SIERRA COLLEGE

System Sizing

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Lesson Plan

- Site Assessment – Any Questions?

- NABCEP Learning Objectives:
  PV System Sizing Principles

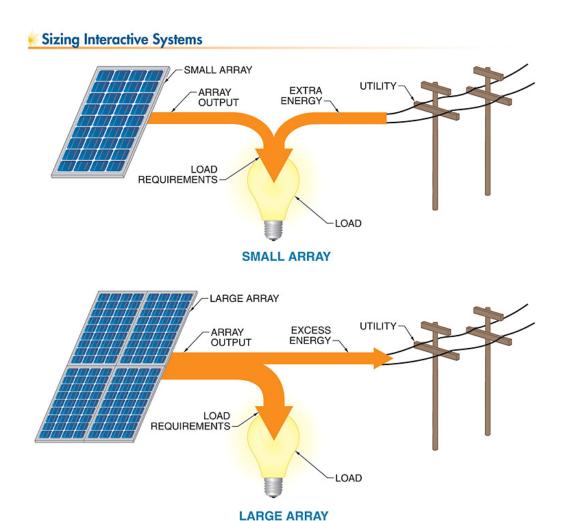| Category	Course Time By %	Exam Items	Level of Testing
1. PV Markets & Applications	5%	3	Comprehension
2. Safety Basics	5%	3	Comprehension Application
3. Electricity Basics	10%	6	Comprehension Problem Solving
4. Solar Energy Fundamentals	10%	6	Comprehension Application Problem Solving
5. PV Module Fundamentals	10%	6	Comprehension Application Problem Solving
6. System Components	15%	9	Comprehension Application Problem Solving
7. PV System Sizing Principles	10%	6	Application Problem Solving Design
8. PV System Electrical Design	15%	9	Application Problem Solving Design
9. PV System Mechanical Design	10%	6	Application Problem Solving Design
10. Performance Analysis, Maintenance and Troubleshooting	10%	6	Analysis Problem Solving
Totals	**100%**	**60**	

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7.	**PV System Sizing Principles** *Suggested Percentage Time Allotment: 10%*	**Learning Priority**
7.1	Understand the basic principles, rationale and strategies for sizing stand-alone PV systems versus utility-interactive PV systems.	Important
7.2	Given the power usage and time of use for various electrical loads, determine the peak power demand and energy consumption over a given period of time.	Important
7.3	Beginning with PV module DC nameplate output, list the de-rating factors and other system losses, and their typical values, and calculate the resulting effect on AC power and energy production, using simplified calculations, and online software tools including PVWATTS.	Critical
7.4	For a specified PV module and inverter in a simple utility-interactive system, determine the maximum and minimum number of modules that may be used in source circuits and the total number of source circuits that may be used with a specified inverter, depending upon the expected range of operating temperatures, the inverter voltage windows for array maximum power point tracking and operation, using both simple calculations and inverter manufacturers' online string sizing software tools.	Critical
7.5	Given a stand-alone application with a defined electrical load and available solar energy resource, along with PV module specifications, size and configure the PV array, battery subsystem, and other equipment as required, to meet the electrical load during the critical design period.	Critical

- Interactive-system sizing is very flexible because the utility can supply extra energy to the system loads and receive excess energy from the utility system.

