PV – 2

DEPARTMENT OF ENERGY
RENEWABLE ENERGY MANAGEMENT BUREAU

MANUAL

for

Solar PV Training

June 2009

This manual was developed by the Department of Energy (DOE) through the technical assistance under the Project on “Sustainability Improvement of Renewable Energy Development for Village Electrification in the Philippines” which was provided by the Japan International Cooperation Agency (JICA).

For a better tomorrow for all.
Japan International Cooperation Agency

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LIST OF ANNEXES

1 OBJECTIVE

DOE and JICA have developed two solar PV training courses since 2005. One is "Solar PV Trainers' Training Course" and the other is "Solar PV Engineers' Training Course". The training courses are designed to assist all PV project stakeholders in the creation of sustainable PV projects in the Philippines. PV training courses should be designed according to the roles of stakeholders.
The former training is provided to central engineers to develop personnel who understand PV technology properly and can teach other engineers. People who have undergone the training and passed the examination will be certified as the qualified PV trainers or assistant trainers. The latter training is provided to rural PV engineers to develop personnel who can conduct monitoring and user training properly.

The objective of this manual is to guide trainers who conduct the Solar PV Training.

2 TRAINING COMPONENTS

The training components are shown below.

Table 1 Training components

Lecture			Hands-on		
Components of Training course	Trainer	Engineer	Components of Training Course	Trainer	Engineer
Basic of solar PV system	A	A	How to use measuring instruments	A	A
Basic of electricity	A	A	Measuring of electrical circuit	A	A
Solar energy	A	A	Performance check of C/C	A	A
PV module & I-V curve	A	A	Inspection of PV system	A	A
Battery	A	A	Monitoring of existing PV system	A	A
Charge controller	A	A	Measuring of I-V curve	A	P
DC light & Inverter	A	A	Measuring of PV module output	A	A
Maintenance	A	A	User training	A	A
Monitoring & Inspection	A	A			
Troubleshooting	A	A			
Procurement	A	P			
User training	A	A			
Design of PV system	A	P			

Notes) A: All P: Partial

All basic knowledge and skills on PV technology are required for the trainers. On the other hand, the knowledge and skills to manage existing PV system properly, such as monitoring, maintenance, troubleshooting and user training, are required for rural engineers. For an effective training, it is necessary to examine the methods and contents of training to be able to meet the expectations and identify the roles of the engineers in advance. The outline of training component is provided in ANNEX 1 "Components of Solar PV Training Course".

3 CURRICULUM

The standard training curriculum is a 6-day program consisting of lectures, exercises, hands-on training and an examination. However, the schedule and curriculum of training should be arranged according to the conditions such as level of trainees and location of hands-on site. The standard training curriculum for PV trainer and PV engineer are provided in ANNEX 2.

4 TRAINING MATERIALS

The training materials are shown in the following table. Main text including all basic knowledge on PV technology is used commonly. Exercises and homework are useful for improving the understanding of trainees. In the hands-on training, the data sheets, measuring instruments and tools are required, and also the PV training kit is useful for indoor training.

Table 2 Training materials

Training method	Training Materials
Lecture	Text *Main text, *Text for design of PV system *Text for user training, *Exercise & homework
	Logistics *Personal computer, *LCD, *Laser pointer *White board & Marker pen, *Audio-Video equipment
Hands-on training	Data sheet for hands-on training
	Measuring instrument *DC/AC clamp meter, *Digital multi meter *Digital Illuminance meter / Pyranometer *AC clamp power tester, *Emission thermometer *Angle locater, *Compass *Hydrometer with gloves & goggles *Variable resistance device for measuring I-V curve etc.
	PV training kit *PV module, *Charge controller, *Battery *DC light with receptacle, *SW, *Cable *DC power supply, *Resistor etc.
	Tools *Screwdriver, *Plier, *Wrench etc.
Examination	Examination Paper
	Blank paper
	Calculator & Pens etc.

DOE and JICA prepared PV training materials summarized over all PV training in February 2009. These materials are useable for PV training. The main text for PV training is provided in ANNEX 3 “Solar PV Technology Training Text”.

5 TRAINING POINTS

Trainers should consider how to best combine the lecture and hands-on training. Basically, the hands-on training deepens the participant's knowledge and understanding on the points covered during the lecture. Repetition of both is important for effective learning.

Usually, reiterative approach of teaching is tough and boring for both trainers and participants, but they have to devote themselves to learning all the topics again to be able to absorb and understand the training modules. Also, for preparatory purposes, it is better to provide the participants with the text in advance.

5.1 Lecture Points

The lecture portion of the training is conducted based on the prescribed texts. The texts contained lots of figures, diagrams, and photos to facilitate better understanding. Therefore, trainers need to prepare what to instruct during the lecture.

Trainers should always pay attention to the level of understanding of the participants and resiliently adapt to it accordingly. The following points should be taken into consideration for effective lecturing:

- Asking the participants to confirm understanding;
- Homework for the review of the lectures;
- Practice to deepen the knowledge;
- Introduction of examples;
- Discussion among participants; and
- Participant presentations.

5.2 Hands-on training Points

The hands-on training is carried out in small groups, with approximately 4 persons per group. Each group has to have at least one trainer for effective training. Data sheet for hands-on training need to be prepared in advance and provided to each participant.
The following points should be taken into consideration for effective training:

- To explain purpose and method of the training before the training;
- To give instruction on how to use the measuring instruments;
- To provide all members with opportunities to monitor using measuring instruments;
- To let the participants process the meaning of the monitored data acquired on-site by themselves ; and
- To instruct them to evaluate the result of monitored values.

If possible, it is better for all the participants to discuss and analyze the results of the hands-on training among themselves. After which, presentations should be carried out to evaluate their respective level of understanding.

6 EXAMINATION

The examination should be done to evaluate the knowledge and understanding of participants. The qualification test is adopted in the solar PV trainer's training and conducted on the last day. On the other hand, the confirmation test is adopted in the solar PV engineer training and conducted before and after training.

6.1 Preparation of examination paper

Exam questions should be prepared by trainers in consideration of the following:

- Contents of exam should cover each subject
- Keeping the same level of exam question
- Maintenance of confidentially for contents of exam question and records

6.2 Examination Rules

The examinees should obey the following rules during the examination:

- Use only pencils, erasers, rulers, calculators, and blank paper for computation.
- Cell phone is not allowed to be used as a calculator.
- Communicating with other examinees is prohibited during the exam.
- The examination time: Two (2) hours for qualification test
Three (3) hours for pre and post confirmation test

In case examinees break the rules, the following response should be taken.

1st : Give warning
2nd: Stop taking the examination and eject from room

6.3 Grading and Evaluation

After the examination, trainers mark the examination papers. Marking of the examinations must be double checked by at least 2 trainers. After marking, the scoring percentage of each subject should be calculated.

1) Solar PV trainers' training

Grading of the participants consists of the examination score and training evaluation. In the training evaluation, it is better for the trainers to discuss among themselves the attitude of the participants utilizing evaluation sheets. Further more, the evaluation sheet has to be filled out with the scores of the each subject and the training evaluation. Finally, the grading result of each trainee has to be decided utilizing a standard set of evaluation items for this purpose.

Table 3 Grading Standard

Result	Qualification	Grading Standard
A	Qualified Trainer	2 subjects >=90 and 4 subjects >=80
B	Qualified Assistant Trainer	3 subjects >=80 and 4 subjects >=70
C	Not qualified Follow-up Training (Lecture) is necessary	Average score ratio >= 60 and fail of one subject to be qualified
D	Not qualified Follow-up Training (Lecture & Hands-on) is necessary	Average score ratio >= 60 but not C
E	Not qualified Follow-up Training (Lecture & Hands-on & Basic Electricity) is necessary	Average score ratio >=50 and < 60
F	Not qualified Additional Training (Beginner's level) is necessary	Average score ratio < 50

2) Solar PV engineers' training

After the pre examination, trainers disclose the score to participants to let them understand their knowledge level and areas for improvement. Also, trainers can understand their knowledge level before training and reflect to their training.

Same with the post examination, trainers disclose the score to participants with the score of pre examination utilizing the evaluation sheet. From the evaluation sheet, the effectiveness of the training can be evaluated and participants can understand which subject is required for improvement.

Example of evaluation sheet is provided in ANNEX 4 "Evaluation Sheet for PV Trainer or PV Engineer"

7 AMENDMENT OF THE MANUAL

The DOE shall review this manual annually, and amend it, if necessary, according to the surrounding circumstances in rural electrification of the country. The amended manual shall be fully authorized among the DOE and approved by Director of Renewable Energy Management Bureau of the DOE.

ANNEX 1　: Components of Solar PV Training Course

Components of Solar PV Training Course

1. Introduction

Topics	Session Guide	Training Approach	Contents
Introduction	Participants will give a self-introduction one by one. The trainer will introduce the background and purpose of this training. Schedule and purpose of this training will be explained	• Rituals • Self introduction • Lecture	• Background • Present Issue of Solar power • Purpose of this training • Schedule & Announcements

2. Lecture

Topics	Session Guide	Training Approach	Contents
Topic 1 Basic of Solar PV System	This topic covers the knowledge on basics of Solar PV system. The trainer will explain how to generate electricity from solar PV system and the applications of PV systems such as SHS, BCS, Mini Centralized System and Centralized System. Also the trainer will explain the meaning of peak load, power consumption and available power. