-Alone Power Systems and Power Backup Systems in Sri Lanka. This guideline was prepared based on the applicable international standards and best industry practices around the world.

The installers can refer the Guidelines on Rooftop Solar Installation for Service Providers to have more information regarding rooftop solar PV systems.

Following documents were referred in preparation of this guideline. Appropriate specifications/ photos/charts have been taken from following documents.

- Guidelines on Rooftop Solar PV Installation for Solar Service Providers, Public Utilities Commission, Sri Lanka
- Off-Grid PV systems: Design and Installation, Global Sustainable Energy Solutions

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LIST OF ABBREVIATIONS

AC	Alternating Current
ATS	Automatic Transfer Switch
AGM	Absorbed Glass Mat
BESS	Battery Energy Storage System
BMS	Battery Management System
BS	British Standard
CB	Circuit Breakers
CEB	Ceylon Electricity Board
DC	Direct Current
FLA	Flooded Lead-Acid
GEL	Gelled Electrolytes
I	Current
IEC	International Electrotechnical Commission
MCB	Miniature Circuit Breaker
MPPT	Maximum Power Point Tracking
PBS	Power Backup System
PCE	Power Conversion Equipment
PPE	Personal Protective Equipment
PWM	Pulse Width Modulation
PUCSL	Public Utilities Commission of Sri Lanka
PV	Photo Voltaic
RCD	Residual Current Device
SAPS	Stand-Alone Power System
SLSEA	Sri Lanka Sustainable Energy Authority
SLSI	Sri Lanka Standards Institute
SPD	Surge Protective Device
TT	TT Earthing system, where two separate earth electrodes are installed at source and customer end.
USAID	United States Agency for International Development
V	Voltage
VRLA	Valve Regulated Lead-Acid

LIST OF DEFINITIONS

Power Backup Systems: Backup power is defined as any device that provides instantaneous, uninterruptible power.

Stand-Alone Power Systems: Stand Alone Power System is an independent power supply (without grid connection) which includes one or several energy sources such as solar panels, a battery for energy storage and a back-up diesel generator.

Earthing or Earthed: A general term used to describe the connection of conductive parts of an Electrical Installation or an appliance to earth.

Electrical Installation: An Electrical Installation comprises any fixed or temporary cable, switchgear, or other electrical equipment or apparatus within a premise or other place where there is an electricity supply (including outdoor locations). Fixed or portable electrical appliances are not considered part of the Electrical Installation.

Qualified Person: One who has skills and knowledge related to the construction and operation of the Solar PV electrical equipment and electrical installations and has received safety training to recognize and avoid the hazards involved.

Off-grid: Stand-alone system not connected to the Grid.

Cycle life: The lifespan of a battery expressed in terms of the number of charge-discharge cycles (typically under standardized conditions) that results in a degradation of the battery's capacity to a specified level, typically 80 percent.

Days of autonomy: The number of days that the system can continue to power the design load with no recharging of the batteries.

Depth of discharge DoD: The number of ampere-hours removed from a fully charged cell or battery, expressed as a percentage of rated capacity.

1. INTRODUCTION

Sri Lanka is on a rapid path to harness its renewable energy resources to reduce dependability on fossil fuel-based electricity generation and to support climate change initiatives.

Stand-Alone Power Systems (SAPS) play a significant role, in the process of harnessing renewables potential in Sri Lanka. Stand-Alone Power Systems are popular in remote areas where national grid connection is not available. In addition, these systems are used to increase the reliability by providing continuous power supply.

The main purpose of the Power Backup Systems is to provide uninterrupted power for critical loads during power outages. Power Backup Systems (PBS) were popular due to intermittent electricity interruptions in Sri Lanka. This guideline can be used for future installation and retrofit of existing Power Backup Systems according to standards procedures.

Given this background, the development of guidelines for Stand-Alone Power Systems and Power Backup Systems is vital for the betterment of the industry.

This document provides a general guideline, and the best practices guide for the design, installation, operation, and maintenance of Stand-Alone Power Systems and Power Backup Systems (PBS) in Sri Lanka.

2. SCOPE OF THE GUIDELINE

In Sri Lanka, there are three types of electrical connections available for small and medium scale houses/industries and commercial applications. They are single phase 30A, three phase 30A and three phase 60A.

This guideline has been developed to design and implement alternative power source (off grid system) for domestic/small scale industrial and commercial applications.

It is not recommended to use this guideline for the system capacity beyond **three phase 60A**.

According to BS 7671, the applicable maximum voltages for these applications are limited to 1,000 V AC and 1,500 Vdc.

2.1 POWER BACKUP SYSTEMS (PBS)

The main purpose of Power Backup Systems is to provide temporary power during a power interruption. Power Backup Systems are popular where the reliability of the power system is important. This is because Power Backup Systems provides a backup power source that can quickly and seamlessly take over in case of a power outage.

In Sri Lanka, two system configurations are popular,

1. Power Backup System connected with grid only.
2. Power Backup System connected with grid and solar system.

For the first configuration, a battery storage system and a Power Conversion Equipment (PCE) are the main components of Power Backup Systems.

It is very common in Sri Lanka; Power Backup Systems are powered by both the grid and solar system.

For this guideline, solar power, grid power and generator power are main energy sources for the Power Backup System.

Schematic diagram of Power Backup System is given in Figure 1: Schemetic of Power Backup System-Grid only and Figure 2: Schemetic of Power Backup System-grid and solar.

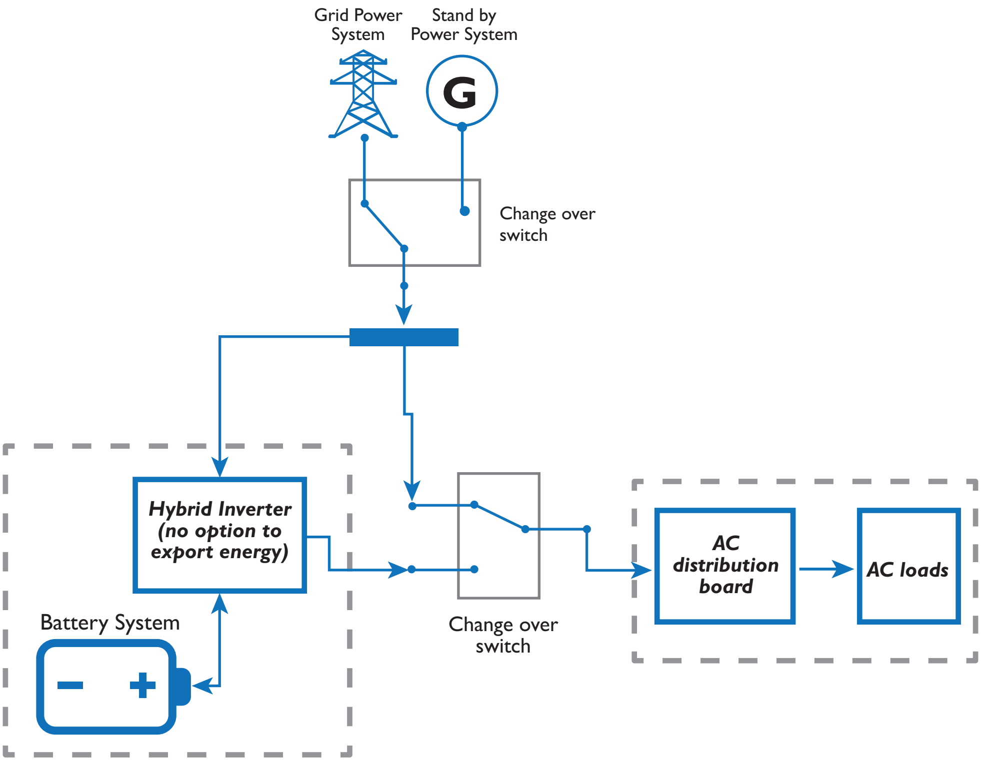


Figure 1: Schematic of Power Backup System-Grid only

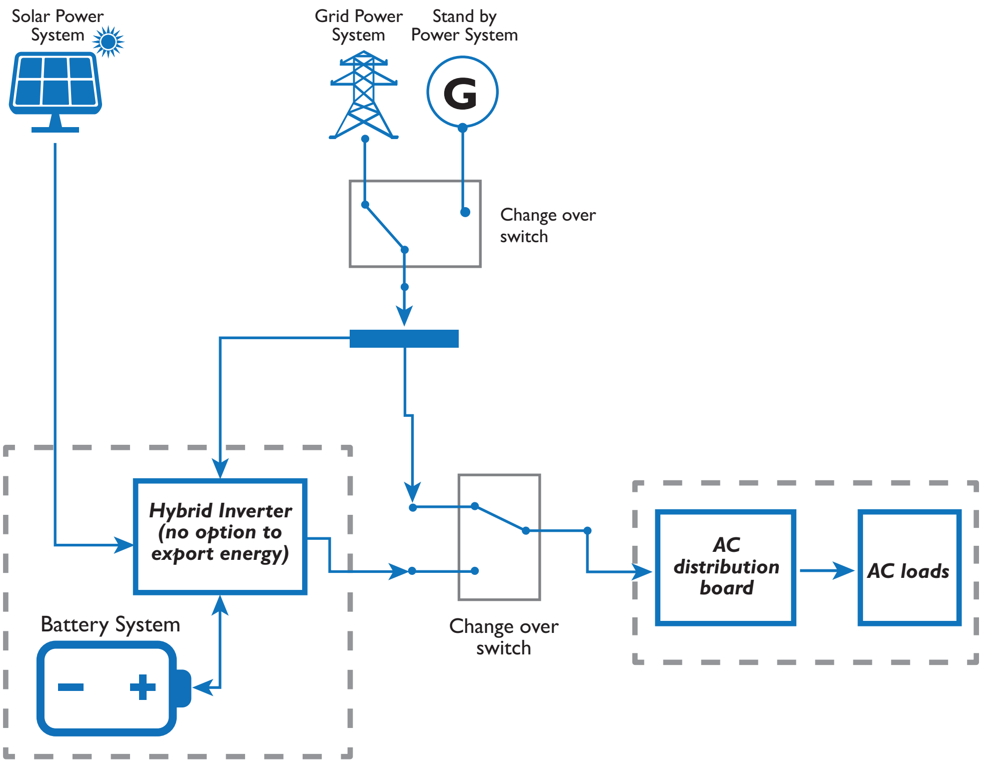


Figure 2: Schematic of Power Backup System-grid and solar

NOTE: INCORRECT EARTHING SYSTEM WITH AN EXISTING POWER BACKUP SYSTEM IN SRI LANKA

During the load shedding period in 2022/2023, significant numbers of Power Backup Systems had been installed in Sri Lanka, and it is observed that most of the installations are not according to the standard.

In Sri Lanka, the earthing system of almost all domestic electrical system is TT, where two separate earth electrodes are installed at source and consumer point as shown in Figure 3: TT Earthing system.

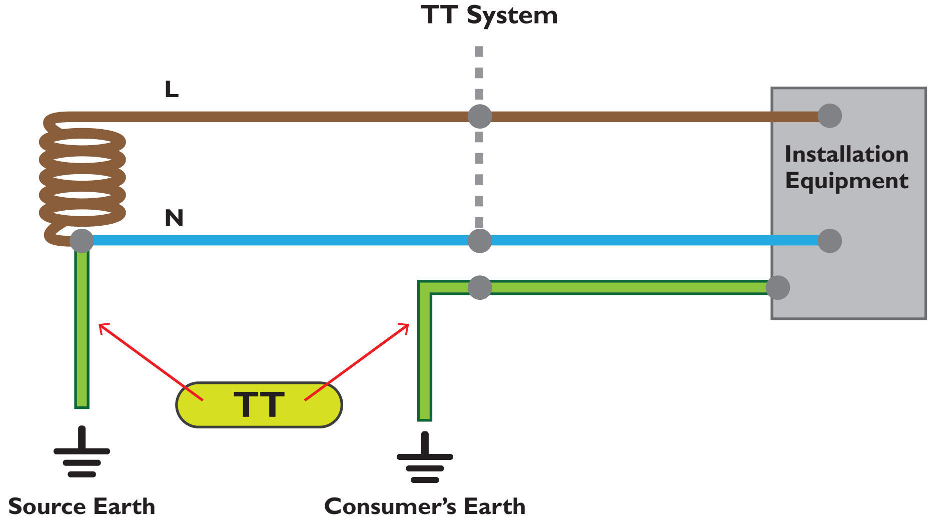


Figure 3: TT Earthing system

If a common inverter/charger is connecting with an existing distribution system, RCD devises will not operate with a TT earthing system.

An earthing system shall be changed to TN-S earthing system during isolate mode operation, in order to make protection devices operations (RCD)

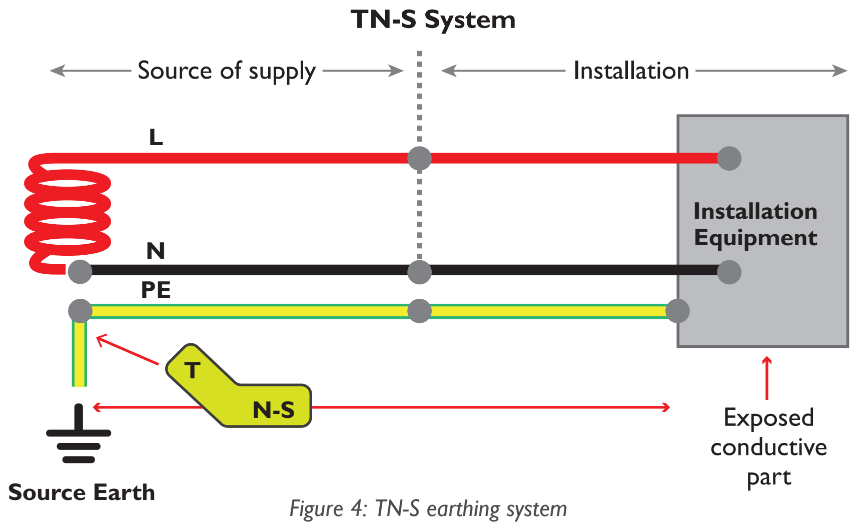


Figure 4: TN-S earthing system

Details of this earthing arrangement is given under the section "6.1 Special earthing arrangement for Power Backup Systems."

2.2 STAND-ALONE POWER SYSTEMS (SAPS)

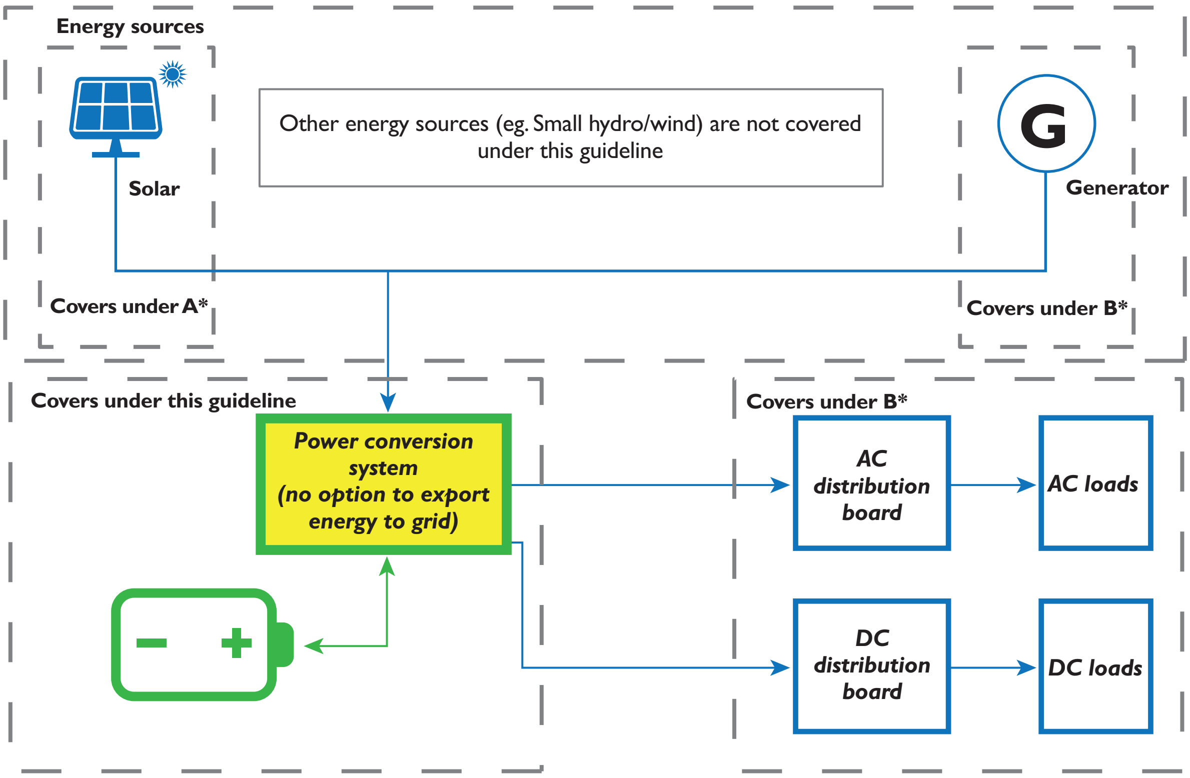
A Stand-Alone Power System (SAPS) is an independent power supply which mostly includes solar panels, a battery for energy storage and a back-up diesel generator. Stand-Alone Power Systems are mostly used in off grid applications where access to the main grid is impossible or costly.

SAPS can be powered through different power sources such as grid power/generator power/wind power/solar power/hydro power and power generated from biomass plants. For this guideline, only solar power system and power from generators were considered.

"Figure 5: Different energy sources and possible output conditions for SAPS" shows the general layout of ESS with all possible energy sources and output conditions.

Solar power is the most common energy source for SAPS applications in Sri Lanka

Output conditions can be AC output with single phase, or three phase system, or DC output based on the application requirement.



A* - Latest version of Guideline on Rooftop Solar PV Installations for Solar Service Providers, Sri Lanka

B* - Latest version of IET Wiring Regulations (BS 7671)

Figure 5: Different energy sources and possible output conditions for SAPS

2.2.1 COMMON SAPS CONFIGURATIONS.

SAPS consist of three major components, a power source, a storage system, and a power distribution system. The following three configurations are commonly used SAPS in Sri Lanka.

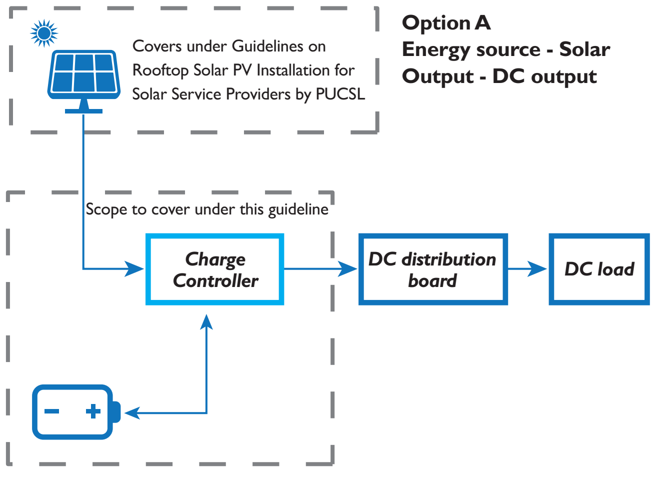


Figure 6: Possible configurations for SAPS- Solar input and DC output

This configuration is suitable for DC loads only.

It is a less complicated system with fewer equipment.

Not suitable for larger distribution of power, due to low DC voltage.

Suitable applications:

- DC light load applications.
- Solar pumping system (without battery)

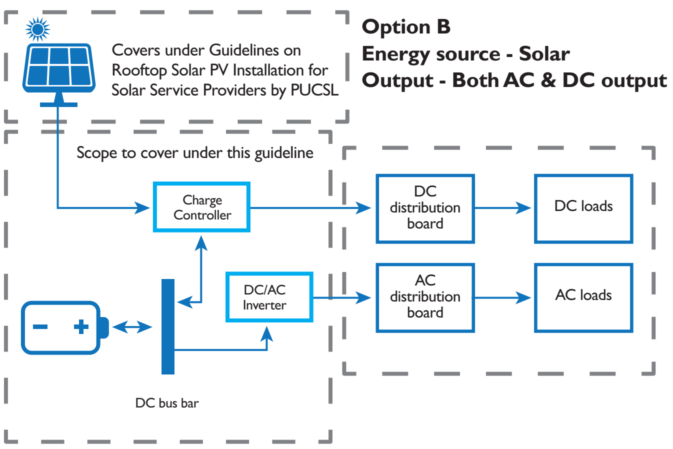


Figure 7: Possible configurations for SAPS-Solar input, both AC and DC output

This system can be powered by both DC and AC loads.

