Short-Course

Solar PV System Installation and Maintenance

NTQF Level IV

Learning Guide -08

Unit of Competence	**Calculating System Components**
Module Title	**Calculating System Components**
LG Code	**EIS PIM4 M01 0120 LO4-LG08**
TTLM Code	**EIS PIM4 TTLM 0120v1**

LO 4: Determine peak AC load and inverter size (if applicable)-08

Instruction Sheet	Learning Guide:- 08

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:

- Determining peak ac load demand;
- Calculating inverter size.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Determine peak ac load demand;
- Calculate inverter size.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below:
3. Read the information written in the information Sheet 1 (page: 63), Sheet 2 (page: 67)
4. Accomplish the Self-Check 1 (page: 66), Self-Check 2 (page: 73)

LO 4: Determine peak AC load and inverter size

Information Sheet 1	Determining peak ac load demand

1 Determining peak ac load demand

1.1 Introduction

Step 4 in the design process is to calculate the peak AC load in order to size the inverter:

LO1: Calculate Energy Demand ↓ LO2: Determine Battery Capacity ↓ LO3: Calculate Array Size ↓ LO4: Determine peak AC load and inverter size ↓ LO5: Calculate Charge Controller Size ↓ LO6: Balance of System	**1) Site survey** A Consumption B Climate data **2) PV generator** C Design PV Generator D Selection of System Voltage **3) Battery sizing (BAT)** E Battery Dimensioning based on consumption **4) Charge Controller (CC)** F Configuration of the Modules (G Charge Controller Dimensioning **5) Inverter (INV)** H Select an Inverter based on the Loads I Cross-Check Battery/Inverter matching **6) Balance of System (BoS)** J Calculate Cabling diameters and length K Calculate the Fuses L Mounting System
5) Inverter Required characteristics from datasheet? Power permanent: Power 30 minutes: Power 5 seconds:	**Battery Cross-check** $C10min = 5h * \frac{PAC}{UDC}$ — P_{AC} Power inverter; U_{DC} System Voltage Take max power of all consumers, plus safe margin (30%), and ensure it falls within inverter characteristics.

Figure 42: Design Step 4

The peak AC load is important to consider when selecting the Inverter in an off-grid PV system with AC loads. Inverters can normally supply a maximum load on a continuous basis and a higher load for short periods of time. This is to ensure that the inverter does not overload and trip when certain equipment (e.g. inductive motors) are switched on. When motors switch on, the peak current can be multiples of the normal operating current.

1.2 Ways of determining the peak load

1.2.1 Load Table

The peak load can be determined by setting up a load table as described in LO1, Information Sheet 1. This load table list all the equipment and their power ratings. The table is separated between AC and DC loads, as only the AC loads are considered when selecting the inverter. Usually, the manufacturer indicates the power rating on the appliance itself. With better information about your appliance, you can accurately predict your demand.

1.2.2 Measurement

Sometimes it is difficult to get the correct power requirements of equipment. Another option is to measure individual equipment power consumption, or even to measure all the equipment simultaneously over a period of time with a data logger. Be careful with inductive loads that can have a very high start-up current. A peak-hold meter can be very handy to determine the peak currents drawn when switching on motors.

Load profile meters can connect in series for smaller loads, or with current transformers (CT's) for bigger loads. The CT clips over the live wire to the load(s). The CT is connected to a device that translates the current to a power value and possibly even transmits it wirelessly to a smart phone or computer. See Figure 43: CT Connection.

Figure 43: CT Connection

Figure 44: Load profile meter

The load profile meter needs to be installed long enough to get a representative sample of the load. From the meter, the load profile can then be extracted (see Figure 45) and the peak load can be determined.

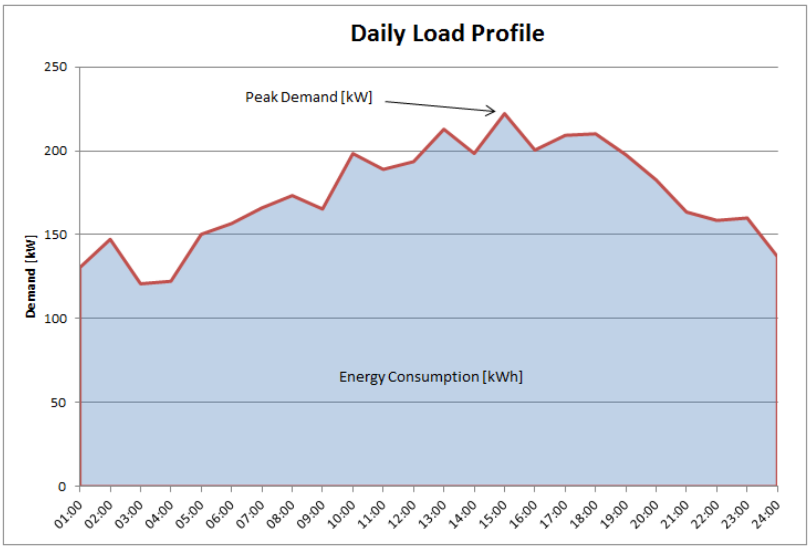

Figure 45: Load Profile Measured

Self-Check - 1	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	**A load table list all the equipment and their power ratings**
	True or false:
2	**A distinction between DC loads and AC loads needs to be made as only AC loads are used to size the inverter?**
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = ____________

Rating: _____________

Name

Date

Information Sheet 2	Calculating inverter size

2 Calculating inverter size

2.1 Introduction

The inverter is sized according to the peak load of all the AC consumers. The inverter DC input voltage must also match the battery voltage. Some inverters can work with different battery voltages.

2.2 Selecting inverter

Always select an inverter designed for solar systems. Many inverters are not designed for solar use and perform poorly in PV systems because of poor efficiency or wave shape. It is also important to consult the inverter datasheet.

Depending on the size of the PV system a simpler or more complex inverter with more programming options can be used.

Some inverters come with integrated charge controllers and some allow other sources of power to charge the battery as well e.g. a diesel generator. These are called hybrid inverters.

2.2.1 Matching the peak load

The first step in selecting the inverter is to match the peak load with the inverter continuous power rating. Most inverters will also have a peak power that is higher than the continuous power rating, but only available for a short period of time. This is to cater for higher start-up currents of some appliances.

When selecting the inverter power rating, allow for a safety margin e.g. 30%. This will leave room for a bit of expansion in future.

SINE WAVE INVERTERS

Steca
A KATEK Brand

	500-12	550-24	1100-24	1500-48
Inverter type		PI 550-24	PI 1100-24	PI 1500-48
Number of inverters / Steca PA Link1		1 / 0	1 / 0	1 / 0
Characterisation of the operating performance				
System voltage	12 V	24 V	24 V	48 V
Continuous power	450 VA	450 VA	900 VA	900 VA
Power 30 min.	500 VA	550 VA	1100 VA	1500 VA
Power 5 sec.	500 VA	1000 VA	1400 VA	2800 VA
Max. efficiency	93 %	93 %	94 %	94 %
Own consumption standby	0.5 W	0.5 W	0.7 W	0.7 W
Own consumption ON	6.0 W	6.0 W	10.0 W	10.0 W
DC input side				
Battery voltage	10.5 V ... 16 V	21 V ... 32 V	21 V ... 32 V	42 V ... 64 V
Reconnection voltage (LVR)	12.5 V	25.0 V	25.0 V	50.0 V
Deep discharge protection (LVD)	10.5 V	21.0 V	21.0 V	42.0 V
AC output side				
Output voltage	230 V AC ±10 %			
Output frequency	50 Hz			
Load detection (standby)	adjustable: 2 W ... 50 W			
Safety				
Protection class	II (double insulated)			
Electrical protection	reverse polarity battery, reverse polarity AC, over voltage, over current, over temperature			
Operating conditions				
Ambient temperature	-20 °C ... +50 °C			
Fitting and construction				
Cable length battery / AC	1.5 m / 1.5 m			
Cable cross-section battery / AC	16 mm² / 1.5 mm²			
Degree of protection	IP 20			
Dimensions (X x Y x Z)	212 x 395 x 130 mm			
Weight	6,6 kg	6,6 kg	9 kg	9 kg

- Deep discharge protection (LVD) adjustable via charge controller together with compatible parallel switch box
- Dimensions and weight per inverter

Figure 46: Inverter Datasheet (Steca Solarix)

Figure 47: Off-grid inverter Victron Phoenix

2.2.2 Matching the Battery Voltage

The inverter also needs to match the battery voltage. For instance the 500-12 model inverter on the datasheet in Figure 46 have a battery voltage of 10.5V-16V and will be suitable for a 12V battery while the 550-24 model have a battery voltage of 21V-32V and will be suitable for a 24V battery.

2.2.3 Surge Capabilities

Some equipment draws a large current for a short period when it turns on e.g. a pressure pump motor or a refrigerator compressor. The inverter must be able to handle these surges without tripping. The datasheet in Figure 46 shows the continuous power for the first inverter as 450VA while allowing 500VA for 30 minutes only. For the second inverter, the continuous power is also 450VA, but the 30min power is higher at 550VA and it allows 1000VA for 5 seconds. The second inverter will therefore be able to handle loads with higher surge currents better for a short period of time (5s).

2.2.4 Waveform

The waveform of an inverter refers to how pure the AC output waveform is. The ideal output waveform is a sinusoidal waveform but many cheaper inverters have a square waveform (worst case) or a modified sine wave (a bit better). These inverters are generally cheaper but may not work with some appliances.

Modified sine wave inverters are very affordable, all-purpose inverters. Using a more basic form of technology than pure sine wave inverters, they produce power which is perfectly adequate for powering simple electronics. Use modified sine wave inverters to provide power for your less sensitive appliances like phone chargers, heaters and air conditioners. Modified inverters are best suited for resistive loads which don't have a start-up surge.

Pure sine wave inverters use more sophisticated technology to protect even the most sensitive electronics. Pure sine wave inverters produce power which equals – or is better than – the power in your home. Appliances which may not function properly or which may be permanently damaged without pure, smooth power will be safe with pure sine inverters. Use these inverters for televisions, laptops, digital microwaves, fridges and other sensitive electronic equipment. Pure Sine inverters can power just about any AC appliance without risk of damage.

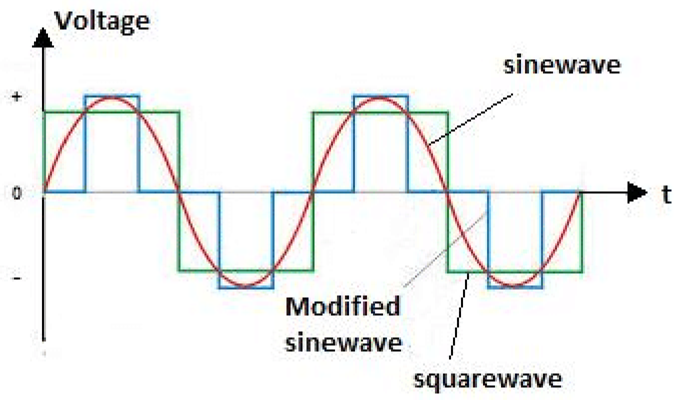

Figure 48: Inverter waveforms

2.2.5 Stand-by Mode

Many inverters still consume power from the battery when there are no appliances on. Some inverters automatically detect the load and will shut themselves down to prevent battery drain. The inverter in Figure 49 has automatic load detection and will switch on when a load is switched on.

Especially the cheaper and simpler inverters often don't have automatic load detection and continue to consume power. In small solar system, this self-consumption of the inverter can make quite a difference with regards to the amount of energy available, so system users should be advised to switch off the inverter at night or when not in use.