Sizing Interactive Systems

SMALL ARRAY
ARRAY OUTPUT
EXTRA ENERGY
UTILITY
LOAD REQUIREMENTS
LOAD
SMALL ARRAY

LARGE ARRAY
ARRAY OUTPUT
EXCESS ENERGY
UTILITY
LOAD REQUIREMENTS
LOAD
LARGE ARRAY

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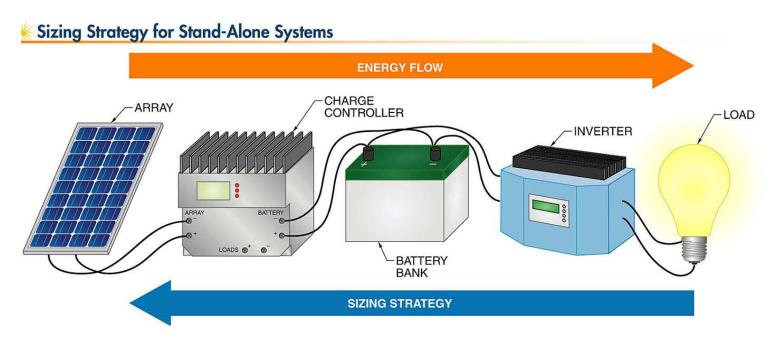www.energyinstructor.info

- Sizing interactive systems begins with calculating the peak array DC power output, which is then derated for various losses and inefficiencies in the system to arrive at a final AC power output.
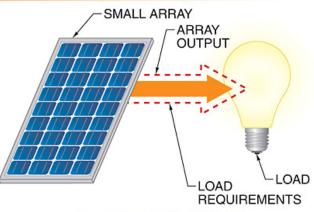
Interactive System Sizing

INTERACTIVE SYSTEM SIZING

|		
PV-Module Rated DC Power Output	185	W
Manufacturer Power Guarantee	0.90	
Number of Modules in Array	16	
Array Guaranteed Power Output	**2664**	W
Array Avg Operating Temperature	50	°C
Temperature Coefficient for Power	-0.004	/°C
Temperature-Corrected Array Power Output	**2398**	W
Array Wiring and Mismatch Losses	0.03	
Net Array Power Output	**2326**	W
Inverter Maximum DC Power Rating	2500	W
Inverter Power Conversion Efficiency	0.92	
Inverter MPPT Efficiency	1.00	
Inverter Maximum AC Power Output	**2140**	W
Average Daily Insolation	5.1	PSH/day
Average Daily Energy Production	**10.9**	kWh/day
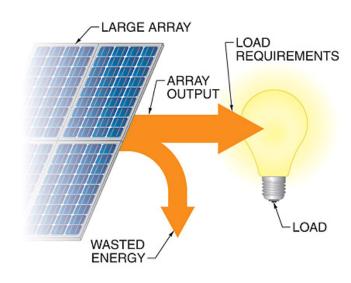
- Sizing strategy for stand alone systems starts at the load side and proceeds backward to the array.

Sizing Strategy for Stand-Alone Systems

Sizing Stand-Alone Systems

SMALL ARRAY — ARRAY OUTPUT — LOAD REQUIREMENTS — LOAD

UNDERSIZED ARRAY

LARGE ARRAY — LOAD REQUIREMENTS — ARRAY OUTPUT — LOAD — WASTED ENERGY
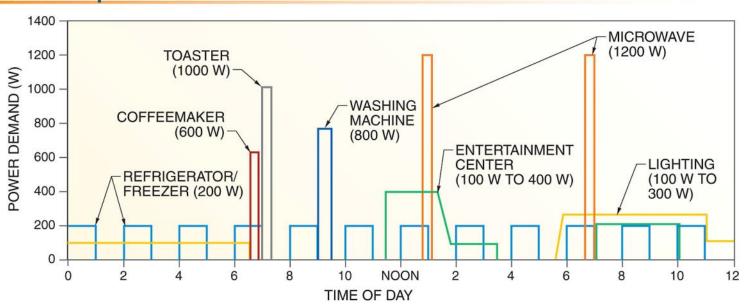
OVERSIZED ARRAY

- Stand-alone systems must be carefully matched to load requirements to avoid reducing load availability or wasting excess energy.

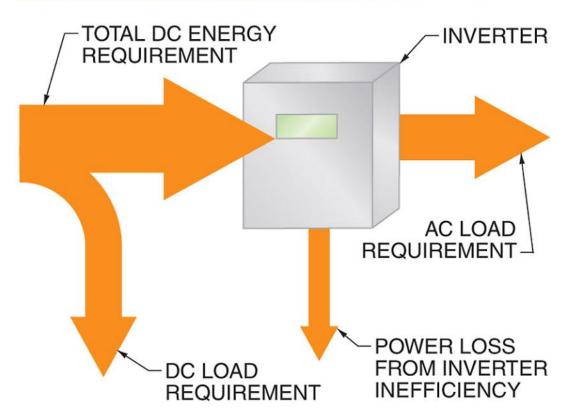- A load analysis tabulates the various kinds of loads and their power and electrical-energy requirements.

Load Analysis

LOAD ANALYSIS   Month:

AC LOADS

Load Description	Qty	Power Rating (W)	Operating Time (hr/day)	Energy Consumption (Wh/day)

DC LOADS

Total AC Power		W
Total DC Power		W
Total Daily AC Energy Consumption		Wh/day
Total Daily DC Energy Consumption		Wh/day
Weighted Operating Time		hr/day
Inverter Efficiency		
Average Daily DC Energy Consumption		Wh/day

- Load requirements include the power demand and electrical-energy consumption for all the expected loads in the system.

Load Requirements

Total DC Energy Requirement

TOTAL DC ENERGY REQUIREMENT

INVERTER

AC LOAD REQUIREMENT

DC LOAD REQUIREMENT

POWER LOSS FROM INVERTER INEFFICIENCY

- The total DC-energy requirement is determined from the requirements for the DC loads (if any) plus the requirements for the AC loads, taking inverter efficiency into account.

- A critical design analysis compares the load requirements and insolation for each month to determine the critical design month.

Critical Design Analysis

CRITICAL DESIGN ANALYSIS

Month	Average Daily DC Energy Consumption (Wh/day)	Array Orientation 1		Array Orientation 2		Array Orientation 3	
		Insolation (PSH/day)	Design Ratio	Insolation (PSH/day)	Design Ratio	Insolation (PSH/day)	Design Ratio
January							
February							
March							
April							
May							
June							
July							
August							
September							
October							
November							
December							

Critical Design Month

Average Daily Energy Consumption   Wh/day
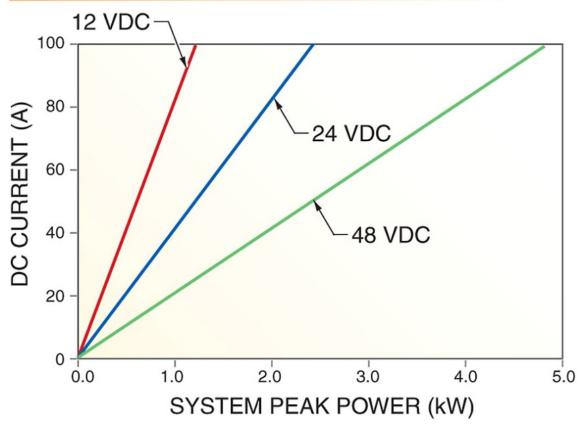
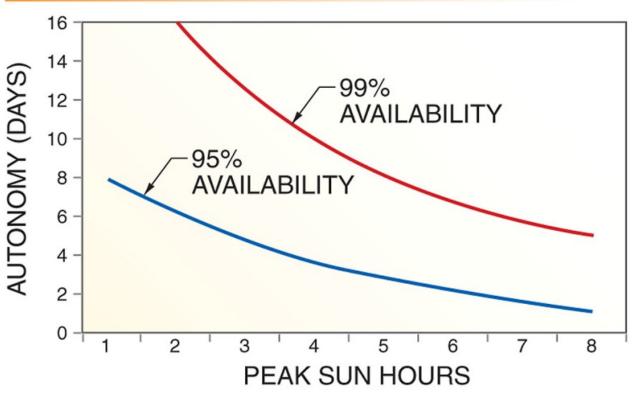Insolation   PSH/day

Optimal Orientation

- DC-system voltage is chosen in proportion with the array size and to keep the operating current below 100 A.
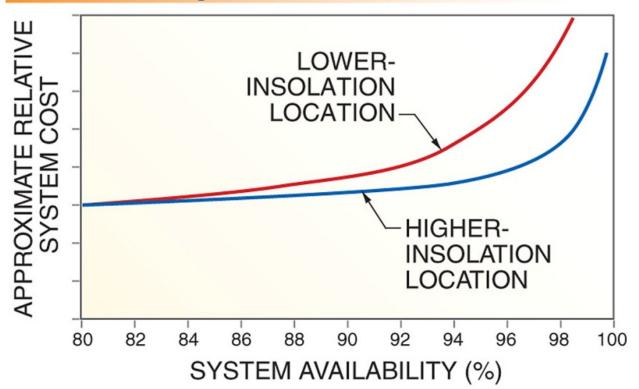
System Availability

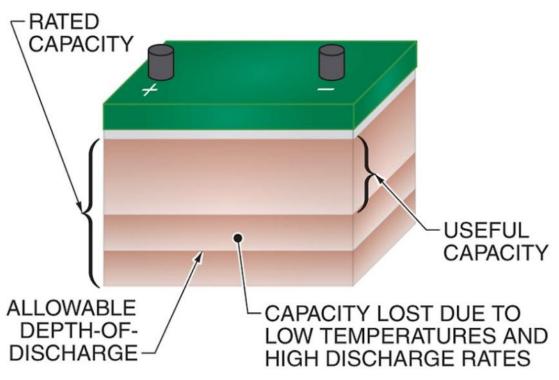- System availability is approximated from the local insolation and the autonomy period.

- Increasing system availability significantly increases the cost of the system.

Battery-Bank Capacity

RATED CAPACITY

USEFUL CAPACITY

ALLOWABLE DEPTH-OF-DISCHARGE

CAPACITY LOST DUE TO LOW TEMPERATURES AND HIGH DISCHARGE RATES

- Due to the allowable depth-of-discharge, low temperatures, and high discharge rates, the amount of useful output in a battery bank is less than the rated capacity.

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☀ **Battery-Bank Sizing**

BATTERY-BANK SIZING

- The battery-bank sizing worksheet uses information from the load analysis to determine the required size of the battery bank.

Average Daily DC Energy Consumption for Critical Design Month		Wh/day
DC System Voltage		VDC
Autonomy		days
Required Battery-Bank Output		A-h
Allowable Depth-of-Discharge		
Weighted Operating Time		hrs
Discharge Rate		hrs
Minimum Expected Operating Temperature		°C
Temperature/Discharge Rate Derating Factor		
Battery-Bank Rated Capacity		A-h
Selected Battery Nominal Voltage		VDC
Selected Battery Rated Capacity		A-h
Number of Batteries in Series		
Number of Battery Strings in Parallel		
Total Number of Batteries		
Actual Battery-Bank Rated Capacity		A-h
Load Fraction		
Average Daily Depth-of-Discharge		

- The array sizing worksheet uses insolation data and load requirements to size the array.

Array Sizing

ARRAY SIZING

Average Daily DC Energy Consumption for Critical Design Month		Wh/day
DC System Voltage		VDC
Critical Design Month Insolation		PSH/day
Battery Charging Efficiency		
Required Array Maximum-Power Current		A
Soiling Factor		
Rated Array Maximum-Power Current		A
Temperature Coefficient for Voltage		/°C
Maximum Expected Module Temperature		°C
Rating Reference Temperature		°C
Rated Array Maximum-Power Voltage		VDC
Module Rated Maximum-Power Current		A
Module Rated Maximum-Power Voltage		VDC
Module Rated Maximum Power		W
Number of Modules in Series		
Number of Module Strings in Parallel		
Total Number of Modules		
Actual Array Rated Power		W