AC system can be used to distribute in greater area with higher distribution voltage.

Suitable applications:

- Small hotels
- Farms

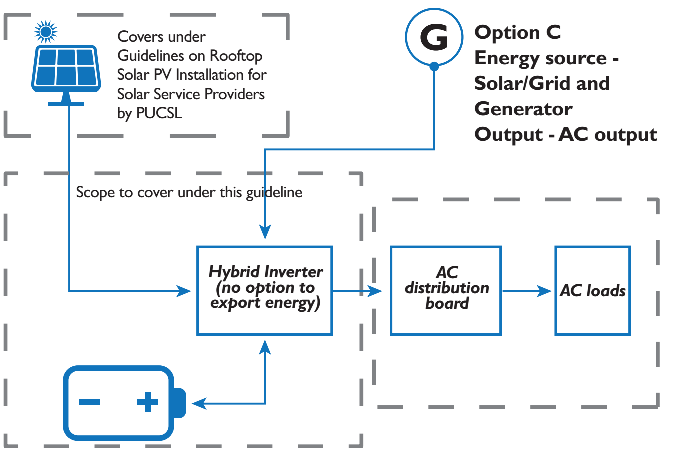


Figure 8: Possible configurations for SAPS-both solar and generator input and AC output

This is suitable for systems with higher demand with an intermittent load.

Suitable applications:

- Larger system

3. HAZARDS AND SAFETY

Any PBS or SAPS may present potential hazards and safety issues. As both PBS and SAPS consists of three main components, a power source (mainly solar power systems), a storage system and a power distribution system, there are general and unique hazards and safety issues related to each component. The necessary awareness of any potential hazards will help to develop a safer system.

Hazards and safety issues related to the roof top solar system are covered under the Guidelines on Rooftop Solar PV Installation for Solar Service Providers by the PUCSL.

The main objective of this section to understand potential hazards of **energy storage systems** which is the main component of both PBS and SAPS.

3.1 POSSIBLE HAZARDS?

A battery storage system poses various risks, and the following highlights some of the major hazards associated with these systems.

Electric shocks

The battery cells can deliver a severe electrical shock when interconnected as battery banks, reaching hazardous voltage levels.

Arc flash

The batteries have sufficient energy to cause an arc flash if it experiences a short circuit or fault.

Thermal runaway

Thermal runaway is a term used for the rapid uncontrolled release of heat from a battery cell; it is a condition when a battery creates more heat than it can effectively dissipate. Thermal runaway in a single cell can result in a chain reaction that heats up neighboring cells. When this process continues, it can result in a battery explosion and resulting fire. This can often be the ignition source for larger battery fires/combustions.

Stranded energy

As with most electrical equipment there is a hazard present to cause electrical outages, but what is unique about a battery energy storage system (BESS) is that often, even after a fire, there is still energy within the BESS. This is difficult to discharge since the terminals are often damaged and presents a hazard to those performing overhaul after a fire. Stranded energy can result in reignition post the fire, sometimes hours or even days later.

Toxic and flammable gases generated

Most batteries create toxic and flammable gases when they undergo thermal runaway. If the gases do not ignite before the lower explosive limit is reached, it can cause an explosion inside the BESS room or container.

3.2 RISK MANAGEMENT OF BESS

There are significant risks associated with BESS, those risk must be identified and managed during the design phase/installation phase and operation phase.

3.2.1 RISK MANAGEMENT THROUGH THE DESIGN

Most of the risks can be managed with a proper system design. The design and selection of materials shall be according to relevant international/local standards.

Designer should consider the following points as well. It is highly recommended to conduct a site inspection and ensure that the design is site specific.

Explosion protection/prevention

If there are enough batteries in a room to cause an explosion, then explosion prevention systems or deflagration venting should be installed.

Fire suppression system

Testing has shown water to be the most effective medium to cool a BESS fire. A suitable sprinkler system needs to be designed.

Battery management system (BMS)

A system that monitors, controls, and optimizes performance of individual or multiple battery modules in BESS and can control the disconnection of the module(s) from the system in the event of abnormal conditions.

Spacing

BESS units should be grouped into small segments limited to certain kilo-watt hours (kWh) and spread out from other segments and walls to prevent horizontal propagation.

Correct design

Correct equipment must be selected during the design phase in accordance with relevant standards and the manufacturer's specifications.

3.2.2 RISK MANAGEMENT DURING THE INSTALLATION AND OPERATION PHASE OF BESS.

The installation of the system shall be done by qualified professionals. Risks can be mitigated by adapting the following procedures during the installation and operation.

Installation phase

All components of the installation must be installed in accordance with the BESS manufacturers' instruction.

- Installation work practices must be in accordance with wiring rules and safety regulations.
- All switches/cables and other equipment must be labeled.
- Workers must be trained and qualified professionals.
- A readily accessible source of clean water shall be available for use in case of battery acid spills.
- Batteries shall be in a well-ventilated space/environment.

- All workers should wear appropriate clothing and personal protective equipment.
- Use appropriate equipment and correct practices.
- Maintain a clean and orderly work area.
- Be trained in First Aid.

Operation phase

- Users must be trained to handle the operation and emergency.
- Maintenance work must be implemented in accordance with manufacturer's guidelines by a qualified professionals.
- Installation of fire/smoke detection system.
- Conduct periodic thermal imaging survey.

3.3 DECOMMISSIONING OF BATTERIES

Proper decommissioning of batteries is vital, unless could lead to serious environmental and health damage due to the sulphiuric acid, lead mercury, nickel, cadmium and lithium present in the batteries.

It is highly recommended decommission/recycle batteries according to guidelines issued by the Central Environmental Authority, Sri Lanka.

4 COMPONENTS OF A POWER BACKUP SYSTEM (PBS)/ STAND-ALONE POWER SYSTEM (SAPS)

Following are key essential components of both PBS/SAPS.

A. Power Sources (Solar PV, Generator, Other) - Solar PV section is covered under the Guidelines on Rooftop Solar PV Installation for Solar Service Providers.

B. Power conversion system (Inverter, charge controllers and associated equipment)

C. Storage (Batteries/Battery management system)

D. Switchgears (SPDs, ATS (Auto/manual), MCBs, cables)

E. Power distribution system (AC loads and DC loads) - Power distribution systems shall be designed and installed according to BS 7671, which is the latest version.

The components related to the charging and discharging system with batteries and associated products (Items B, C and D on above list) are covered under this guideline.

The Components related to power sources are not covered under this guideline.

4.1 POWER CONVERSION SYSTEM

The most critical component of a Stand-Alone Power System/Power Backup System is Power Conversion Equipment (PCE). The primary function of a power conversion system is to convert electricity from DC/DC, AC/DC, and DC/AC. The following are some of additional functions of a power conversion system.

- Charging of batteries
- Provide protection functions.
- Switching functions
- Regulation functions (Voltage/Frequency/Power factor)
- Battery management functions

Solar charge controllers and inverters are main power conversion equipment.

The Power Conversion Equipment (PCE) shall be complied with the following Sri Lankan standards. SLS 1543 Sri Lanka Standard Specification for Safety of Power Converters for use in Photovoltaic Power Systems - Part 1:2016 General Requirements (IEC 62109-1:2010) Part 2:2016 Particular Requirements for Inverters (IEC 62109-2:2011) SLS 1680: 2020 Sri Lanka Standard Specification for Safety of Hybrid Inverter for Solar PV System

4.1.1 SOLAR CHARGE CONTROLLERS

A solar charge controller is the basic power conversion equipment which is used for off grid applications. It converts solar energy to charge batteries without overcharging them. Most modern charge controllers are equipped with output control and protection systems to prevents damage caused by the over discharge of batteries. Charge controller converts DC-to-DC power.

PWM (Pulse Width Modulation) and MPPT (Maximum Power Point Tracking) are two types of charge controllers available in the market. The MPPT charge controllers are available with a higher charging current rating.

PWM charge controller

PWM charge controllers are used for small scale systems. The operation principle of PWM controller is to set the output voltage of solar panel/s close to the nominal voltage of the battery bank (generally a little higher) to charge batteries from solar panel/s. PWM charge controllers are directly coupled with the battery.

With PWM charge controllers, the solar panels operating voltage is little bit higher than the battery voltage. Most of the time, the solar panels operating voltage is less than its maximum power point voltage, and this makes PWM less efficient in energy conversion.

PWM charge controllers are the cheapest power conversion equipment available in the market.

Selection of solar panels for PWM charge controller application

Solar panel voltage must be **SLIGHTLY HIGHER** than battery nominal voltage to charge batteries using PWM charge controllers with higher efficiency.

As the voltage difference between solar panel vs. battery increases, energy conversion efficiency will be reduced with PWM charge controllers.

PWM charge controllers are good for small off grid systems where the efficiency of the system is not a major concern.

MPPT charge controllers

MPPT stands for Maximum Power Point Tracking. The MPPT charge controller includes a DC-to-DC voltage converter, converting the voltage of the solar array to what is required by the batteries, with minimum loss of power. This helps to harness the maximum energy from the solar array at its maximum power point. Energy conversion efficiency of MPPT (about 98 percent) charge controllers is significantly higher than PWM charge controllers.

Selection of solar panels for MPPT charge controller application

As there is DC-to-DC voltage converter with in MPPT charge controller, battery voltage and solar array voltages are independent of the operation of the MPPT charge controller.

This gives more flexibility to select solar panels for the application along with MPPT charge controllers.

Parameters	12/24-5	12/24-10	12/24-20	12/24-30
Battery Voltage	12/24 V with automatic system voltage detection			
Rated charge current	5A	10A	20A	30A
Automatic load disconnect	Yes			
Maximum solar voltage	28V/55V (1)			
Self-consumption	< 10 mA			
Load output	Manual control + low voltage disconnect			
Protection	Battery reverse polarity (fuse) Output short circuit Over temperature			
Overload protection	Shut down after 60 s in case of 130% load			
	Shut down after 5 s in case of 160% load			
	Shut down after 5 s in case of 160% load			
Grounding	Common positive			
Operating temp. range	-20 to +50°C (full load)			
Humidity (non-condensing)	Max 95%			
BATTERY				
Charge voltage 'absorption'	14.2V/28,4V			
Charge voltage 'float'	13.8V/27,6V			
Low voltage load disconnect	11,2V/22,4V			
Low voltage load reconnect	12,6V/25,2V (manual) 13,1V/26,2V (automatic)			
ENCLOSURE				
Protection class	IP20			
Terminal size	5 mm²/AWG10			
Weight	0,15kg			0,2kg
Dimensions (h x w x d)	70 x 133 x 33,5 mm (2.8 x 5.3 x 1.3 inch)			
STANDARDS				
Safety	IEC 62109-1			
EMC	EN 61000-6-1, EN 61000-6-3, ISO 7637-2			
1) For 12V use 36 cell solar panels For 24V use 72 cell solar panels or 2 x 36 cell in series		2) The controller switches to the lower float voltage level 2 hours after the absorption voltage has been reached. Whenever the battery voltage becomes lower than 13V, a new charge cycle is triggered.		

Figure 9: Sample specification of PWM charge controller

Parameters	150/70	150/85	150/100
Battery voltage	12/24/48 V Auto Select (36 V: manual)		
Rated charge current	70 A	85 A	100 A
Nominal PV power, 12 V 1a,b)	1000 W	1200 W	1450 W
Nominal PV power, 24 V 1a,b)	2000 W	2400 W	2900 W
Nominal PV power, 36 V 1a,b)	3000 W	3600 W	4350 W
Nominal PV power, 48 V 1a,b)	4000 W	4900 W	5800 W
Max. PV short circuit current 2)	50 A (max 30 A per MC4 conn.)	70 A (max 30 A per MC4 conn.)	
Maximum PV open circuit voltage	150 V absolute maximum coldest conditions 145 V start-up and operating maximum		
Maximum efficiency	98 %		
Self-consumption	Less than 35 mA @ 12 V/20 mA @ 48 V		
Charge voltage 'absorption'	Default setting: 14,4/28,8/43,2/57,6 V (adjustable with: rotary switch, display, VE.Direct or Bluetooth)		
Charge voltage 'float'	Default setting: 13,8/27,6/41,4/55,2 V (adjustable: rotary switch, display, VE.Direct or Bluetooth)		
Charge voltage 'equalization'	Default setting: 16,2 V/32,4 V/48,6 V/64,8 V (adjustable)		
Charge algorithm	multi-stage adaptive (eight preprogrammed algorithms) or user defined algorithm		
Temperature compensation	-16 mV/-32 mV/-64 mV/°C		
Protection	PV reverse polarity/Output short circuit/Over temperature		
Operating temperature	-30 to +60 °C (full rated output up to 40 °C)		
Humidity	95 %, non-condensing		
Maximum altitude	5000m (full rated output up to 2000m)		
Environmental condition	Indoor, unconditioned		
Pollution degree	PD3		
Data communication	VE.Can, VE.Direct and Bluetooth		
Remote on/off	Yes (2 pole connector)		
Programmable relay	DPST AC rating: 240 VAC/4 A DC rating: 4 A up to 35 VDC, 1 A up to 60 VDC		
Parallel operation	Yes, parallel synchronised operation with VE.Can (max. 25 units) or Bluetooth (max. 10 units)		
ENCLOSURE			
Colour	Blue (RAL 5012)		
PV terminals 3)	35 mm²/AWG2 (Tr models) Two pairs of MC4 connectors (MC4 models)	35 mm²/AWG2 (Tr models) Three pairs of MC4 connectors (MC4 models)	
Battery terminals	35mm²/AWG2		
Protection category	IP43 (electronic components), IP22 (connection area)		
Weight	3 kg	4,5kg	
Dimensions (h x w x d) in mm	Tr models: 185 x 250 x 95 MC4 models: 215x 250 x 95	Tr models: 216 x 295 x 103 MC4 models: 246 x 295 x 103	
STANDARDS			
Safety	EN/IEC 62109-1, UL 1741, CSA C22.2		
STORED TRENDS			
Data stored	Battery voltage,current and temperature, as well as load output current, PV voltage and PV current.		
Number of days trends data is stored	46		
1a) If more PV power is connected, the controller will limit input power. 1b) The PV voltage must exceed Vbat + 5 V for the controller to start. Thereafter the minimum PV voltage is Vbat + 1 V. 2) A PV array with a higher short circuit current may damage the controller. 3) MC4 models: several splitter pairs may be needed to parallel the strings of solar panels Maximum current per MC4 connector: 30 A (the MC4 connectors are parallel connected to one MPPT tracker)			

Figure 10: Sample specification of MPPT charge controller

4.1.1.1 Operation principle of PWM vs MPPT charge controllers.

Figure 11: IV curve for PWM/MPPT charge controller presents a situation of an IV curve for a PWM charger controller and a MPPT charge controller.

The PWM charge controller is directly connected with the batteries. Then the solar module operating voltage will be slightly higher than the battery terminal voltage. Assuming a discharged battery the initial charge voltage will be around 13 V, and assuming a voltage loss of 0.5 V over the cabling plus controller, the panel will be at Vpwm = 13.5 V. When the corresponding current is at 13.5 V and is about 6A, then the total active power from the solar module is 81W, which is the operating power from solar module to battery.

In a MPPT charge controller, the solar module operates closer to its maximum power point voltage, harnessing the maximum power from the solar module. However, the maximum power of the solar module present is 100 W.

Note: PWM charge controllers are less efficient than MPPT charge controllers.

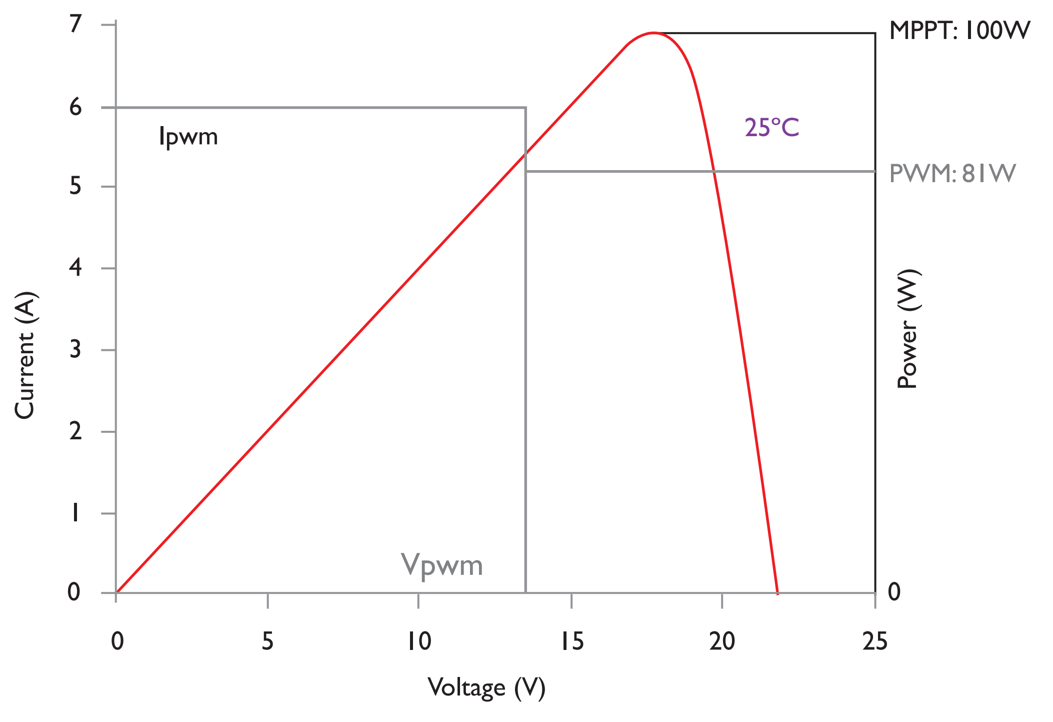


Figure 11: IV curve for PWM/MPPT charge controllers

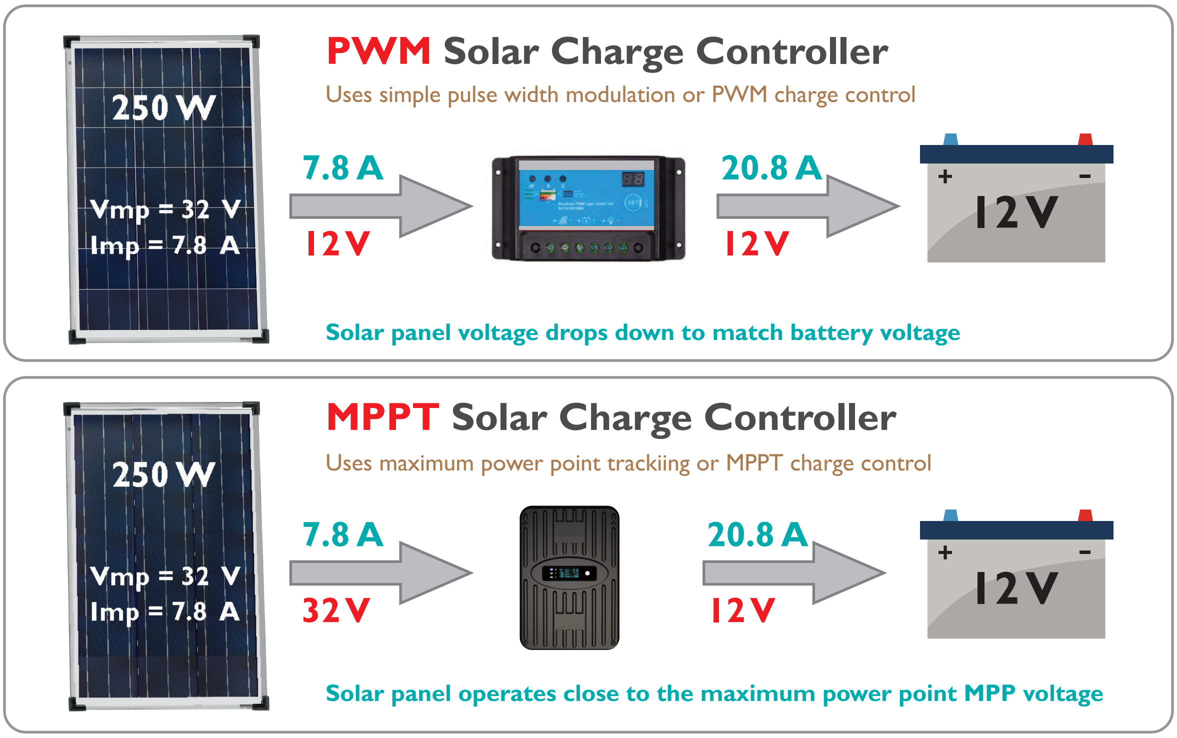


Figure 12: Representation of energy conversions from PWM and MPPT charge controllers

Table 1: Features of PWM vs MPPT charge controllers

PWM Charge Control	MPPT Charge Control
It is directly coupled; PV array & battery voltages must match.	It is connected via DC-to-DC converter, PV array voltage can be much higher than battery voltage
Generally, operates below the Vmpp, resulting in lower efficiency of the system. Recommended values for Vmpp are listed below: 12V systems: Vmpp > 15V 24V systems: Vmpp > 30V 36V systems: Vmpp > 45V 48V systems: Vmpp > 60V	Generally, operates at the Vmpp value of the solar panel, and the efficiency of the MPPT charge controller is higher than PWM controllers.
Good for small applications	Good for medium to larger systems
PV array, sized in Amps (based on current produced when PV array is operating at battery voltage)	PV array, sized in Watts (based on the Controller Max. Charging Current x Battery Voltage)

4.1.2 CHARGERS

A charger is a device which converts AC power to DC power and, then charges the batteries. The input power can be from a grid supply or generator supply. Chargers must be selected according to types of batteries and charging methods and voltages.