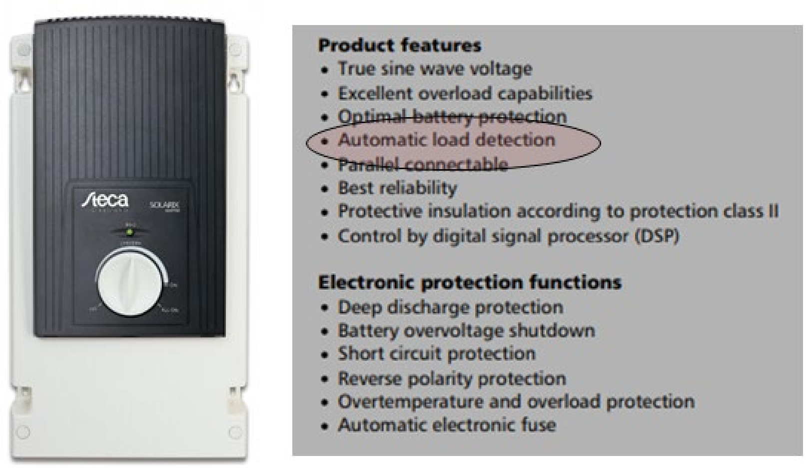

Figure 49: Automatic Load Detection

2.3 Adama Design

For the Adama Design, the peak load was calculated using a load table (see Table 1). The Calculated load was 2317W. If we apply a safety margin to it, the required peak load is:

Peak Load = 2317W x 1.3 = 3012W.

From Figure 50 we can see that the Phocos Anygrid PSW K-5kW inverter's rated power is 5000W while it can handle surges of 2 x rated power (10000W) for 5 seconds.

There is normally a minimum size battery specified for an inverter:

$\boldsymbol{C}10min = 5h * \frac{PAC}{UDC}$	P_{AC} Power inverter U_{Dc} System Voltage

In the case of Adama, the minimum is:

$$\boldsymbol{C}10min = 5h * \frac{5000W}{48V} = 521Ah$$

The selected battery of 541Ah is larger than 521Ah therefore ok.

PSW-H [3 kW/5 kW]
Any-Grid™ Hybrid Inverter Charger

phocos

Technical Data

Type	PSW-H-3KW-120/24V	PSW-H-3KW-230/24V	PSW-H-5KW-230/48V
Output Waveform	Pure Sine Wave		
System Voltage	24 VDC		48 VDC
Rated Power	3000 VA / 3000 W		5000 VA / 5000 W
Max. Charge Current (PV)	80 A		
Max. Charge Current (AC)	80 A		
Max. Total Charge Current	80 A		
Max. AC Input Current	40 A	30 A	40 A
Float Charge	27.6 VDC (adjustable)		55.2 VDC (adjustable)
Boost Charge	28.8 VDC (adjustable)		57.6 VDC (adjustable)
Equalization Charge	29.6 VDC (adjustable)		59.2 VDC (adjustable)
Deep-Discharge Protection	22 VDC (adjustable)		44 VDC (adjustable)
Reconnect Level	25.6 VDC (adjustable)		51.2 VDC (adjustable)
Overvoltage Protection	33 VDC		66 VDC
Undervoltage Protection	18.8 VDC		37.5 VDC
Max. PV Panel Voltage	250 VDC	450 VDC	
PV Panel MPP Voltage	90 ~ 230 V	90 ~ 430 V	120 ~ 430 V
Max. Usable PV Power	2400 W	4000 W (2400 W for battery charging)	4800 W
Max. PV Array Power	3000 Wp	5000 Wp	6000 Wp
AC Frequency	50 / 60 Hz auto recognition		
AC Output Voltage	110 ~ 120 VAC ±5% (adjustable)	220 ~ 240 VAC ±5% (adjustable)	
Surge Power	2x rated power for 5 seconds		
Extensibility	Up to 9 units in parallel or 3-phase		
Inverter Efficiency (from Battery)	> 90 % peak	> 91 % peak	> 93 % peak
Inverter Efficiency (from PV)	> 96 % peak		

Figure 50: Phocos inverter datasheet

Self-Check - 2	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	**Always allow for a safety margin when sizing the inverter.**
	True or false:
2	**A pure sine wave inverter is suitable for all loads**
	True or false:

For each of the following question choose the best answer and circle the letter of your choice.

N°	An AC inverter is NOT selected according to the following criteria	
1	**Question**	
	A – The Battery Voltage	B – The AC peak load
	C – The PV Array Voltage	D – The inverter surge capability

Note: the satisfactory rating is as followed

Satisfactory	3 points
Unsatisfactory	Below 3 points

Answer Sheet

Score = ____________

Rating: _____________

Name

Date