Parameters	12/30 (1+1) & (3)	12/50 (1+1) & (3)	24/16 (1+1) & (3)	24/25 (1+1) & (3)
Input voltage	85 -250 VAC (full power from 100 VAC, startup from 90 VAC)			
DC input voltage range	90 - 375 VDC			
Frequency	45-65 Hz			
Power factor	1			
Back current drain	<1 mA			
No load power consumption	1 W			
Maximum Efficiency	95 %	94 %	96 %	96 %
Charge voltage - Absorption/Float/ Storage	Normal: 14.4 V/13.8 V/13.2 V High: 14.7 V/13.8 V/13.2 V Li-ion: 14.2 V/N/A/13.5 V		Normal: 28.8 V/27.6 V/26.4 V High: 29.4 V/27.6 V/26.4 V Li-ion: 28.4 V/N/A/27.0 V	
Fully programmable	Yes, with Bluetooth and/or VE.Direct			
Maximum input current setting	3 – 10 A			
Number of battery connections	(1+1) models: 2 (2nd output via 2 pole terminal & 4 A max) | (3) models: 3			
Charge current house battery	30 A	50 A	16 A	25 A
Low current mode	15 A	25 A	8 A	12,5 A
Temperature compensation - Default	-16 mV/°C		-32 mV/°C	
Charge current starter battery	4 A Max (1+1 output models only)			
Charge algorithm	6-stage adaptive (3 stage for Li-ion)			
Protection	Battery reverse polarity (fuse, not user accessible)/Output short circuit/Over temperature			
Can be used as power supply	Yes, output voltage can be set with Bluetooth and/or VE.Direct			
Operating temp. range	-20 to 60 °C (0 – 140 °F) Rated output current up to 40 °C, derate linearly to 20 % at 60 °C			
Humidity (non-condensing)	max 95 %			
Remote on/off	Yes (2 pole terminal)			
Relay (programmable)	Yes (SPDT - 5 A up to 250 VAC/5 A up to 28 VDC)			
Bluetooth	Power: -4 dBm | Frequency: 2402 – 2480 MHz			
ENCLOSURE				
Material & Color	aluminium (blue RAL 5012)			
Battery connection	Screw terminals 16 mm² (AWG6)			
AC-connection	IEC 320 C14 inlet with retainer clip (AC cord ordered separately)			
Protection category	Electronic components: IP43 | Connection area: IP22			
Weight kg (lbs)	2,7 kg (6 lbs)			
Dimensions (h x w x d)	180 x 249 x 116 mm (7.1 x 9.8 x 4.6 inch)			
STANDARDS				
Safety	EN 60335-1, EN 60335-2-29			
Emission	EN 55014-1, EN 61000-6-3, EN 61000-3-2			
Immunity	EN 55014-2, EN 61000-6-1, EN 61000-6-2, EN 61000-3-3			
Vibration	IEC68-2-6:10-150Hz/1.0G			

Figure 13: Sample specification of a charger

4.1.3 INVERTERS

An inverter is a device that converts DC power to AC power.

Inverters connect to a battery bank, and they are voltage specific (12V, 24V, 48V or 120V DC).

Inverters can be categorized in two categories: **unidirectional inverters and bidirectional inverters.**

> Note: Unidirectional inverters only connect the battery bank to the AC loads. It is important to confirm the suitability of the stand-alone inverters output condition (e.g. Voltage values, wave form) with the intended load.
>
> Further, these inverters **MIGHT FAIL** if there is another AC source on the load side.

Parameters	C12/1200 C24/1200	C12/1600 C24/1600	C12/2000 C24/2000	12/3000 24/3000 48/3000	24/5000 48/5000
Parallel and 3-phase operation	Yes				
INVERTER					
Input voltage range (VDC)	9,5 – 17 V 19 – 33 V 38 – 66 V				
Output	Output voltage: 230 VAC ± 2 % Frequency: 50 Hz ± 0,1 % (1)				
Cont. output power at 25 °C (VA) (2)	1200	1600	2000	3000	5000
Cont. output power at 25 °C (W)	1000	1300	1600	2400	4000
Cont. output power at 40 °C (W)	900	1200	1450	2200	3700
Cont. output power at 65 °C (W)	600	800	1000	1700	3000
Peak power (W)	2400	3000	4000	6000	10000
Max. efficiency 12/24/48V (%)	92/94/94	92/94/94	92/92	93/94/95	94/95
Zero load power 12/24/48V (W)	8/10/12	8/10/12	9/11	20/20/25	30/35
Zero load power in AES mode (W)	5/8/10	5/8/10	7/9	15/15/20	25/30
Zero load power in Search mode (W)	2/3/4	2/3/4	3/4	8/10/12	10/15
GENERAL					
Programmable relay (3)	Yes				
Protection (4)	a - g				
VE.Bus communication port	For parallel and three phase operation, remote monitoring and system integration				
Remote on-off	Yes				
Common Characteristics	Operating temperature range: -40 to +65 °C (fan assisted cooling) Humidity (non-condensing): max 95 %				
ENCLOSURE					
Common Characteristics	Material & Colour: aluminium (blue RAL 5012) Protection category: IP21				
Battery-connection	battery cables of 1.5 meter included		M8 bolts	2+2 M8 bolts	
230 V AC-connection	G-ST18i plug		Spring-clamp	Screw terminals	
Weight (kg)	10	12	18	30	
Dimensions (hxwhd in mm)	375 x 214 x 110		520 x 255 x 125	362 x 258 x 218	444 x 328 x 240
STANDARDS					
Safety	EN 60335-1				
Emission Immunity	EN 55014-1/EN 55014-2				
1) Can be adjusted to 60 Hz and to 240 V 2) Non-linear load, crest factor 3:1 3) Programmable relay that can a.o. be set for general alarm, DC under voltage or genset start/stop function. AC rating: 230 V/4 A DC rating: 4 A up to 35 VDC, 1 A up to 60 VDC	4) Protection key: a) output short circuit b) overload c) battery voltage too high d) battery voltage too low e) temperature too high f) 230 VAC on inverter output g) input voltage ripple too high				

Figure 14: Sample specification of unidirectional inverter

Note: Bidirectional inverters have an added advantage as it can be operated as a battery charger. Typically, a genset can be connected and the batteries can be charged through the bidirectional inverter. The advantage of a bidirectional inverter is that the changeover switch is not required as with the generator. Further, batteries can be charged while supplying AC loads. Bidirectional inverters are often called **INVERTER-CHARGERS.**

12 Volt 24 Volt 48 Volt	12/500/20 24/500/10 48/500/6	12/800/35 24/800/16 48/800/9	12/1200/50 24/1200/25 48/1200/13	12/1600/70 24/1600/40 48/1600/20	12/2000/80 24/2000/50 48/2000/25
Power Control/PowerAssist	No	Yes	Yes	Yes	Yes
Three Phase and parallel operation	Yes	Yes	Yes	Yes	Yes
Transfer switch	16 A	16 A	16 A	16 A	35 A
INVERTER					
Input voltage range	9,5 – 17 V 19 – 33 V 38 – 66 V				
Output	Output voltage: 230VAC ± 2% Frequency: 50Hz ± 0,1% (1)				
Cont. output power at 25°C(3)	500 VA	800 VA	1200 VA	1600 VA	2000 VA
Cont. output power at 25°C	430 W	700 W	1000 W	1300 W	1600 W
Cont. output power at 40°C	400 W	650 W	900 W	1100 W	1400 W
Cont. output power at 65°C	300 W	400 W	600 W	800 W	1000 W
Peak power	900 W	1600 W	2400 W	2800 W	3500 W
Maximum efficiency	90/91/92%	92/93/94%	93/94/95%	93/94/95%	93/94/95%
Zero-load power	6/6/7 W	7/7/8 W	10/9/10 W	10/9/10 W	10/9/10 W
Zero-load power in search mode	2/2/3 W	2/2/3 W	3/3/3 W	3/3/3 W	3/3/3 W
CHARGER					
AC Input	Input voltage range: 187-265 VAC Input frequency: 45 – 65 Hz				
Charge voltage 'absorption'	14,4/28,8/57,6 V				
Charge voltage 'float'	13,8/27,6/55,2 V				
Storage mode	13,2/26,4/52,8 V				
Charge current house battery (4)	20/10/6 A	3 5/1 6/9 A	5 0/2 5/13 A	7 0/4 0/20 A	80/50/25 A
Charge current starter battery	1A (12 V and 24 V models only)				
Battery temperature sensor	Yes				
GENERAL					
Programmable relay (5)	Yes				
Protection (2)	a - g				
VE.Bus communication port	For parallel and three phase operation, remote monitoring and system integration (RJ45-spliter ASS030065510 needed for 500/800/1200 VA models)				
Remote on-off	On/off/charger only			On/off	
DIP switches	Yes (6)	Yes (6)	Yes (6)	Yes (7)	Yes (7)
Internal DC fuse	125/60/30 A	150/80/40 A	200/100/50 A	200/125/60 A	no
Common Characteristics	Operating temp. range: -40 to +65°C (fan assisted cooling) Humidity (non-condensing): max 95%				
ENCLOSURE					
Common Characteristics	Material & Colour: Steel/ABS (blue RAL 5012) Protection category: IP 21				Steel (RAL 5012), IP22
Battery-connection	16/10/10 mm²	25/16/10 mm²	35/25/10 mm²	50/35/16 mm²	M8 bolts
230V AC-connection	G-ST18i connector				Screw
Weight	4,4 kg	6,4 kg	8,2 kg	10,2 kg	15,5 kg
Dimensions (h x w x d) mm	311 x 182 x 100	360 x 240 x 100	406 x 250 x 100	470 x 265 x 120	506 x 236 x 147
STANDARDS					
Safety	EN-IEC 60335-1, EN-IEC 60335-2-29, EN 62109-1				
Emission Immunity	EN 55014-1, EN 55014-2, EN-IEC 61000-3-2, EN-IEC 61000-3-3, IEC 61000-6-1, IEC 61000-6-2, IEC 61000-6-3				
Automotive Directive	ECE R10-5				
1) Can be adjusted to 60Hz and to 240V 2) Protection: a. Output short circuit b. Overload c. Battery voltage too high d. Battery voltage too low e. Temperature too high f. 230VAC on inverter output g. Input voltage ripple too high	3) Non-linear load, crest factor 3:1 4) Up to 25°C ambient 5) Programmable relay which can be set for: general alarm, DC under voltage or generator start/stop signal function AC rating: 230V/4A DC rating: 4A up to 35VDC, 1A up to 60VDC 6) Remote/battery charge voltage/inverter frequency/search mode 7) Battery charge voltage/search mode				

Figure 15: Sample specification of unidirectional inverter (INVERTER-CHARGER)

4.1.4 HYBRID INVERTER

A Hybrid inverter consists of a charge controller, charger, and inverter as one unit. There are two types of hybrid inverters

- Grid tied hybrid inverter - which is having export to grid function.
- Off grid hybrid inverter - which is not having export to grid function.

Model	Model 01	Model 02	Model 03	Model 04	Model 05
Battery Input Data					
Battery Type	Lead-acid or Lithium-ion				
Battery Voltage Range (V)	40-60				
Max. Charging Current (A)	120	150	190	210	240
Max. Discharging Current (A)	120	150	190	210	240
Charging Strategy for Li-ion Battery	Self-adaption to BMS				
Number of Battery Input	1				
PV String Input Data					
Max. DC Input Power (W)	6500	7800	10400	13000	15600
Max. DC Input Voltage (V)	800				
Start-up Voltage (V)	160				
MPPT Voltage Range (V)	200-650				
Rated DC Input Voltage (V)	550				
Max. Operating PV Input Current (A)	13+13			26+13	
Max. Input Short-Circuit Current (A)	17+17			34+17	
No. of MPP Trackers/No. of Strings per MPP Tracker	2/1+1			2/2+1	
AC Input/Output Data					
Rated AC Input/Output Active Power (W)	5000	6000	8000	10000	12000
Max. AC Input/Output Apparent Power (VA)	5500	6600	8800	11000	13200
Rated AC Input/Output Current (A)	7.6/7.2	9.1/8.7	12.1/11.6	15.2/14.5	18.2/17.4
Max. AC Input/Output Current (A)	8.4/8	10/9.6	13.4/12.8	16.7/15.9	20/19.1
Max. Three-phase Unbalanced Output Current (A)	11.4/10.9	13.6/13	18.2/17.4	22.7/21.7	27.3/26.1
Max. Continuous AC Passthrough (grid to load) (A)	45				
Peak Power (off-grid) (W)	2 times of rated power, 10s				
Power Factor Adjustment Range	0.8 leading to 0.8 lagging				
Rated Input/Output Voltage/Range (V)	220/380V, 230/400V 0.85Un-1.1Un				
Rated Input/Output Grid Frequency/Range(Hz)	50/45-55, 60/55-65				
Grid Connection Form	3L+N+PE				
Total Current Harmonic Distortion THDi	<3% (of nominal power)				
DC Injection Current	<0.5% In				
Efficiency					
Max. Efficiency	97.6%				
Euro Efficiency	97.0%				
MPPT Efficiency	>99%				
Equipment Protection					
Integrated	DC Polarity Reverse Connection Protection, AC Output Overcurrent Protection AC Output Overvoltage Protection, AC Output Short Circuit Protection, Thermal Protection DC Terminal Insulation Impedance Monitoring, DC Component Monitoring, Ground Fault Current Monitoring Power Network Monitoring, Island Protection Monitoring, Earth Fault Detection, DC Input Switch Overvoltage Load Drop Protection, Residual Current (RCD) Detection, Surge protection level				
Surge Protection Level	TYPE II(DC), TYPE II(AC)				
Interface					
Communication Interface	WIFI, RS485, CAN				
General Data					
Operating Temperature Range (°C)	-40 to +60°C, >45°C Derating				
Permissible Ambient Humidity	0-100%				
Permissible Altitude	2000m				
Noise (dB)	≤55				
Ingress Protection(IP) Rating	IP 65				
Inverter Topology	Non-Isolated				
Over Voltage Category	OVC II(DC), OVC III(AC)				
Cabinet Size (WxHxD mm)	422×658×254 (Excluding Connectors and Brackets)				
Weight (kg)	38				
Type of Cooling	Intelligent Air Cooling				
Warranty	5 Years/10 Years the Warranty Period Depends the Final Installation Site of Inverter, More Info Please Refer to Warranty Policy				
Grid Regulation	IEC 61727, IEC 62116, CEI 0-21, EN 50549, NRS 097, RD 140, UNE 217002, OVE-Richtlinie R25, G99, VDE-AR-N 4105				
Safety/EMC Standard	IEC/EN 61000-6-1/2/3/4, IEC/EN 62109-1, IEC/EN 62109-2				

Figure 16: Sample specification of hybrid inverter

INVERTER OUTPUT

SAPS systems and Power Backup Systems often struggle with system failures and equipment damage due to the poor power quality. Quality equipment needs to be selected for critical/ sensitive loads.

Warranties: For off-grid solar systems, product warranties can vary based on the components used. In general, charge controllers often come with warranties of 1 to 5 years, while solar inverters (grid tie/hybrid) typically come with warranties ranging from 5 to 10 years, depending on the manufacturer. Other components: wiring, and other system components may have varying warranty periods.

4.2 BATTERY TECHNOLOGIES

Batteries are the main energy storage device for this kind of small energy storage application. There are many different types of batteries available in the market. A suitable battery shall be selected based on the application.

Lead-acid batteries and lithium batteries are the commonly used batteries for Power Backup Systems and Stand-Alone Power Systems. Each has different performance characteristics and installation requirements which must be considered when selecting these batteries.

The following are applicable standards for batteries. It is highly recommended that selected batteries shall be according to the following standards.

IEC 61427 - Secondary cells and batteries for renewable energy storage - General requirements and methods of testing.

IEC 62619 - Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications.

IEC 60896 - Stationary lead-acid batteries

UL 1642 - Standard for safety lithium batteries.

4.2.1 LEAD-ACID BATTERIES

Lead-acid batteries are the most frequently used battery type for energy storage systems because it has a lower cost than batteries with the latest technology. There are several different lead-acid battery models available to suit various applications. These are traction batteries, starting batteries, stationery batteries and deep cycle solar batteries.

The most suitable lead-acid battery for energy storage systems is called deep cycle solar batteries. Flooded Lead-Acid (FLA) batteries and Valve Regulated Lead-Acid (VRLA) are two types of lead-acid deep cycle batteries.

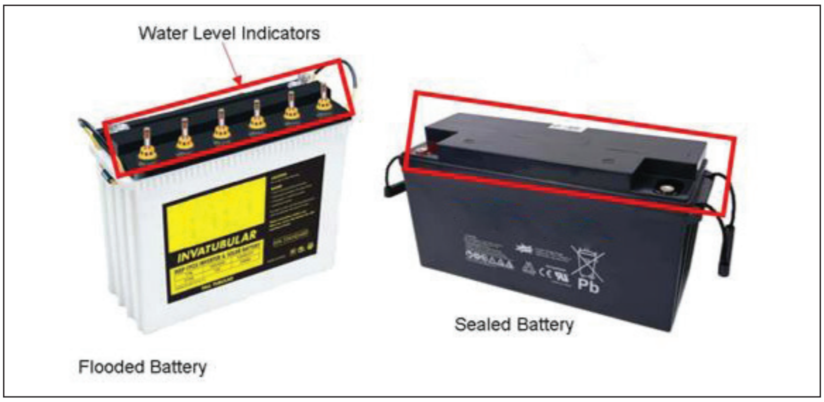


Figure 17: Sample specification of AGM battery

Flooded Lead-Acid (FLA) batteries

Flooded batteries can be identified by having a small, ventilated access to their internal structure with removable plugs that allow verifying the specific gravity of liquid and the state of charge of the battery. The main downside of these batteries is that they emit gases that are generated by the internal electrochemical reactions. Therefore, these batteries must be in an area with vented access where air circulates constantly. The accumulation of these gases within a small, closed area can be dangerous.

Valve Regulated Lead-Acid (VRLA) batteries.

VRLA batteries are a sealed type with small, regulated valves to release gases. These batteries require less maintenance compared to Flooded Lead-Acid batteries. AGM (Absorbed Glass Mat) and GEL (Gelled Electrolytes) are two types of batteries under this technology, Both AGM and GEL products have particularly low self-discharge so that they will not go flat during long periods without charge, and they are good for applications which requires several days of autonomy.

A new AGM battery: the AGM Super Cycle battery

A truly innovative battery

The AGM Super Cycle batteries are the result of recent battery electrochemistry developments. The paste of the positive plates is less sensitive to softening, even in case of repeated 100% discharge of the battery, and new additives to the electrolyte reduce sulfation in case of deep discharge.

Exceptional 100% depth of discharge (DoD) performance

Tests have shown that the Super Cycle battery does withstand at least three hundred 100% DoD cycles. The tests consist of a daily discharge to 10,8V with $I = 0,2C_{20}$, followed by approximately two hours rest in discharged condition, and then a recharge with $I = 0,2C_{20}$. The two hours rest period in discharged condition will damage most batteries within 100 cycles, but not the Super Cycle battery. We recommend the Super Cycle battery for applications where an occasional discharge to 100% DoD, or frequent discharge to 60-80% DoD is expected.

Smaller and lighter

An additional advantage of the new chemistry is a slightly smaller size and less weight compared to our standard deep cycle AGM batteries.

Low internal resistance

The internal resistance is also slightly lower compared to our standard deep cycle AGM batteries.

Recommended charge voltage:

	Float Service	Cycle service Normal	Cycle service Fast recharge
Absorption		14,2 - 14,6 V	14,6 - 14,9 V
Float	13,5 - 13,8 V	13,5 - 13,8 V	13,5 - 13,8 V
Storage	13,2 - 13,5 V	13,2 - 13,5 V	13,2 - 13,5 V

Specifications

Article number	V	Ah C5 (10,8V)	Ah C10 (10,8V)	Ah C20 (10,8V)	l x w x h mm	Weight kg	CCA @0°F	RES CAP @80°F	Terminals
Model 01	12	13	14	15	151 x 100 x 103	4,1			Faston
Model 02	12	22	24	25	181 x 77 x 175	6,5			M5 insert
Model 03	12	34	36	38	267 x 77 x 175	9,5			M5 insert
Model 04	12	52	56	60	224 x 135 x 178	14	300	90	M5 insert
Model 05	12	82	90	100	260 x 168 x 215	26	500	170	M6 insert
Model 06	12	105	114	125	330 x 171 x 214	33	550	220	M8 insert
Model 07	12	145	153	170	336 x 172 x 280	45	600	290	M8 insert
Model 08	12	200	210	230	532 x 207 x 226	57	700	400	M8 insert

Cycle life

≥ 300 cycles @ 100% DoD (discharge to 10,8V with $I = 0,2C_{20}$, followed by approximately two hours rest in discharged condition, and then a recharge with $I = 0,2C_{20}$)

≥ 700 cycles @ 60% DoD (discharge during three hours with $I = 0,2C_{20}$, immediately followed by recharge at $I = 0,2C_{20}$)

≥ 1000 cycles @ 40% DoD (discharge during two hours with $I = 0,2C_{20}$, immediately followed by recharge at $I = 0,2C_{20}$)

Figure 18: Sample specification of AGM battery

4.2.2 LITHIUM BATTERIES

The most suitable and recommended technology for solar power applications are Li-ion batteries. There are many Li-ion chemistry configurations, but the predominant technology for solar power applications is the Lithium Iron Phosphate (LiFePO4) and Lithium-ion (Li-ion) technologies. They have the highest depth of discharge (about 80 percent). They have low self-discharging rates (and lifetime of five to ten years), and have a high energy density, which means smaller dimensions. Li-ion batteries have superior efficiency (95-99% efficiency) and a very low internal resistance, which makes them faster to charge. Another major advantage of Li-ion batteries is that they can deliver more charging and discharging cycles than lead-acid batteries would.

Figure 19 : Li Fe PO4 battery

Our LFP batteries have integrated cell balancing and cell monitoring. The cell balancing/monitoring cables can be daisy-chained and must be connected to a Battery Management System (BMS).

Battery Management System (BMS)

The BMS will:

1. Generate a pre-alarm whenever the voltage of a battery cell decreases to less than 3.1 V (adjustable 2.85 V - 3.15 V).
2. Disconnect or shut down the load whenever the voltage of a battery cell decreases to less than 2.8 V (adjustable 2.6 V - 2.8 V).
3. Stop the charging process whenever the voltage of a battery cell increases to more than 3.75 V or when the temperature becomes too high or too low.

See the BMS datasheets for more features.

Battery specification								
VOLTAGE AND CAPACITY	12,8/50	12,8/100	12,8/160	12,8/180	12,8/200	12,8/330	25,6/100	25,6/200-a
Nominal voltage	12,8 V	12,8 V	12,8 V	12,8 V	12,8 V	12,8 V	25,6 V	25,6 V
Nominal capacity @ 25°C*	50 Ah	100 Ah	160 Ah	180 Ah	200 Ah	330 Ah	100 Ah	200 Ah
Nominal capacity @ 0°C*	40 Ah	80 Ah	130 Ah	150 Ah	160 Ah	260 Ah	80 Ah	160 Ah
Nominal capacity @ -20°C*	25 Ah	50 Ah	80 Ah	90 Ah	100 Ah	160 Ah	50 Ah	100 Ah
Nominal energy @ 25°C*	640 Wh	1280 Wh	2048 Wh	2304 Wh	2560 Wh	4220 Wh	2560 Wh	5120 Wh
*Discharge current ≤1C								
CYCLE LIFE (capacity ≥ 80 % of nominal)								
80 % DoD	2500 cycles							
70 % DoD	3000 cycles							
50 % DoD	5000 cycles							
DISCHARGE								
Maximum continuous discharge current	100 A	200 A	320 A	360 A	400 A	400 A	200 A	400 A
Recommended continuous discharge current	≤50 A	≤100 A	≤160 A	≤180 A	≤200 A	≤300 A	≤100 A	≤200 A
End of discharge voltage	11,2 V	11,2 V	11,2 V	11,2 V	11,2 V	11,2 V	22,4 V	22,4 V
Internal resistance	2mΩ	0,8mΩ	0,9mΩ	0,9mΩ	0,8mΩ	0,8mΩ	1,6mΩ	1,5mΩ
OPERATING CONDITIONS								
Operating temperature	Discharge: -20°C to +50°C Charge: +5°C to +50°C							
Storage temperature	-45°C to +70°C							
Humidity (non-condensing)	Max. 95 %							
Protection class	IP 22							
CHARGE								
Charge voltage	Between 14 V/28 V and 14,4 V/28,8 V (14,2 V/28,4 V recommended)							
Float voltage	13,5 V/27 V							
Maximum charge current	100 A	200 A	320 A	360 A	400 A	400 A	200 A	400 A
Recommended charge current	≤30 A	≤50 A	≤80 A	≤90 A	≤100 A	≤150 A	≤50 A	≤100 A
OTHER								
Max storage time @ 25°C*	1 year							
BMS connection	Male + female cable with M8 circular connector, length 50cm							
Power connection (threaded inserts)	M8	M8	M8	M8	M8	M10	M8	M8
Dimensions (hxwxd) mm	199 x 188 x 147	197 x 321 x 152	237 x 321 x 152	237 x 321 x 152	237 x 321 x 152	265 x 359 x 206	197 x 650 x 163	237 x 650 x 163
Weight	7 kg	14 kg	18 kg	18 kg	20 kg	29 kg	28 kg	39 kg
* When fully charged								

Figure 20: Sample specification of Li-Iron Phosphate battery

Table 2: Comparison of battery technologies

Typical values of batteries				
Parameters	Lithium batteries	Lead-acid batteries		
		Flooded	Sealed AGM	Sealed GEL
Upfront cost	High	Low	Moderate	High
Cost per kWh cycle	Lowest	Low	Low to moderate	Moderate
Expected lifespan	10+ years	3-5 years	4-5 years	5-6 years
Maximum recommended DOD*	80%	50%	50%	50%
Regular maintenance	None	Watering, equalizing, and cleaning	None	None
Best applications	All renewable energy systems	Full-time residences with committed, hands-on owners willing to do regular maintenance and replacement	Part time residences with intermittent use	Part time residences without high surge loads
Worst applications	Projects on light budget	Part time residences with intermittence use	Systems requiring deep discharge	Systems requiring high amperage charging and discharging

4.2.3 BATTERY MANAGEMENT SYSTEM (BMS)

Battery monitoring systems are required to monitor state of charge of the battery bank to ensure it is not either overcharged or over discharged. Charge controllers regulate the current flowing in and out of a battery bank. Hence, lead-acid batteries can be operated with a charge controller.

Li-ion battery system needs a high level of monitoring system, which is called Battery Management System (BMS).

Battery Management System (BMS) is an electronic control system that monitors and regulate the charging and discharge of batteries. It provides a higher level of control and protection for the battery bank as it can monitor the charge current, voltage and temperature of battery cells, including down to the individual cell level.

All Li-ion batteries must be used only with a BMS while meeting the battery manufacturer's specifications.

Some Li-ion battery systems require integration with other system components, such as the inverter and charge controller.

4.3 FACTORS TO BE CONSIDERED FOR BATTERY SELECTION.

The following factors need to be considered when selecting a battery for an application.

Energy storage capacity of a battery - Ampere-hour (Ah) is the unit to measure battery capacity. It can be converted to kWh units from the equation below, where Ah - battery capacity, V - Battery voltage.

$$kWh = \frac{Ah \times V}{1000}$$

Discharge rate - the rate of discharge and battery temperature have a significant impact on battery capacity. The discharge rate of a battery is given as Cx. rating or #C rating.

Cx. rating = discharge current x X (in hours).

This equation can be written as

$$\text{Discharge current (A)} = \frac{\text{Cx rating (Ah)}}{\text{x (in hours)}}$$

Depth of Discharge (DoD) - A battery's depth of discharge (DoD) indicates the percentage of the battery that has been discharged relative to the overall capacity of the battery.

Batteries have a recommended DoD to prevent damage.

$$\text{DoD (\%)} = \frac{\text{discharged capacity}}{\text{rated capacity}} \times 100\%$$

Daily DoD - The daily DoD represents the regular battery discharge over the period of a day.

State of Charge (SoC) - is a measure of how much of the initial battery capacity is available and is expressed in terms of a percentage of the battery rated capacity. Therefore, SoC plus DoD will always be 100%.

$$\text{SoC (\%)} = \frac{\text{available capacity}}{\text{rated capacity}} \times 100\%$$

Battery life - Battery life depends on several factors in which numbers of cycle and temperature are the main factors. Figure 6: Effect of depth of discharge on the cycle life of a Lead-acid battery shows the effect of cycles with battery life cycle.

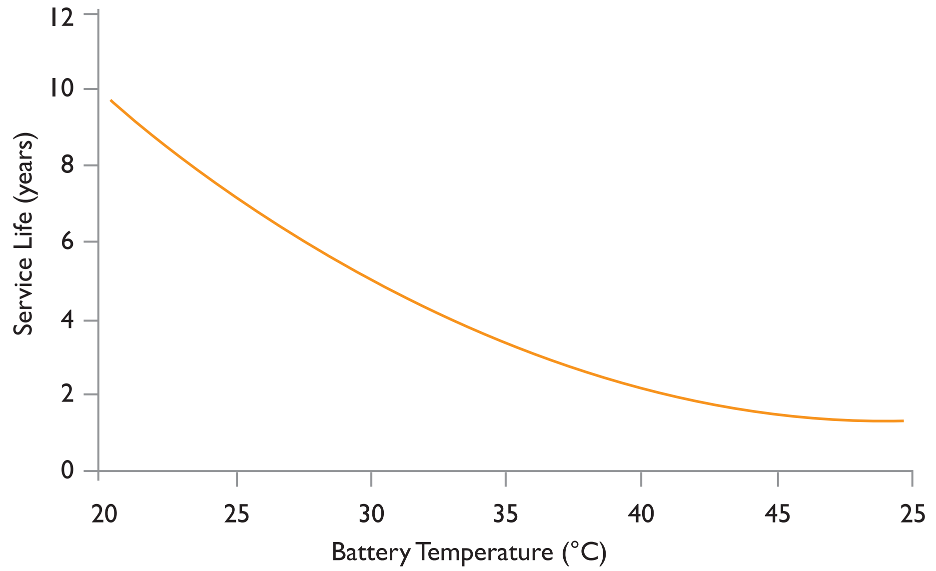


Figure 21: Relationship between service life and temperature

Cycle life - Cyclic life is the number of charge/discharge cycles are battery can sustain in its useful life. There is relationship between the Daily DoD and its life cycle, which is indicated in Figure 25: Effect of depth of discharge on the cycle life of a lead-acid battery.

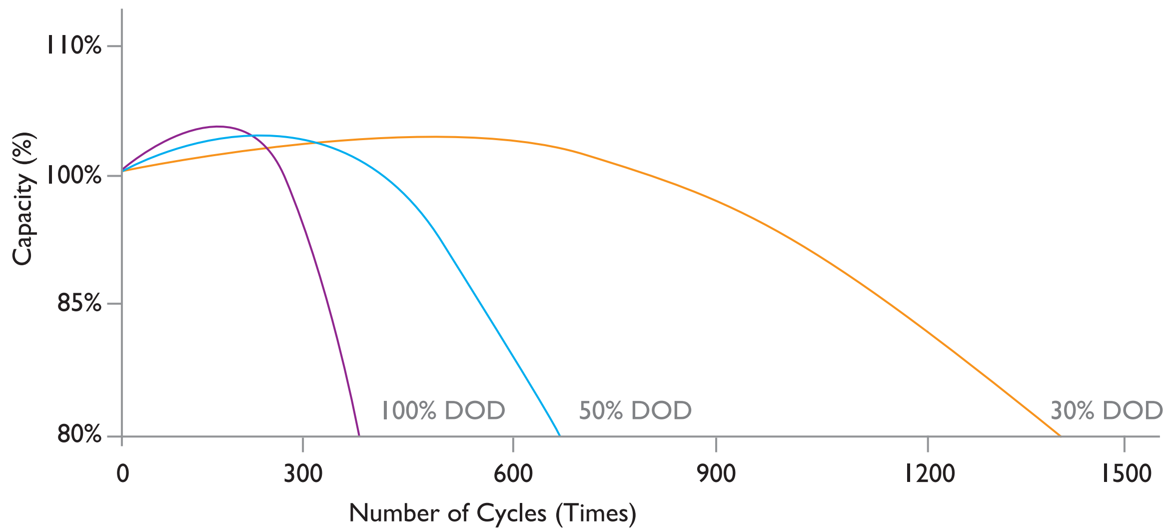


Figure 22: Effect of depth of discharge on the cycle life of a lead-acid battery

5 DESIGN OF POWER BACKUP SYSTEM/STAND-ALONE POWER SYSTEM (SAPS)

5.1 POWER BACKUP SYSTEM

The main objective of Power Backup Systems is to provide emergency or back up power during a main power interruption. The Power Backup Systems shall be designed to cater for critical loads for a shorter period. In most cases, power and energy requirement of PBS can be calculated using the basic table, given in Table 3 : Data gathering table for power and energy estimation.

5.2 STAND-ALONE POWER SYSTEM

The design of the Stand-Alone Power System can be divided into four steps.

1. Estimation of power and energy requirements of the application
2. Estimation of capacity of SAPS
3. Sizing of components
4. Design of electrical wiring system.

5.3 ESTIMATION OF POWER AND ENERGY REQUIREMENTS OF THE APPLICATION

The most important part of Stand-Alone Power System is to understand the power and energy requirement of the application. It is vital to understand the application and critical loads of the application clearly and accurately, as SAPS are not cheap. The estimation of the power and energy requirement can be done in two ways.

Load assessment using a table - this is a very basic approach, suitable for small systems and new systems where data logging is not available.

Load assessment using power logging equipment- recommend for larger and complex system. Data will be collected through a data logger.

5.3.1 Data gathering using a table.

A simple load assessment can be developed using the table below. It is recommended to consider seasonal variations as well.

Table 3 : Data gathering table for power and energy estimation.

No	Appliance/Load Name	Qty	Power (Watts)	Peak Power (W)	Hours per day	Approximate time of use
1	Washing Machine	1	500		1	9.00 am to 10.00 am
2	Blender	1	300		0.1	3.00 pm to 4.00 pm
3	TV	1	150		3	7.00 pm to 11.00 pm

5.3.2 DEVELOPMENT OF DAILY LOAD PROFILE

Based on the collected load data, the daily load profile must be developed. If there is no significant seasonal variation, the average daily load profile can be developed. If there are seasonal variations, the load profiles for different cases can be developed.

The following chart shows sample daily load profiles of a household and a small shop. These two load profiles are required for a different Stand-Alone Power System.

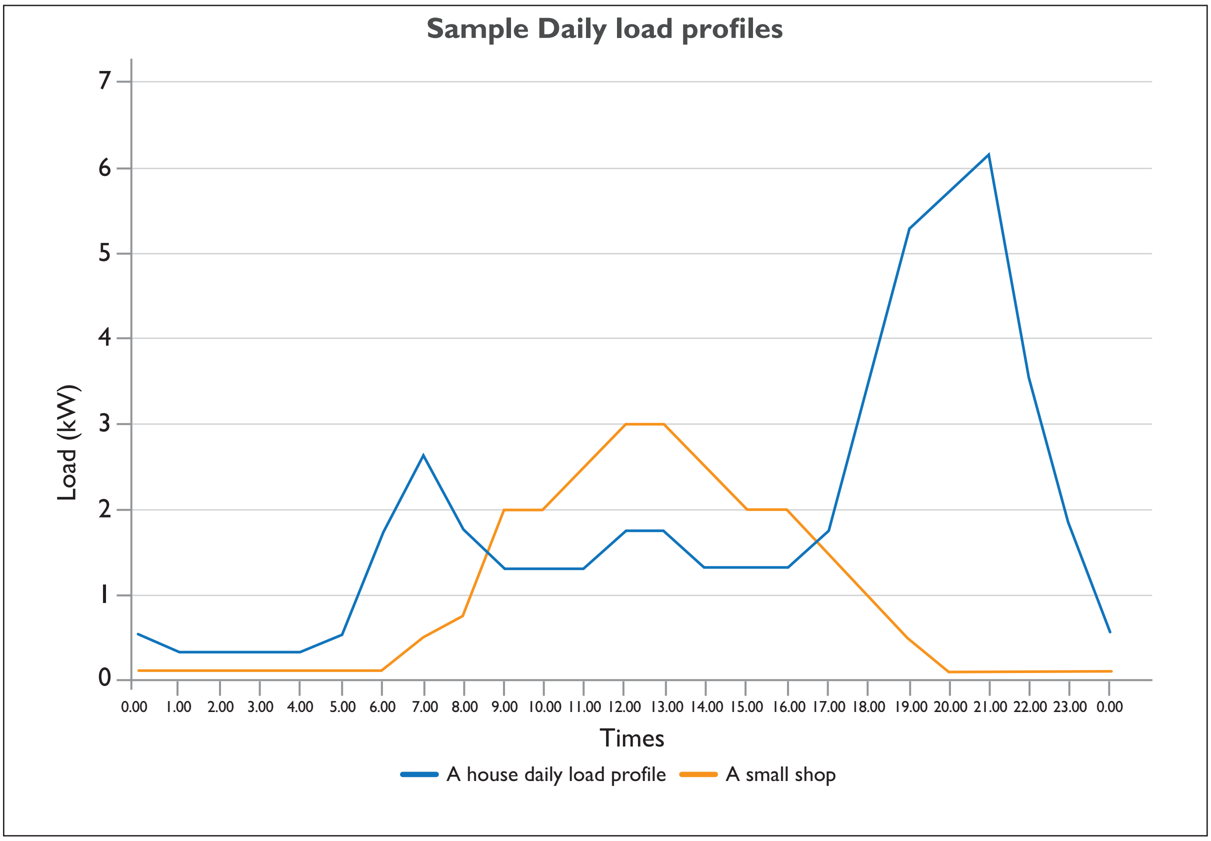


Figure 23: Sample daily load profiles

Area under the load profiles provides daily energy requirement for each application.

5.4 ESTIMATION OF CAPACITY OF SAPS

Both battery power and energy capacities can be calculated using both the daily load profile and the daily generation profiles of each generation resource.

For illustration purposes, the daily load profile of a house and the above daily generation profiles can be taken.

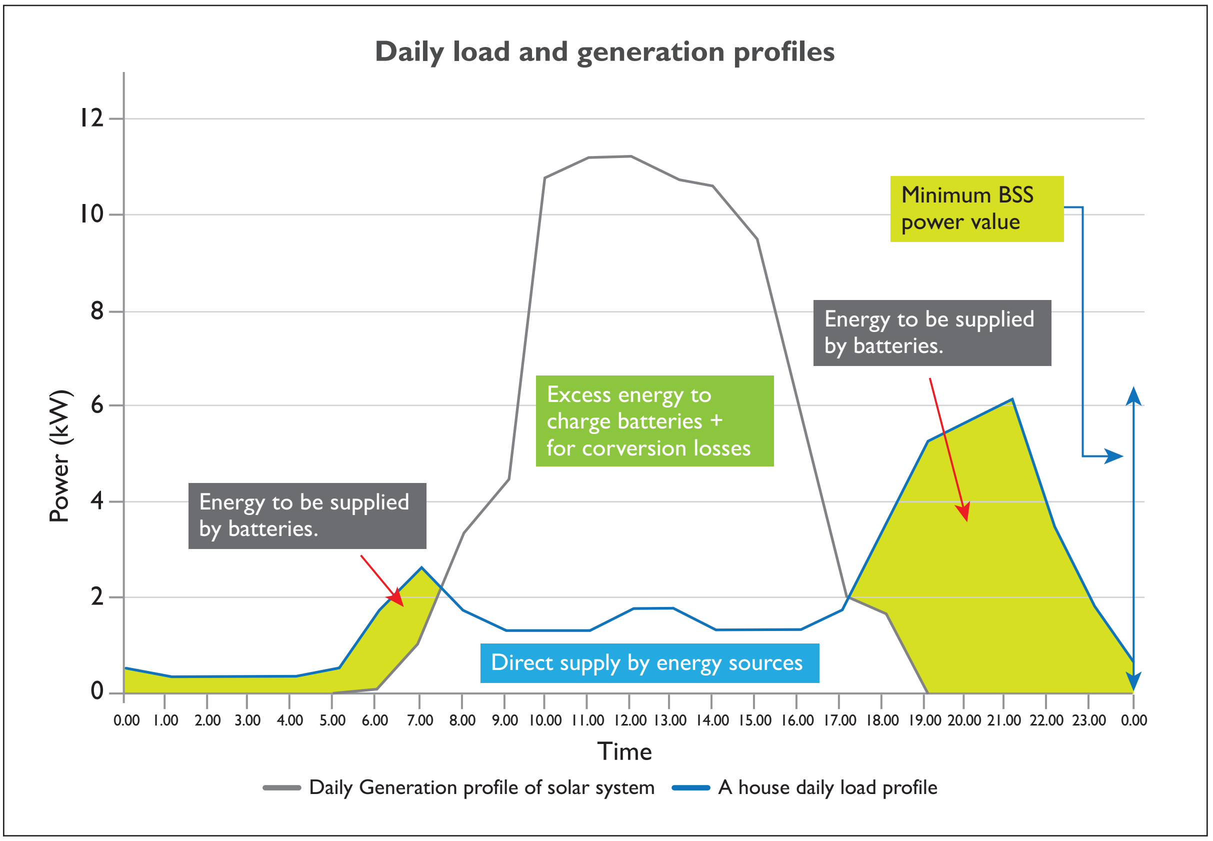


Figure 24: Further into daily load profile analysis

Generation systems (solar systems) must be developed to meet the following criteria.

Amount of energy represents by the area under load profile + energy loss during conversion = amount of energy represents by the area under generation profile

The power capacity of SAPS must be a minimum capacity value of SAPS (as per the chart) + the suitable tolerance based on the application of the system (e.g., for motor application, it must be able to provide the starting power).

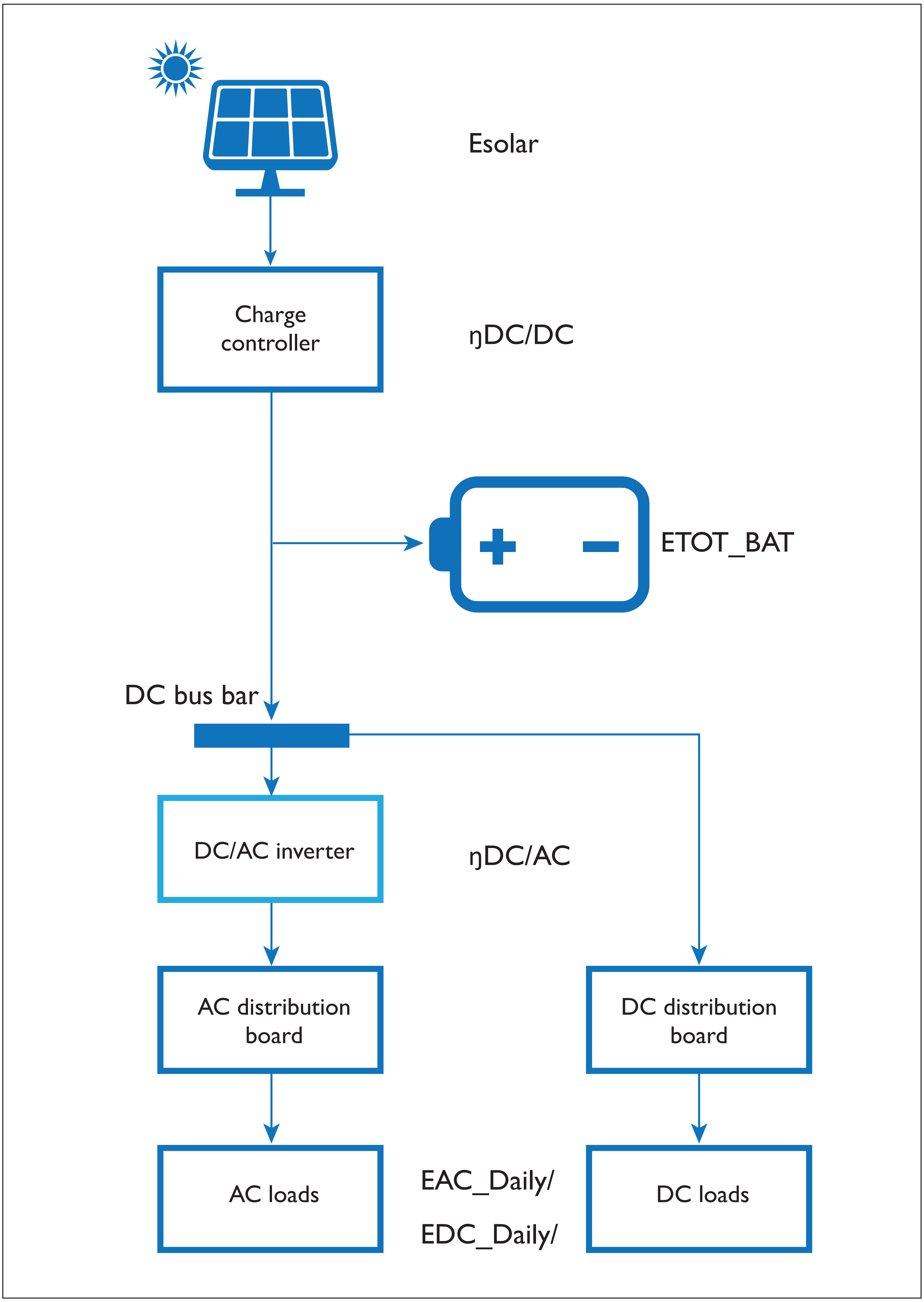


Figure 25: Schematic diagram of energy flow

Where:

E_{AC_Daily} - Daily AC energy requirement from daily load profile.

E_{DC_Daily} - Daily DC energy requirement from daily load profile.

$n_{DC/AC}$ - DC/AC conversion efficiency.

$n_{DC/DC}$ - DC/DC conversion efficiency (efficiency of charge controllers).

E_{DAILY_BAT} - Daily battery energy requirement for loads (both AC and DC).

E_{TOT_BAT} - Total battery energy requirement.

E_{DIR_SOLAR} - Direct day-time energy requirement from solar system.

E_{Solar} - Solar energy requirement.

'n - No of days (Autonomy)

$$E_{DAILY\_BAT} = \frac{E_{AC\_Daily}}{n_{DC/AC}} + EDC\_Daily$$

$$E_{TOT\_BAT} = (1+n)\ E_{DAILY\_BAT}$$

$$E_{Solar} = 1.25 \times \frac{(E_{TOT\_BAT} + E_{DIR\_SOLAR})}{\eta_{DC/DC}}$$

As a rule of thumb, the solar energy requirement shall be designed with an additional 25%.

The conversion efficiency of PWM charge controllers is not straight forward, as it depends on battery voltage and solar PV module voltage.

5.5 SIZING OF COMPONENTS

The main components of a Stand-Alone Power System are solar modules, charge controllers/ inverters and battery storage systems.

5.5.1 SIZING OF BATTERY STORAGE SYSTEM

The battery capacity is determined by both the energy and power requirement of the SAPS. Additionally, it is vital to select the most suitable battery type/technology and capacity based on the application as well.

The numbers of calculations/iterations are required to determine the battery specifications. The following steps can be used as a guideline only.

Note: Batteries are the most vulnerable and expensive component in SAPS. It is highly recommended to follow the manufacturer instruction/warranty condition and application notes for battery selection.	
Parameters relating to the energy requirement of the batteries	Parameters relating to the discharging current of the batteries
• Daily energy demand • Daily maximum depth of discharge • Days of autonomy to maximum depth of discharge • Temperature	• Maximum current required for peak demand • Surge demand • Maximum allowed charging current

The Capacity of batteries is measured in Ah with the voltage. Voltage shall be selected based on the application.

$$\text{Total battery capacity (in } Ah\text{)} = \frac{E_{TOT\_BAT} \text{ (in Wh)}}{V_{BAT\_DC} \text{ (in Vdc)} \times DoD}$$

V_{BAT_DC} - Battery system voltage in Vdc.

E_{TOT_BAT} - Total battery energy requirement.

DoD - Depth of Discharge

It is recommended to consider the following factors when sizing the battery storage system.

- The capacity of most batteries vary with the temperature. This must be taken into consideration if there is a significant temperature variation.
- Life cycle of a battery will depend on the number of cycles of a battery as well. Battery technology shall be considered based on the application.
- For some applications, there is a significant surge current, and the battery shall be selected considering the surge current capabilities.

Maximum demand current capability

The battery system shall be capable of supplying maximum demand current during the operation. Battery data sheet provides Cx value of the battery. Battery surge current capability can be calculated from the formula below.

$$I_{DISCHRGE\_BAT} = \frac{\text{Cx rating (Ah)}}{\text{x value in hours}}$$

The following surge current criteria must be fulfilled by the battery system to provide the current during maximum load and the surge current required for some loads.

$$I_{DISCHRGE\_BAT} >> I_{MAX\_LOAD}$$

Where

$$I_{MAX\_LOAD} = \frac{P_{MAX}}{V_{BAT\_DC}}$$

5.5.2 SIZING OF POWER CONVERSION EQUIPMENT

There are two types of power conversion equipment, DC/AC inverters and charge controllers.

Inverters

The main function of an inverter is to convert DC power to AC power. Additionally, it provides protection functions and switching functions as well.

When selecting an inverter, the following main parameters to be considered include, input voltage, output voltage and inverter capacity.

Input voltage - it is always equal to battery system voltage.

Output voltage - mostly 230V, 50Hz

Inverter capacity - it shall be based on the daily load profile. The inverter shall be able to deliver the maximum demand of the load. Several inverters can be connected in parallel if the capacity of one inverter is not sufficient. Single phase inverters can be arranged to get three phase connection.

Charge controllers

There are two types of charge controllers, knowing the capabilities of these two types, will help to select the most suitable charge controller for a particular application.

Charge controllers' capacities are defined based on the battery voltage levels. Normal battery voltage levels are 12V/24V/48V and 60V.

Figure 9: Sample specification of PWM charge controller is a specification of a sample PWM charge controller and Figure 10: Sample specification of the MPPT charge controllers provides the specification of MPPT charge controllers.

In the market PWM charger controllers are available up to 60A charging current, while MPPT charge controllers are available up to 100 A charging current, for 48V battery voltages.

PWM charge controllers are used for small applications as the efficiency of PWM charge controllers are low compared with MPPT charge controllers, and the capacity of PWM charge controllers are limited.

NOTE:

Maximum solar PV input voltage of PWM charge controllers is in a lower range compared with MPPT charge controllers.

Efficiency of PWM charge controllers is dependent on battery voltage and solar PV voltage, and the efficiency of PWM charge controllers is not straight forward.

MPPT charge controllers have about 98 percent peak efficiency.

Sizing of charge controller

PWM charge controllers

PWM charge controllers are not capable of regulating voltage. The correct voltage and the current combination need to be selected. The important parameters of the PWM charge controller are battery voltage and the current capacity of the charge controller.

The rate current capacity of the charge controller shall be more than the battery charging current.

As per the rule of thumb, battery charging current shall be about ten percent to -20 percent of battery capacity. Several charge controllers can be connected in parallel if the capacity of one charge controller is not sufficient.

Sizing of MPPT charge controllers

Battery voltage and current capacities are the main parameters to select a MPPT charge controller. Rated current capacity shall be little bit higher than the charging current of the battery system.

5.5.3 SIZING OF SOLAR MODULES

The number of solar modules required for the application can be estimated from following formula.

$$\text{No. of solar modules} = \frac{E_{solar}\ (kWh)}{4\ \text{hours} \times P_{solar}}$$

Where :

$$E_{Solar} = 1.25 \times \frac{E_{TOT\_BAT}}{\eta_{DC/DC}}$$

$$P_{solar} = \text{Solar module capacity } (kWp)$$

As a rule of thumb, the solar energy requirement shall be designed with an additional 25%.

However, $\eta_{DC/DC}$ is the most important value. If the charge controller is PWM type, $\eta_{DC/DC}$ is not straightforward and it is dependent on the solar module capacity. This conversion efficiency will be reduced as the increase of the voltage value gap between battery voltage and solar module voltage.

For MPPT charge controllers, this can be taken at around 98%.

5.6 DESIGN OF ELECTRICAL WIRING SYSTEM

The design of an electrical wiring system must be done by a competent engineer according to the following regulations.

The components of a Stand-Alone Power System can be categorized in to three sections.

1. Energy source
2. Storage system
3. End user system

Each section must be designed according to the relevant standards which are given below.

Energy source (for solar applications only) - PUCSL Guideline for design and installation of rooftop solar system

Storage system - According to latest versions of IEC 61427-1 and IEC 61427-2

End user system - According to IET Wiring Regulations (BS 7671, latest version)

6 EARTHING OF THE SYSTEM

The earthing system is a critical component of any electrical system. Earthing is needed for ELECTRICAL SAFETY, and it also creates a REFERENCE POINT in a circuit to which voltages are measured.

To establish electrical safety, two earthing systems must be implemented.

Body earthing - all exposed metal parts of the system shall be properly earthed.

Electrical earthing - the purpose of electrical earthing is to make suitable arrangements for the operation of protection devices (e.g., RCD).

TN-S earthing system can be used for isolated off grid applications. Figure 4: Earthing system for isolated off-grid application provides basic guideline for such earthing system.

A TT earthing system is the most commonly used earthing system in Sri Lanka. Figure 5: TT to TN-S earthing system shall be applicable for the situation where grid connected system switch over to an isolated mode.

Note: Island mode isolator must be interlocked with N-E bond relay to make sure of a proper earthing mechanism.

It is highly recommended to design and implement an earthing system according to the latest version of BS 7671.

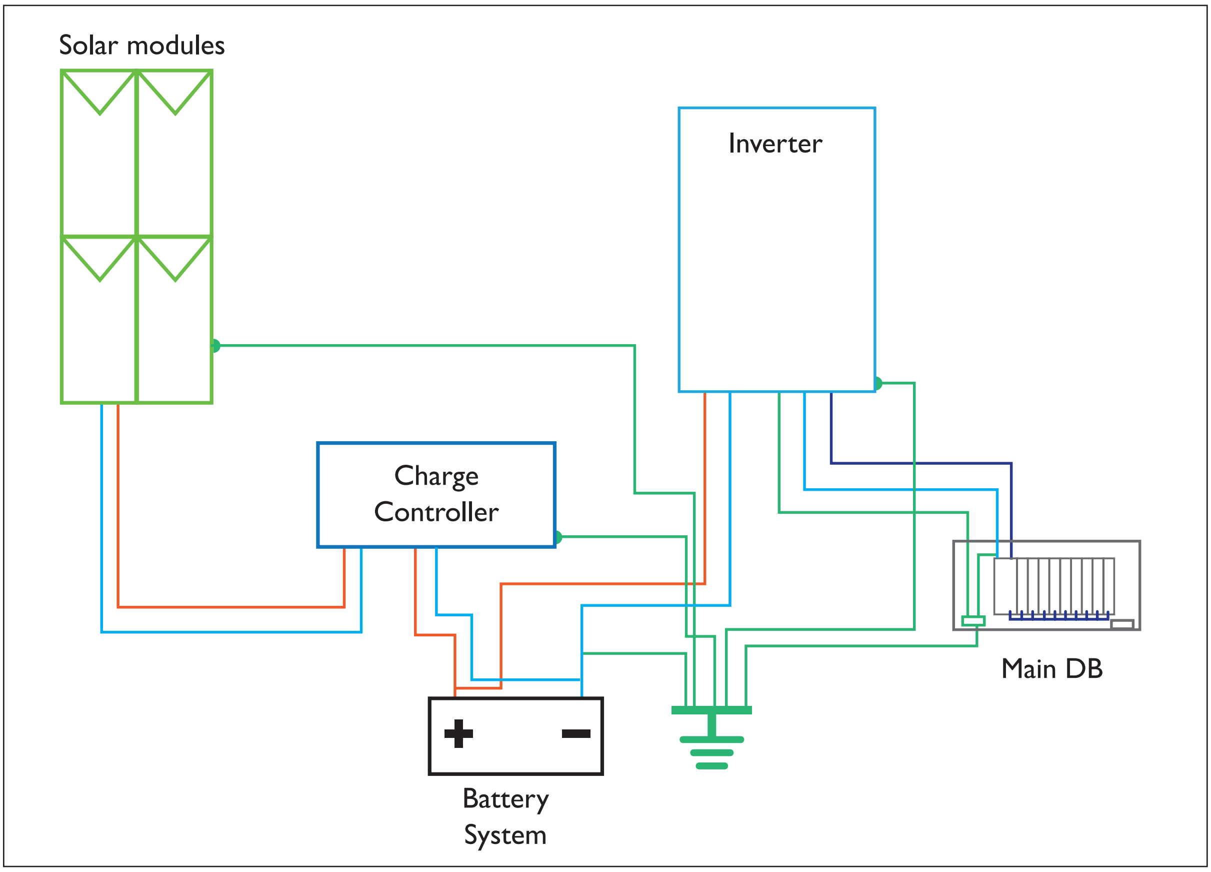


Figure 26: Earthing arrangement for small SAPS system

6.1 SPECIAL EARTHING ARRANGEMENT FOR POWER BACKUP SYSTEMS

TT earthing system is the commonly used earthing system in most of the installation is Sri Lanka. Those systems are designed to operate with the grid. When it switches to off-grid mode with Power Backup System, the earthing arrangement shall be changed from TT to TN-S. Example schematic for TT to TN-S operation is given below, Figure 16: Earthing system for isolated off-grid application.

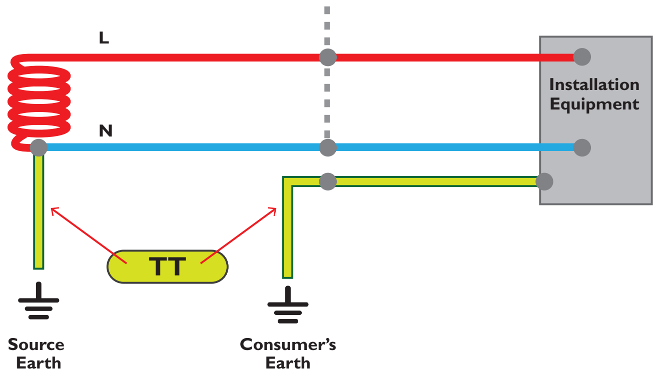


Figure 27: TT earthing system

In a TT earthing system, there are two earth points, one is at the source end and other is at the consumer's end.

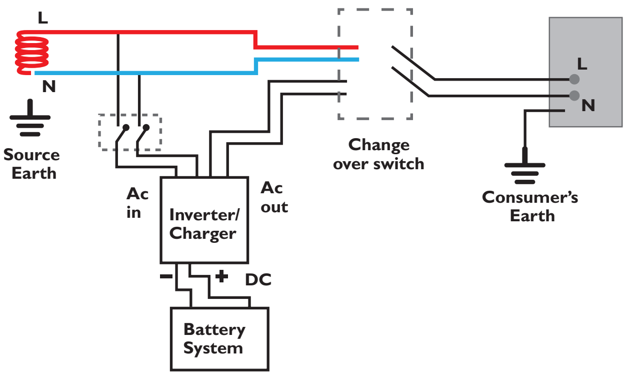


Figure 28: Wrong connection diagram

Most of Power Backup System had been connected as per Figure 28: Wrong connection diagram.

The main problem is when switched to backup power mode, there is no earthing connection at the source.

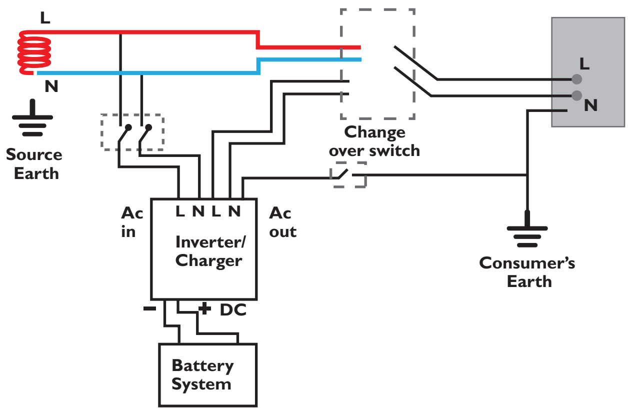


Figure 29: Correct connection of PBS

Figure 29: Correct connection of PBS shows how to connect a PBS with an existing TT earthing system. As switched on, the earthing system shall be TN-S.

Earth switch shall be connected while PBS is disconnected with the grid, earth switch shall be open when PBS relates to the grid.

All components for the above arrangement shall be selected according to current and voltage ratings of equipment. The above configuration can be arranged by a manual system or via control circuit. The appropriate system shall be selected based on equipment and application of the system.

7 INSTALLATION OF BATTERY ENERGY STORAGE SYSTEM (BESS)

A battery system is the major component of a PBS or SAPS. The installation of a solar system and a power distribution system is covered separately under solar installation guidelines and BS 7671. The focus of this section is mainly on battery system installation.

7.1 BATTERY BANK INSTALLATION

A battery bank is a collection of batteries connected either in series or parallel or both to increase energy storage capacity.

An unbalanced battery bank will lead to the loss of efficiency, incorrect charging and premature ageing of the batteries. If a large battery bank is needed, it is not recommended to develop the battery bank out of numerous series/parallel 12V lead-acid batteries.

Wiring resistance plays a major role in the wiring of battery bank as the internal resistance of batteries are negligible.

7.1.1 CONNECTING BATTERIES IN PARALLEL

When the current flows through the least resistance path, it is very important to keep equal wire resistance batteries connected in parallel. It is highly recommended to consider the following wiring configurations for battery banks when implementing parallel wiring.

The main objective of the following four configurations is to keep the same wiring length for all batteries.

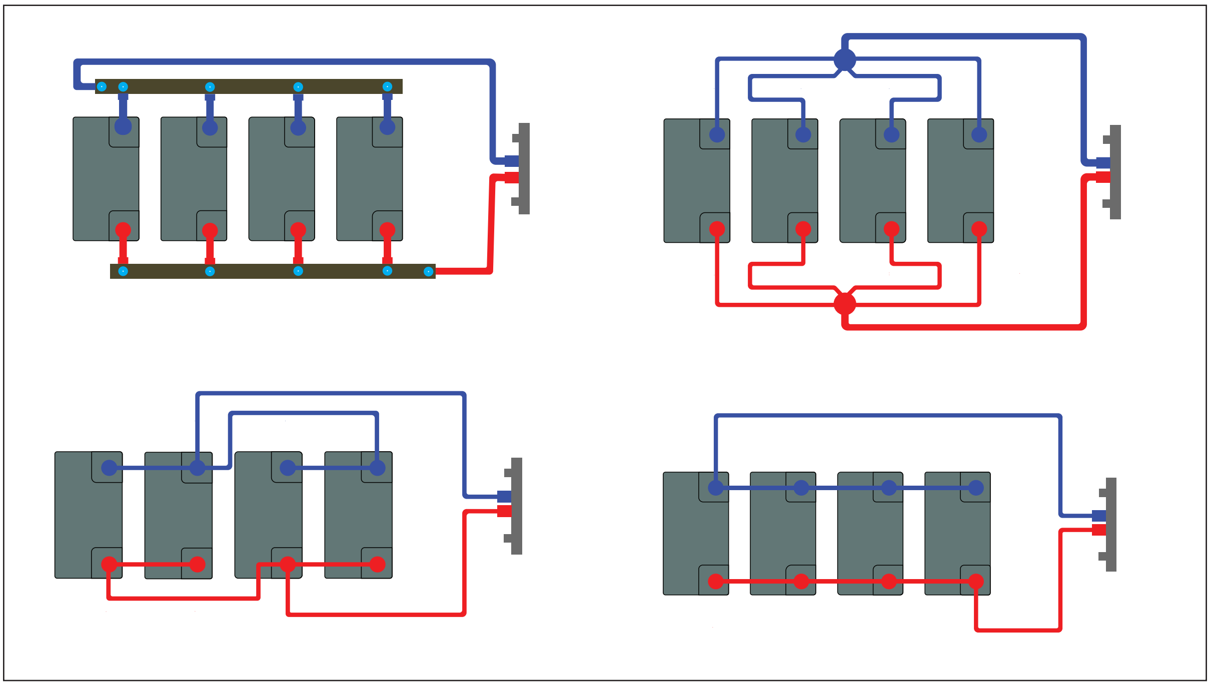


Figure 30: Battery bank parallel wiring

7.1.2 CONNECTING BATTERIES IN SERIES

Batteries shall be connected in series to increase voltage. It is important to balance batteries when connecting them in series. If the internal resistance of two batteries is different, voltage between terminals will be unbalanced (which will increase over time) and will lead to one battery being constantly overcharged and another being undercharged. This is a reason for premature failure of batteries.

This can be minimized by measuring battery terminal voltage of individual batteries before connecting them in series.

During operation, it is highly recommended to measure individual battery voltages as a part of the operation and maintenance procedure.

A battery balancing device can be used to monitor the unbalance condition of batteries which are connected in series.

7.2 DC CABLING

It is important to use the correct cables and sizes for DC applications. Losses due to cables and the cost of cables can be reduced with the proper design of cables.

It is highly recommended to consider the following when selecting DC cables and accessories.

- Increase of system voltage to reduce cable sizes.
- Use of DC/DC converter for low voltage requirements in DC high voltage system
- Not to use cable with coarse strands
- Not to use non-flexible cables
- Not to use AC cables for DC applications
- Use of proper cable connectors/ferrules
- Keep cables as short as possible

All cables, connectors, isolators, etc. shall comply with the following requirements.

a) current rating of the devise shall be greater than rating of the main battery overcurrent protective device.

b) The voltage rating of at least 1.25 x the nominal battery operation voltage

7.2.1 DC CABLE SIZING

Cable size can be reduced by increasing the system voltage. In most DC load applications the system voltage shall be equal to the voltage of the load.

By selecting the most suitable higher system voltage, voltage drops across the cable can be reduced.

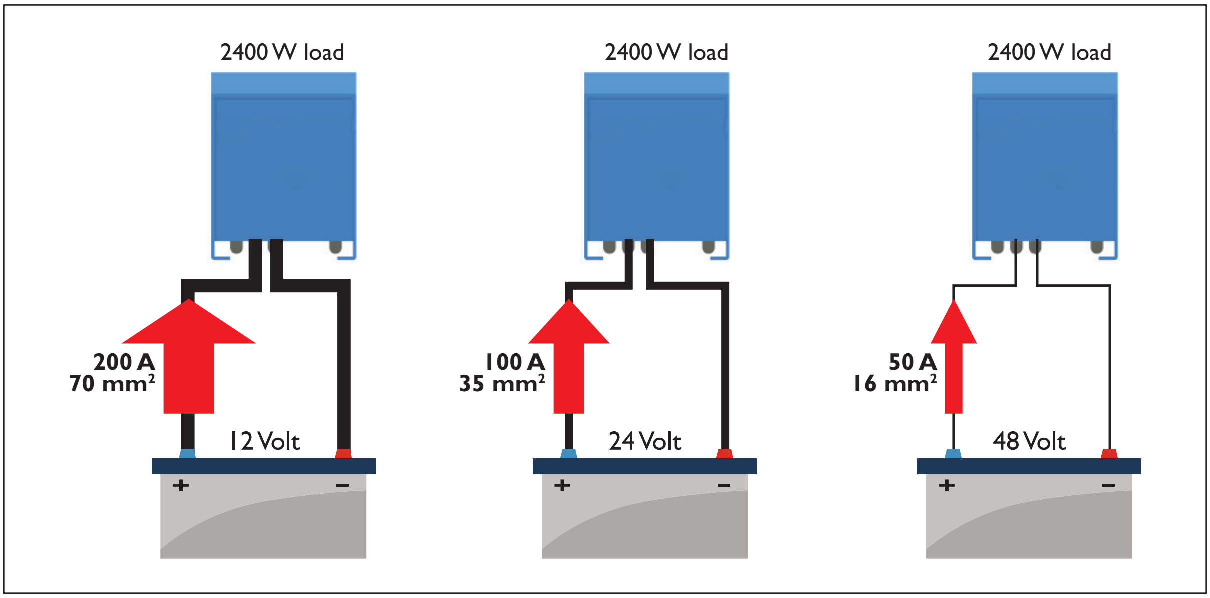


Figure 31: Increase voltage and reduced cable size

The following voltages are recommended for DC cable distance less than 05m.

- 12 V: up to 3000VA
- 24 V: up to 5000VA
- 48 V: 5000VA and up.

Rule of thumb

For general calculations of cable length less than 05m, the following equation can be used to calculate the cable sizes.

Cable size in mm^2 = Load current (A)/3

e.g. If the current is 100A then the suitable cable size is about 33 mm^2.

7.2.2 DC CABLE CONNECTIONS

It is important to connect DC cables with proper connection methods as DC cables carry high current.

Use of the following cable termination items are highly recommended.

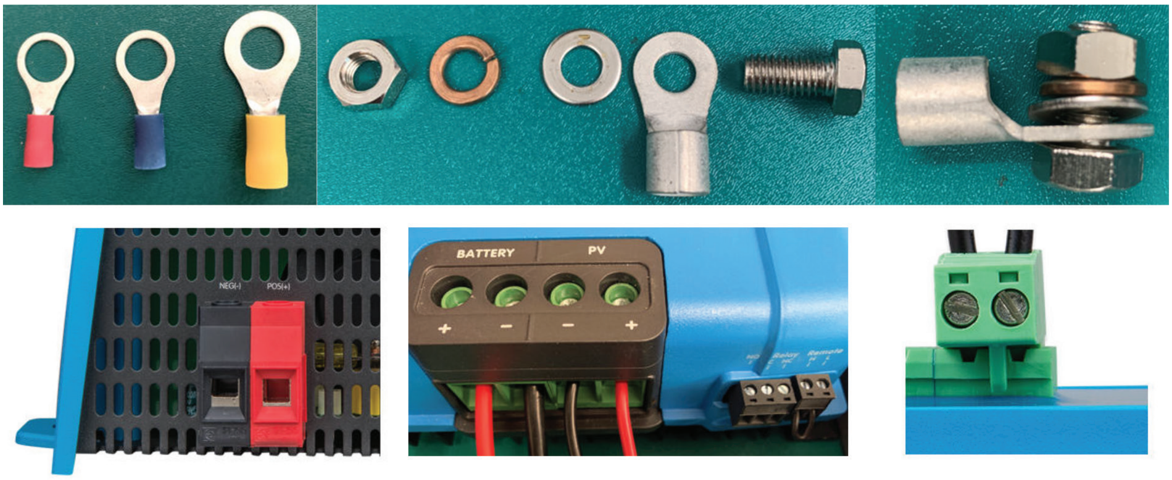


Figure 32: DC cable connection component

Note

It is highly recommended to use insulated tools for installation works to avoid damages due to short circuiting of a DC system during installation.

7.3 FUSES AND CIRCUIT BREAKERS (CB)

DC systems generate high current, and this leads to heat generation and failure of batteries, that can cause a fire. It is important to connect all loads via DC fuses. The current rating, voltage rating and speed of the fuse shall be considered based on the application.

DC isolators shall be installed to disconnect battery system when it is not in use.

7.3.1 SELECTION OF FUSES/CIRCUIT BREAKERS (CB)

There are four selection criteria to select the correct fuse/CB, they are :

- Current rating
- Voltage rating
- Speed
- Type

Current rating: The current rating of the fuse/CB must be less than the current rating of the cable which is connected with the fuse.

Voltage rating: The voltage rating of the fuse/CB must be equal or higher than the expected voltage of the system.

Speed: Slow blow fuses are commonly used in DC applications.

Type: Based on the application, the correct type of fuse/CB must be selected.

7.4 MINIMUM REQUIREMENTS FOR SAFETY OF BATTERY STORAGES

The following steps must be taken to meet the minimum safety requirements of a battery storage system

7.4.1 MAIN OVERCURRENT PROTECTION

An overcurrent protective device shall be installed on the positive output terminal of the battery system. This device shall;

a) be rated for DC operation.

b) have a voltage rating of at least 1.25 x the nominal battery voltage.

c) have an interrupt rating that is higher than the battery's rated short circuit current.

The overcurrent protective device shall be installed so that the cable between the battery terminal and the protective device is kept as short as possible.

7.4.2 BATTERY ISOLATION

An isolator shall be installed on the output terminals of the battery system. This device shall;

a) Interrupt both positive and negative cables

b) be rated for DC. Operations.

c) have a voltage rating of at least 1.25 x the nominal battery voltage.

d) have an interrupt rating that is higher than the battery's rated short circuit current.

7.4.3 BATTERY INSTALLATION

The following general measures need to be observed when a battery storage system is installed.

a) The battery system shall be installed in a suitable enclosure or location with access restricted to authorized personnel, whilst allowing suitable access for maintenance.

b) Battery enclosures/rooms shall be provided with sufficient ventilation.

c) The battery system shall be mounted on a structure (floor/wall) able to withstand the weight of the battery system.

d) The battery terminals shall be protected to prevent accidental short-circuiting.

e) Devices that could form a spark, such as overcurrent protective devices and isolators, shall be located outside battery enclosures/rooms and in a suitably ventilated zone away from areas where there could be a build-up of explosive gasses.

f) Battery enclosures and containment shall be suitably corrosion resistant.

g) Any electrical cable, connectors, electronic devices or other components within a battery enclosure shall be suitably corrosion resistant. Otherwise, these parts shall be located outside the battery enclosure and in a suitably ventilated zone.

h) The location shall be selected to suit the operating temperature range of the battery. Appropriate insulation and/or thermal control shall be provided where required.

i) The location shall be selected with consideration to fire escape routes and exists.

j) Personal protective equipment (PPE) should be located within battery room.

k) Appropriate safety signs shall be fixed on a battery enclosure/battery room (Figure 33 : Sign board_1, Figure 34 : Sign board_2)

l) Explosive or corrosive gas emitting battery systems should not be located within 500mm (20”) horizontally of any other equipment from 100mm (4 inches) below the battery terminals expect where there is a solid separation barrier (Figure 8: Exclusion zone for equipment located near a battery system).

m) No electrical equipment shall be mounted above explosive or corrosive gas emitting batteries. No metal should be installed above a battery that could fall onto the batteries.

Detailed information on the safe installation of lead-acid batteries is contained in BS EN 50272.

Figure 33 : Sign board_1

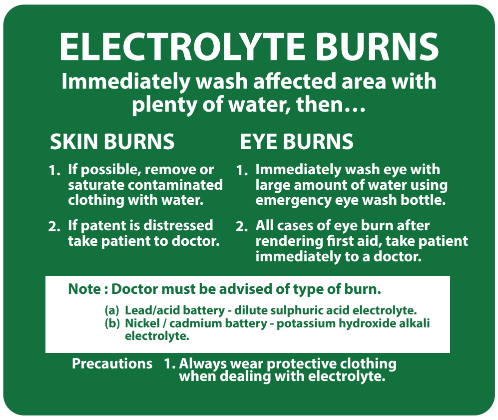


Figure 34: Sign board_2

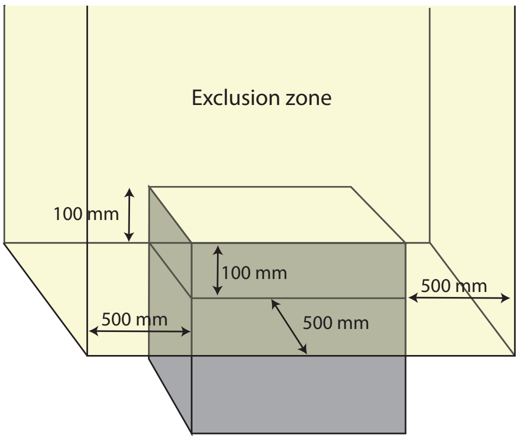


Figure 35: Exclusion zone for equipment located near a battery system.

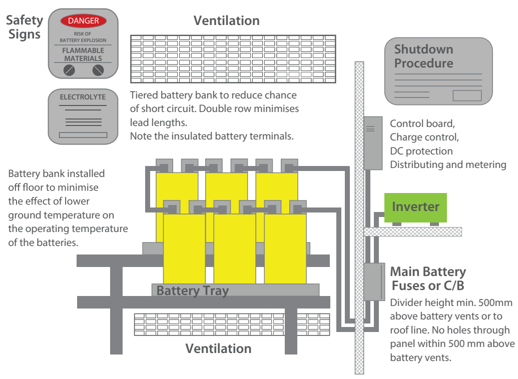


Figure 36: Example of battery room layout with divided wall

Figure 35 and 36 - Off Grid PV Power Systems, system installation guidelines, the Pacific Power Association.

The Stand-Alone Power System should comply with IEC 61427-1 and IEC 61427-2.

8 TESTING AND COMMISSIONING

After installation, a battery system and pre-assembled BESS shall be commissioned in accordance with the manufacturer's instructions. The following procedures should be followed in general.

- Ensure all wires are properly torqued and/or sealed.
- Ensure an earthing system is in order/check continuity and all connections.
- Check continuity and insulation of all wires.
- Test to ensure that all strings and arrays of solar system are correctly marked and connected.
- Check polarity of all installations.
- Battery system voltage/Individual battery voltages, where relevant
- Other relevant battery parameters, such as specific gravity, state of charge, etc
- Isolation in accordance with specified shut down procedure.
- Confirmation of functioning charge and discharge cycle

Inspection and testing of circuits according to BS 7671

Check list in Annexure A - can be used as guideline for inspection.

9 OPERATION AND MAINTENANCE OF THE SYSTEM

The complexity of the operation depends on the size of the system and mode of the operation.

Most small systems don't need special skills for operation. However, it is highly recommended to display the following shutdown procedure and train operational staff regularly.

SHUTDOWN PROCEDURE

WHERE POSSIBLE, TURN OFF ALL APPLIANCES, LIGHTING, REFRIGERATOR/FREEZERS ETC. PRIOR TO SHUTTING DOWN.

1. **ISOLATE THE AC SUPPLY SIDE (HOUSE)**
   TURN THE MAIN AC SWITCH AT THE MAIN SWITCHBOARD TO OFF
2. **ISOLATE THE PV ARRAY**
   TURN OFF THE DC ISOLATORS
3. **POWER OFF THE AC INVERTER**
   TURN OFF THE SOLAR MAIN SWITCH
4. **TURN OFF THE BATTERY ISOLATOR**
   TURN OFF THE BATTERY CIRCUIT BREAKERS

TO STARTUP FOLLOW PROCEDURE IN REVERSE

Figure 37: Shutdown procedure

The battery system maintenance is the most critical part of a maintenance system.

It is highly recommended that a quick maintenance check after one month is conducted to ensure the system is in good condition, as well as routine system checks every following month.

Note

Must follow the battery manufacturer's battery maintenance system and procedures.

The following general procedures/inspections are recommended for the maintenance of a battery bank.

- Check regularly all terminal connections are tight and clean.
- Check battery bank terminal voltages at no load or low load.
- Measure specific gravity of battery liquids of flooded type batteries.

Annexure A - Installation and commissioning check list.

Annexure B - Check list for maintenance of off grid system can be used in general for maintenance works.

Annexure C - Sample calculation

Annexure D - Applicable International Standards

Annexure E - Sample wiring diagrams

ANNEXURE A: INSTALLATION AND COMMISSIONING CHECK LIST

Item No	Type of Item	Details	Status
PV module			
1	PV Module		
2	Series combination of modules		
3	Parallel combination of modules		
4	Solar Mounting structure		
5	Hardware for connecting module to frame		
6	Hardware for connecting frame to roof (if required)		
Solar Controller			
7	Cable between module & solar regulator		
8	Conduit		
9	Fastening hardware for cable/conduit		
10	Solar Regulator		
11	Hardware for fastening controller to wall		
12	Fuse/Circuit breaker between solar module/controller		
Batteries			
13	Batteries		
14	Timber (if battery floor mounted)		
15	Battery racks/stands (if required)		
16	Battery Box (if required)		
17	Coverings for terminals (if required)		
18	Cable between controller and battery		
19	Lugs or fasteners for cable connection to battery		
20	Battery fusing		
21	Adequate Battery enclosure is provided		
Inverter			
22	Inverter		
23	Inverter Power rating (Continuous, ½ minute and Surge)		
24	Transformer/Transformer less		
25	Cable between batteries and inverter		
26	Cable between charger and batteries		
27	Lights for shed/battery room		
28	Light Switches		

29	Cable between controllers/batteries and lights		
30	Fastening hardware for lights/switches		
31	Fastening hardware for lighting cable		
32	Installation Tools (Recommend technician prepares a list)		
Compulsory Safety Equipment:			
33	Safety Goggles		
34	Leather Gloves		
35	Water Washing bottle		
36	Bicarbonate Soda		
37	Water Bucket		

ANNEXURE B: CHECK LIST FOR MAINTENANCE OF OFF GRID SYSTEM CAN BE USED IN GENERAL FOR MAINTENANCE WORKS

Equipment Enclosure & Adapt Unit	
Check and keep enclosure free of dirt, clutter, obstruction and vermin	Daily
Check that equipment enclosure remains locked at all times	Dail
Maintain equipment at cool temp, protected and well ventilated	Weekly
Ensure safety labelling and instructions remain displayed and clearly visible	Weekly
Inverter/Charger	
Check all component operating lights are normal	Weekly
Check and clean air filter if applicable (vacuum cleaner or soft brush)	Monthly
Clean any excess dirt or dust from the outside case (soft brush or damp cloth)	Monthly
Visually inspect for any loose cables or connections	Annually
Batteries	
Test and record individual battery cell voltages on a chart (use a DC voltmeter)	Twice a year (minimum)
Remove dirt, insects and vermin from on or near battery bank	Monthly
Inspect condition of batteries, battery cables, sleepers, terminals and covers	Monthly
Check the temperature sensor is correctly bonded to a battery cell	Monthly
Ensure battery bank receives full charge (See Battery Charging section)	Every 7-10 days
Ensure battery bank receives full equalization charge (See Battery Charging section)	Twice a year (minimum)
Solar Array	
Check & clean dirt off panel surface to ensure optimal performance (mop or cloth)	Twice a year
Check & cut-back any potential shade build-up (e.g. vegetation)	Twice a year
Inspect condition of panels, cables & array frame for damage or corrosion	Annually
Solar MPPT/Inverter	
Check MPPT and/or battery monitor display for any error messages	Monthly
Check and clean air filter on applicable models (vacuum cleaner or soft brush)	Monthly
Clean any excess dirt or dust from the outside case (soft brush or damp cloth)	Monthly
Visually inspect for any loose cables or connections	Monthly

ANNEXURE C: SAMPLE CALCULATION

1 SAMPLE CALCULATION (DESIGN OF STAND-ALONE POWER SYSTEM)

A Stand-Alone Power System consists of the following major parts.

1. Power generation system (e.g., Solar power system)
2. Power conversion system
3. Energy storage system
4. Consumer load (Load profile)

A power generation system (solar power) is covered under solar design guidelines which is published by the PUCSL.

The intention of this sample calculation to provide guidance to do a basic design for a small-scale Stand-Alone Power System. It is highly recommended to use dedicated software tools for medium to larger system designs.

The following calculations for a sample project has been given as follows,

- Load assessment (Development of load profile)
- Sizing of battery system
- Sizing of power conversion system
- Sizing of solar system

2 LOAD ASSESSMENT (LOAD PROFILE).

The most important part of the design of Stand-Alone Power System or Power Backup System is the assessment of the power and energy requirement of the customer.

This assessment helps to understand how much electricity is consumed and at what time of the day.

Further, it is important to understand the efficiency improvements and the possibility of load shifting to optimize the design.

There are two methods for power and energy assessment.

- Basic load assessment with a table, this is suitable for small scale applications and new installations.
- Data logging method, this is suitable for existing larger installations which need more accurate assessment.

2.1 DATA COLLECTION AND CALCULATION OF DAILY POWER AND ENERGY REQUIREMENT

Following table format can be used to collect data. It is important to collet data as accurate as possible.

Table 4: Data collection table

Time duration	Lights	Ceiling fans	Television	Computer/laptop/ monitor/printer	Mini Refrigerator
00.00-01.00	3	1	0		1
01.00-02.00	3	1	0		1
02.00-03.00	3	1	0		1
03.00-04.00	3	1	0		1
04.00-05.00	3	1	0		1
05.00-06.00	6	1	0		1
06.00-07.00	7	1	0		1
07.00-08.00	5	1	0		1
08.00-09.00	1	1	0	1	1
09.00-10.00	1	1	0	1	1
10.00-11.00	1	1	0	1	1
11.00-12.00	1	1	0	1	1
12.00-13.00	1	1	0	1	1
13.00-14.00	1	1	0	1	1
14.00-15.00	1	1	0	1	1
15.00-16.00	1	1	0	1	1
16.00-17.00	2	1	1	1	1
17.00-18.00	3	1	1	1	1
18.00-19.00	15	1	1	1	1
19.00-20.00	15	1	1		1
20.00-21.00	15	1	1		1
21.00-22.00	10	1	1		1
22.00-23.00	4	1	1		1
23.00-24.00	3	1	0		1

Table 5: Daily power and energy calculation

Time duration	Lights	Ceiling fans	Television	Computer/ laptop/monitor/ printer	Mini Refrigerator	Total (Wh)
Capacity (W)	10	75	250	100	100	
00.00-01.00	30	75	0	0	100	205
01.00-02.00	30	75	0	0	100	205
02.00-03.00	30	75	0	0	100	205
03.00-04.00	30	75	0	0	100	205
04.00-05.00	30	75	0	0	100	205
05.00-06.00	60	75	0	0	100	235
06.00-07.00	70	75	0	0	100	245
07.00-08.00	50	75	0	0	100	225
08.00-09.00	10	75	0	100	100	285
09.00-10.00	10	75	0	100	100	285
10.00-11.00	10	75	0	100	100	285
11.00-12.00	10	75	0	100	100	285
12.00-13.00	10	75	0	100	100	285
13.00-14.00	10	75	0	100	100	285
14.00-15.00	10	75	0	100	100	285
15.00-16.00	10	75	0	100	100	285
16.00-17.00	20	75	250	100	100	545
17.00-18.00	30	75	250	100	100	555
18.00-19.00	150	75	250	100	100	675
19.00-20.00	150	75	250	0	100	575
20.00-21.00	150	75	250	0	100	575
21.00-22.00	100	75	250	0	100	525
22.00-23.00	40	75	250	0	100	465
23.00-24.00	30	75	0	0	100	205
			Total daily energy requirement (Wh)			**8,130**
			Total daily energy requirement (kWh)			**8.13**
			Maximum capacity (kW)			**0.675**

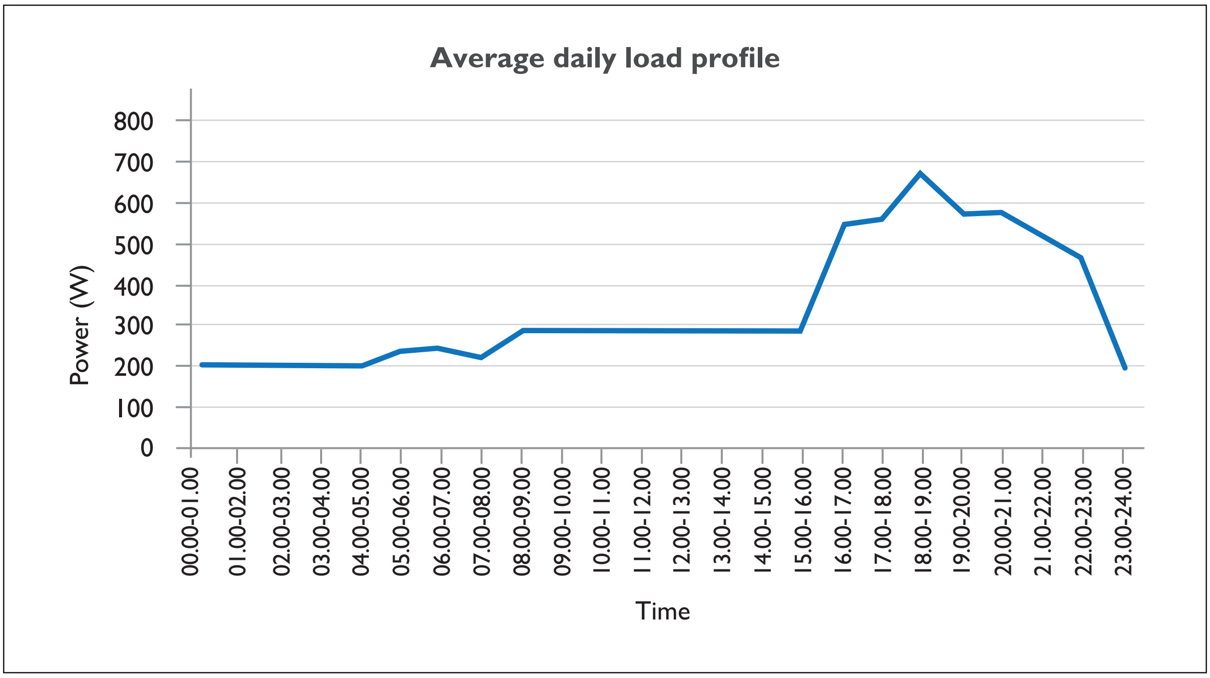


Figure 38: Sample daily load profile

2.2 DAILY LOAD ASSESSMENT FROM DATA LOGGERS

Data loggers can be used to record actual load profile of existing operational system, then develop average daily load profile.

3. SIZING OF BATTERIES

Sizing of batteries and solar system can be done using simulation software such as PVsyst/Homer. Solar irradiation data, and can be used for those simulations and can be get more accurate result.

For a small system, the basic calculation can be done with the following steps.

3.1 STEP 1

Since, we are closer to the equator, sunlight is available for 365 days in different levels. Daily energy requirement can be divided in to two sections.

Section 1 - energy requirement from 0.00 H to 7.00 H and 17.00 H to 24.00 H (night-time requirement)

Section 2 - energy requirement from 7.00 H to 17.00 H (day-time requirement)

Night-time requirement shall be met through battery storage and day-time requirement can be met mostly from the solar system with battery support.

Daily energy requirement for section 1 (night-time requirement) - 5,080 Wh (5.08 kWh)

Daily energy requirement for section 2 (day-time requirement) - 3,050 Wh (3.05 kWh)

3.2 STEP 2

Required battery energy capacity can be calculated as follows.

Night-time energy requirement shall be provided by the batteries only. Additionally, battery capacity shall be capable to handle some percentage of day-time requirement in case of low sunlight days.

This percentage can be varied according to the location and application.

For this calculation, it is taken 25% of day-time energy requirement to be met by batteries.

The total energy requirement from batteries = 5.08 kWh + 25% x 3.05 kWh = 5.85 kWh.

The following equation can be used to calculate daily energy requirement from batteries.

$$E_{DAILY\_BAT} = \frac{E_{AC\_Daily}}{n_{DC/AC}} + E_{DC\_Daily}$$

E_{DC_Daily} is zero for this application.

$n_{DC/AC}$ - is vary from 92% to 95%

E_{DAILY_BAT} = 5.85 kWh / 93% = 6.29 kWh

Total energy requirement from the battery system can be calculated from the following equation.

$$E_{TOT\_BAT} = (1+n)\ E_{DAILY\_BAT}$$

If numbers of autonomy days are 1, then :

$E_{TOT\_BAT} = (1+n)\ E_{DAILY\_BAT} = (1+1) \times 6.29\ kWh = 12.58\ kWh$

3.3 STEP 3

The total battery capacity can be calculated using the following equation.

V_{BAT_DC} has to be selected based on the application and total capacity of batteries.

Depending on the battery technology, DoD value shall be selected. For lead-acid batteries, 50% DoD value was taken for the calculation.

If we select lead-acid batteries with 48Vdc voltage for this application, then the total battery capacity will be;

$$\text{Total battery capacity } (in\ Ah) = \frac{E_{TOT\_BAT}\ (in\ Wh)}{V_{BAT\_DC}\ (in\ Vdc)} \times DoD) = (12.58 \times 1000 / (48 \times 50\%) = 524\ Ah$$

Article number	V	Ah CS (10.8V)	Ah C10 (10.85V)	Ah C20 (10.8V)
BAT412123081	12	200	210	230

3.4 SURGE CURRENT CAPABILITY TEST

The maximum demand during the day is about 675 W.

Maximum current during maximum demand = 675W /48Vdc = 14.06 A

Battery system discharge current can be calculated from following formula.

$$\text{Discharge current (A)} = \frac{\text{Cx rating } (Ah)}{x\ (in\ hours)}$$

Discharge capability of the battery system is much higher than maximum current requirement.

One of the following battery combinations can be selected for the application.

Table 6: Battery Combinations

Combination	Single battery voltage (Vdc)	System DC voltage (Vdc)	Battery capacity (Ah) at C10	No of batteries	Calculated possible maximum discharge current (A)	Arrangement
1	12	48	210	4	84.0	4 batteries series to get 48Vdc,total battery capacity will be 840 Ah.

4. SIZING OF POWER CONVERSION SYSTEM

Inverter shall be capable of handling maximum demand of the system. The maximum demand of this system is about 980 W.

Best practice is to keep additional 10-20% capacity to accommodate future expansions to improve surge current withstand capacity.

Required inverter capacity can be 800 W - 1,200 W.

5. SIZING OF SOLAR SYSTEM

Sizing of solar system - correct type and capacity of charge controller shall be selected. PWM charge controllers are suitable for small application and MPPT charge controllers shall be selected for medium and large size applications.

For this kind of applications, it is recommended to use MPPT charge controllers.

$$E_{Solar} = 1.25 \times \frac{(E_{TOT\_BAT} + E_{DIR\_SOLAR})}{\eta_{DC/DC}}$$

For this application

$$E_{TOT\_BAT} = 12.58 \text{ kWh}$$

$$E_{DIR\_SOLAR} = 3.05 \text{ kWh}$$

$$n_{DC/DC} = 95\%$$

$$E_{Solar} = 1.25 \times \frac{(12.58 + 3.05)}{(98\%)} = 19.9 \text{ kWh}$$

In Sri Lankan context, 4 kWh units per day can be generated from 1kWp of solar system.

Then the required capacity of the solar system

$$\text{Capacity of the solar system } (kWp) = \frac{E_{solar}\ (kWh)}{\frac{4kWh}{kWp}} = \frac{19.9}{4} = 5 \text{ kWp}$$

Then the solar system capacity can be selected as 5 kWp.

6. SIZING OF CHARGE CONTROLLER

Charge controller shall be capable to handle both 5kWp solar system 48Vdc, 840 Ah battery system.

Three parameters to be satisfied when selecting a charge controller.

1. Compatible with battery bank voltage.
2. Compatible with solar input voltage.
3. Compatible with charging current.

Battery voltage of this application is 48Vdc, Solar capacity is about 5kWp and charging current can be calculated as follows.

$$\text{Charging current} = \frac{\text{Solar system capacity (W)}}{\text{Battery voltage (Vdc)}}$$

Charging current for this application is about 104 A (5,000 W/48Vdc)

Their option is the most suitable charge controller for this application.

Parameters	150/70	150/85	150/100
Battery voltage	12/24/48 V Auto Select (36 V: manual)		
Rated charge current	70 A	85 A	100 A
Nominal PV power, 12 V 1a,b)	1000 W	1200 W	1450 W
Nominal PV power, 24 V 1a,b)	2000 W	2400 W	2900 W
Nominal PV power, 36 V 1a,b)	3000 W	3600 W	4350 W
Nominal PV power, 48 V 1a,b)	4000 W	4900 W	5800 W
Max. PV short circuit current 2)	50 A (max 30 A per MC4 conn.)	70 A (max 30 A per MC4 conn.)	
Maximum PV open circuit voltage	150 V absolute maximum coldest conditions 145 V start-up and operating maximum		
Maximum efficiency	98 %		
Self-consumption	Less than 35 mA @ 12 V/20 mA @ 48 V		
Charge voltage 'absorption'	Default setting: 14,4/28,8/43,2/57,6 V (adjustable with: rotary switch, display, VE.Direct or Bluetooth)		
Charge voltage 'float'	Default setting: 13,8/27,6/41,4/55,2 V (adjustable: rotary switch, display, VE.Direct or Bluetooth)		
Charge voltage 'equalization'	Default setting: 16,2 V/32,4 V/48,6 V/64,8 V (adjustable)		
Charge algorithm	multi-stage adaptive (eight preprogrammed algorithms) or user defined algorithm		
Temperature compensation	-16 mV/-32 mV/-64 mV/°C		
Protection	PV reverse polarity/Output short circuit/Over temperature		
Operating temperature	-30 to +60 °C (full rated output up to 40 °C)		
Humidity	95 %, non-condensing		
Maximum altitude	5000m (full rated output up to 2000m)		
Environmental condition	Indoor, unconditioned		
Pollution degree	PD3		
Data communication	VE.Can, VE.Direct and Bluetooth		
Remote on/off	Yes (2 pole connector)		
Programmable relay	DPST AC rating: 240 VAC/4 A DC rating: 4 A up to 35 VDC, 1 A up to 60 VDC		
Parallel operation	Yes, parallel synchronised operation with VE.Can (max. 25 units) or Bluetooth (max. 10 units)		

Figure 39: Sample specification of Charge Controller

ANNEXURE D: APPLICABLE INTERNATIONAL STANDARDS

Quality Certification, Standards, Minimum specifications and Testing for Grid-connected Rooftop Solar PV Systems/Power Plants In Sri Lanka

It is very important to consider the Quality Certification and following the applicable Standards for installation of grid-connected rooftop solar PV systems. Because, as per the present context, Sri Lanka is planning to installed the solar PV in mass-scale to meet the 70% of electricity generation from renewable energy. Hence, it is also imperative to put in place an efficient and rigorous monitoring mechanisms, adherence to the standards and following the quality assurance.

The relevant standards and certifications for a grid-connected rooftop solar PV system/plant (component-wise, up to LV side) are given below: [currently, all applicable standards (International and Sri Lanka) are listed, and bifurcation of mandatory and advisory is done]

Solar PV Modules/Panels – Specification and Standards

IEC 61215/SLS	Design Qualification and Type Approval for Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
IEC 61646/SLS	Design Qualification and Type Approval for Thin-Film Terrestrial Photovoltaic (PV) Modules
IEC 62108 /SLS	Design Qualification and Type Approval for Concentrator Photovoltaic (CPV) Modules and Assemblies
IEC 61701- As applicable	Salt Mist Corrosion Testing of Photovoltaic (PV) Modules
IEC 61853- Part 1	Photovoltaic (PV) module performance testing and energy rating -: Irradiance and temperature performance measurements, and power rating
IEC 62716	Photovoltaic (PV) Modules - Ammonia (NH3) Corrosion Testing (Advisory - As per the site condition like dairies, toilets)

IEC 61730-1,2 /SLS	Photovoltaic (PV) Module Safety Qualification - Part 1: Requirements for Construction, Part 2: Requirements for Testing
IEC 62804	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation (PID). IEC TS 62804-1: Part 1: Crystalline silicon (Mandatory for system voltage is more than 600 VDC and advisory for system voltage is less than 600 VDC)
IEC 62759-1	Photovoltaic (PV) modules - Transportation testing, Part 1: Transportation and shipping of module package units
Electrical Protection	Electrical Protection Class II and CE guidelines or latest for safety

Minimum Warranty	Manufacturer Warranty for Modules shall cover manufacturing defects for a period of Minimum 10 years. Minimum performance of 90% of the rated output for first 10 years, and 80% of the rated output for the next 15 years. 25-year performance warranty that guarantees a maximum degradation will not exceed 2.5% in the first year, and 0.5-0.7%/yr. thereafter. Economic life should be more than 25 years. Module fill factor shall be 0.78 or higher
Solar PV Inverters/Power conditioning unit - Specification and Standards	
Grid-connected inverter	inverter that is able to operate in parallel with the distribution or transmission system of an electrical utility
IEC 62109-1, IEC 62109-2	Safety of power converters for use in photovoltaic power systems Safety compliance (Protection degree IP 65 for outdoor mounting) The manufacturer shall declare the solar hybrid inverter for the following environmental conditions: • Environmental category: manufacture must declare indoor/outdoor use • Suitability for wet locations or not • Pollution degree rating: minimum PD3 • Ingress protection (IP) rating: Minimum IP55 • Ultraviolet (UV) exposure rating, as per clause 6.4 in IEC 62109-1 • Ambient temperature 5 - 500C and relative humidity 95% ratings.
IEC 61683 (For stand Alone System)	Photovoltaic Systems - Power conditioners: Procedure for Measuring Efficiency (10%, 25%, 50%, 75% & 90-100% Loading Conditions) Protection degree IP 65 for outdoor mounting, IP 54 for indoor mounting An inverter or inverter function intended to supply AC power to a load that is not connected to the mains. NOTE Stand-alone inverters may be designed to be paralleled with other non-mains sources (other inverters, rotating generators, etc.). Such a system does not constitute a grid-interactive system IEC 62109-2: 2011
BS EN 50530 (Will become IEC 62891) (For Grid Interactive system)	Overall efficiency of grid-connected photovoltaic inverters: This European Standard provides a procedure for the measurement of the accuracy of the maximum power point tracking (MPPT) of inverters, which are used in grid-connected photovoltaic systems. In that case the inverter energizes a low voltage grid of stable AC voltage and constant frequency. Both the static and dynamic MPPT efficiency is considered.
IEC 62116/UL 1741/IEEE 1547/ SLS1547	Utility-interconnected Photovoltaic Inverters - Test Procedure of Islanding Prevention Measures
IEC 60255-27	Measuring relays and protection equipment - Part 27: Product safety requirements
IEC 60068-2 (1, 2, 14, 27, 30 & 64)	Environmental Testing of PV System - Power Conditioners and Inverters

IEC 61000- 2,3,5	Electromagnetic Interference (EMI), and Electromagnetic Compatibility (EMC) testing of PV Inverters (as applicable)
SLS-1680-2020	Sri Lanka Standard Specification For Safety Of Hybrid Inverter For Solar PV System Type 1: Grid-connected solar hybrid inverter The grid-connected inverter that is able to operate in parallel with the utility and excess electric power able to flow into the utility if the utility permits. Type 2: Grid interactive solar hybrid inverter The grid-interactive inverter that is known as a grid-connected inverter and additionally able to operate in both stand-alone and parallel modes when required IECTS 61836: 2016 Solar photovoltaic energy systems – Terms, definitions and symbols. IEC 62040-1: 2017 Uninterruptible power systems (UPS) – Part 1: Safety requirements. IEC 62040-2: 2016 Uninterruptible power systems (UPS) – Part 2: Electromagnetic compatibility (EMC) requirements. IEC 62040-3: 2011 Uninterruptible power systems (UPS) – Part 3: Method of specifying the performance and test requirements. SLS 1543-1: 2016 Safety of power converters for use in photovoltaic power systems – Part 1 General requirements, this standard is equivalent to IEC 62109-1: 2010, Safety of power converters for use in photovoltaic power systems – Part 1 General requirements. SLS 1543-2: 2016 Safety of power converters for use in photovoltaic power systems – Part 2 Particular requirements for inverters, IEC 62109-2: 2011, Safety of power converters for use in photovoltaic power systems – Part 2 Particular requirements for inverters.
Minimum Warranty	Grid PV Inverter warranty shall cover of 10 years of manufacturer warranty. This warranty shall cover the defects or damages that may occur to the inverter parts
Fuses - Specification and Standards	
IEC 60947 (Part 1, 2 & 3), EN 50521/ SLS	General safety requirements for connectors, switches, circuit breakers (AC/ DC)
IEC 60269-6/SLS	Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems.
Surge Arrestors - Specification and Standards	
IEC 61643-11:2011 (SPD)/SLS	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low voltage power systems - Requirements and test methods
Cables - Specification and Standards	
IEC 60227, IEC 60502(Part 1 & 2) /SLS	General test and measuring method for PVC (Polyvinyl chloride) insulated cables (for working voltages up to and including 1100 V, and UV resistant for outdoor installation)

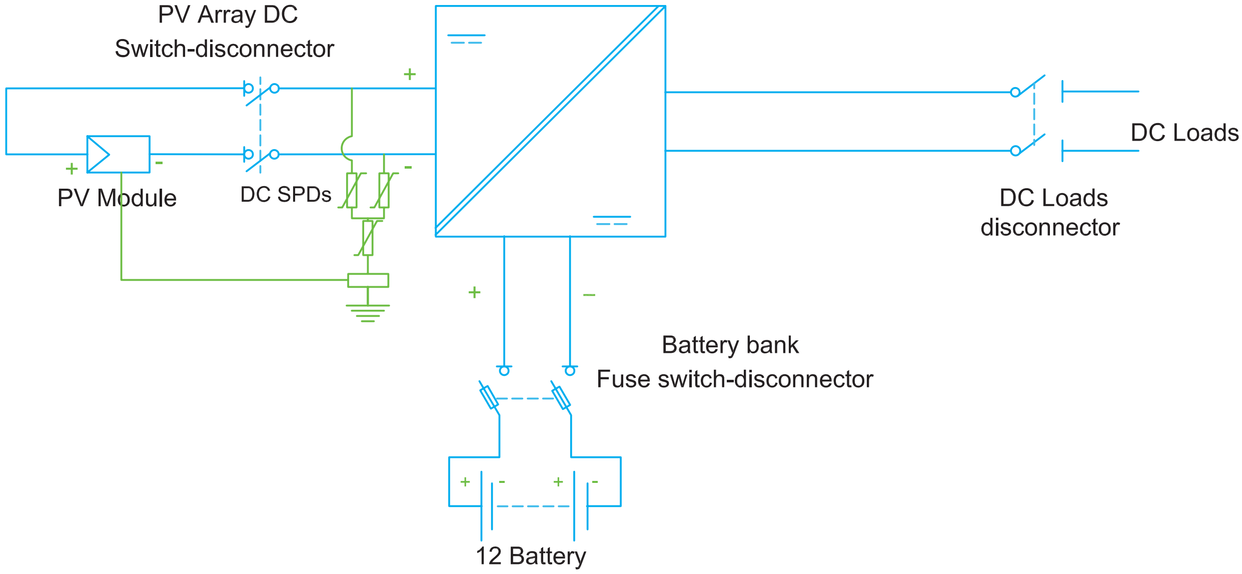
BS EN 50618/SLS 1542 (2016)	Electric cables for photovoltaic systems (BT(DE/NOT)258), mainly for DC cables For use at the DC side of photovoltaic system, with a nominal DC voltage of 1.5kV between conductors and between conductor and earth. The cables are suitable to be used with Class II equipment. The cable are design to operate at a nominal maximum conductor temperature of 90 °C, but for a maximum of 20 000 hours a maximum conductor temperature of 120 °C at a maximum ambient temperature of 90 °C is permitted.
Earthing/Lightning - Specification and Standards	
IEC 62561 Series (Part 1,2 & &) (Chemical earthing)/SLS	IEC 62561-1 Lightning protection system components (LPSC) - Part 1: Requirements for connection components IEC 62561-2 Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes IEC 62561-7 Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds
Junction Boxes - Specification and Standards	
IEC 60529 /SLS	Junction boxes and solar panel terminal boxes shall be of the thermo plastic type with IP 65 protection for outdoor use, and IP 54 protection for indoor use
Energy Meter	
IEC/BS/SLS	a.c. Static direct connected watt-hour Smart Meter Class 1 and 2 - Specification (with Import & Export/Net energy measurements)
Solar PV Roof Mounting Structure	
SLS/IEC/BS	Material for the structure mounting
Solar PV-based battery storage systems/Solar Deep Cycle Battery	
IEC 60896, IEC 60896, IEC 62485, IEC 60095, IEC 60254/SLS	Lead-acid, Solar Deep Cycle Battery Minimum 03 years warranty, DOD -50%,
IEC 60896, IEC 62485	Nickel Cadmium, Solar Deep Cycle Battery

IEC 62619 IEC 62620 IEC 62133	Lithium iron, Lithium iron phosphate (liFePO4 or LFP) Solar Deep Cycle Battery Charging cycles 5000, Minimum 05 years warranty, Economic life should be more than 10 years DOD -80%, For domestic installations, battery system DC voltages shall not exceed 600V, For non-domestic installations, DC voltages should not exceed 1500V
Declaration of extended producer responsibility covering the safe disposal/recycling of ESS Component in an environmentally safe manner. Considering these facts, solar storage batteries to import as individual battery units or as an integral part of another equipment meant for providing off-grid electricity to residential units. Batteries and battery modules should meet relevant product standards	
Photovoltaic pumping systems	
IEC 62253:2011	IEC 62253:2011 defines the requirements for design, qualification and performance measurements of photovoltaic (PV) pumping systems in stand-alone operation. The outlined measurements are applicable for either indoor tests with PV generator simulator or outdoor tests using a real PV generator. This standard applies to systems with motor pump sets connected to the PV generator directly or via a converter (DC to DC or DC to AC).
Declaration of extended producer responsibility covering the safe disposal/recycling of ESS Component in an environmentally safe manner. Considering these facts, solar storage batteries to import as individual battery units or as an integral part of another equipment meant for providing off-grid electricity to residential units. Batteries and battery modules should meet relevant product standards	

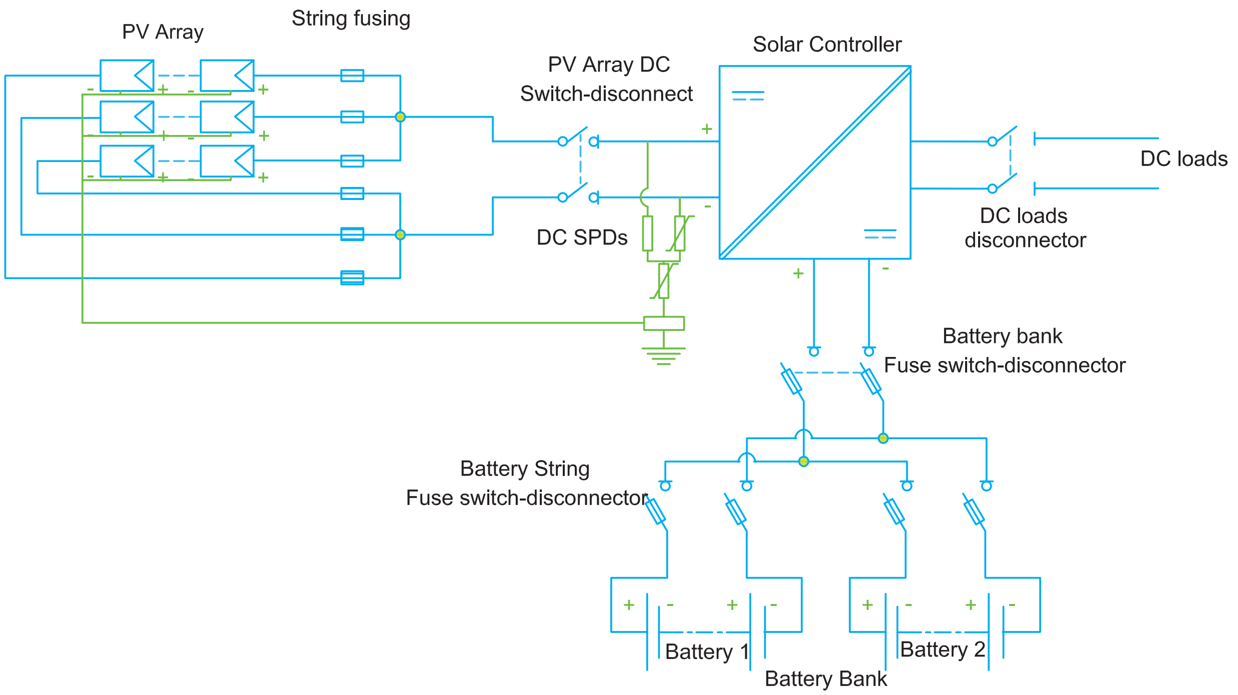
Note

- Equivalent standards may be used for different system components of the plants. In case of clarification following person/agencies may be contacted.
    - Sri Lanka Sustainable Energy Authority (SLSEA) and Sri Lanka Standard Institute (SLSI)
    - Sri Lanka Sustainable Energy Authority evaluates, registers, and approves PV modules and hybrid PV Inverters for the Solar PV Storage Application imported by the SLSEA registered Solar PV Service Providers.

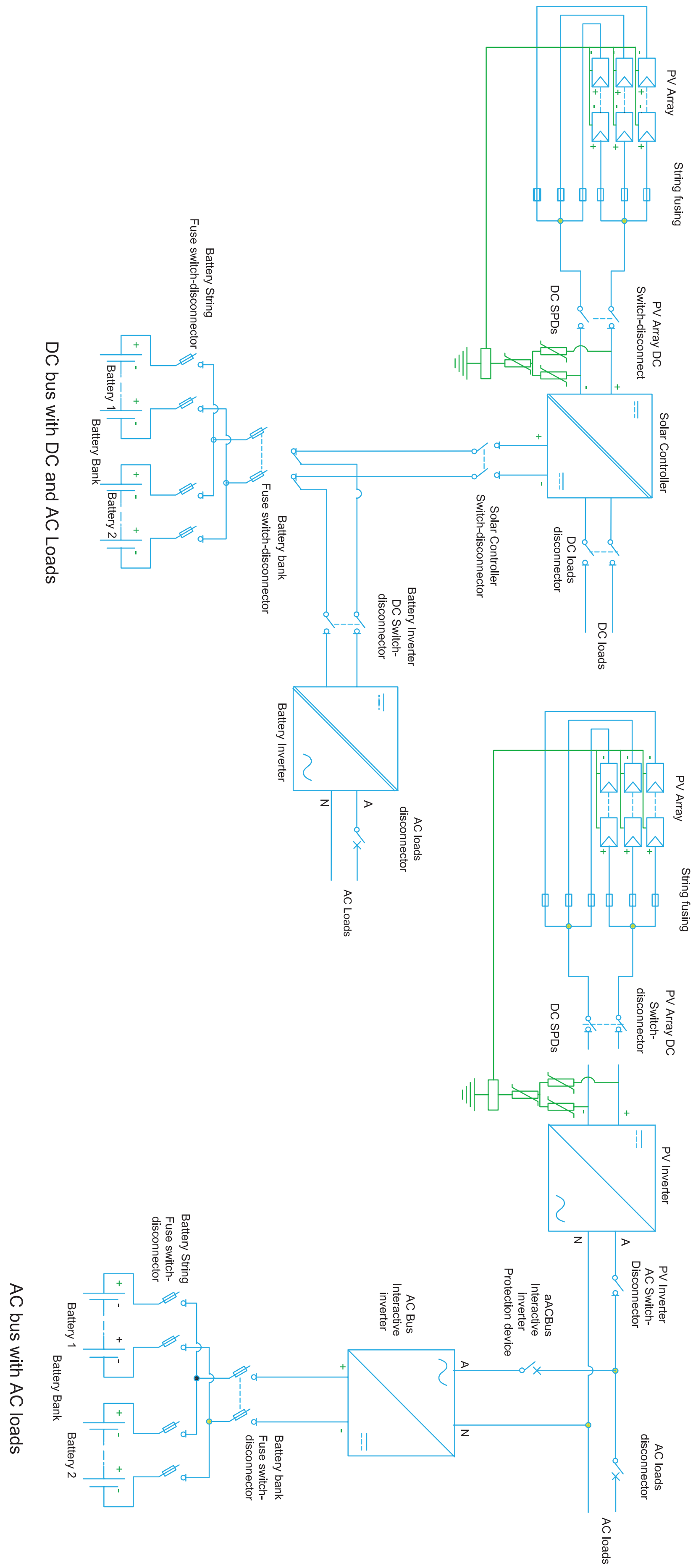
ANNEXURE E: SAMPLE WIRING DIAGRAMS



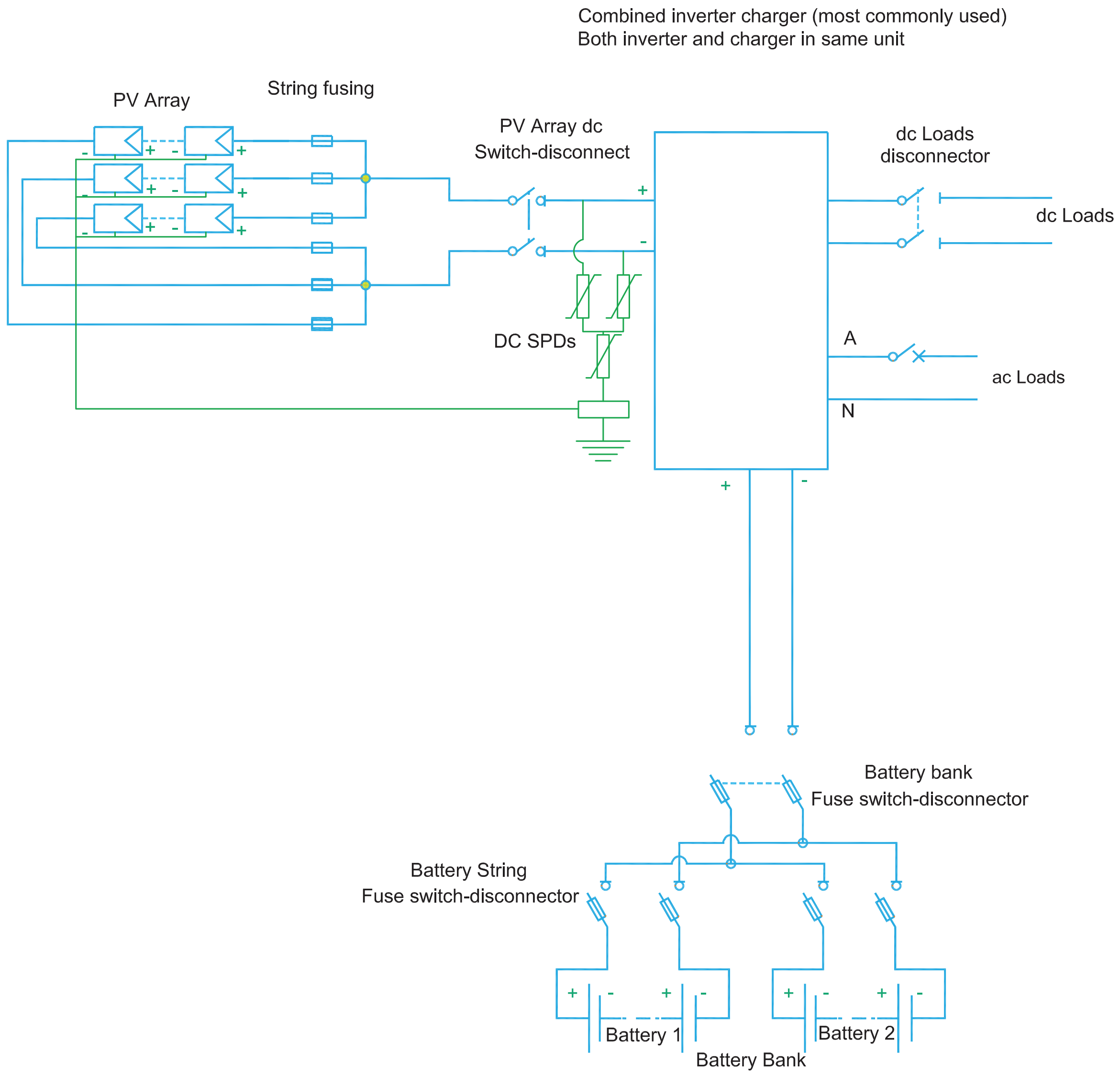
DC bus - simple DC only system (typical for rural residences)



DC bus - larger DC only system



PV Array
String fusing
PV Array DC
Switch-disconnect
DC SPDs
Solar Controller
DC loads
disconnector
DC loads
Solar Controller
Switch-disconnector
Battery Inverter
DC Switch-
disconnector
Battery bank
Fuse switch-disconnector
Battery String
Fuse switch-disconnector
Battery 1
Battery Bank
Battery 2
Battery Inverter
AC loads
disconnector
AC Loads
DC bus with DC and AC Loads
PV Array
String fusing
PV Array DC
Switch-
disconnector
DC SPDs
PV Inverter
PV Inverter
AC Switch-
Disconnector
aACBus
Interactive
inverter
Protection device
AC Bus
Interactive
inverter
AC loads
disconnector
AC loads
Battery bank
Fuse switch-
disconnector
Battery String
Fuse switch-
disconnector
Battery 1
Battery Bank
Battery 2
AC bus with AC loads



DC bus with DC and AC loads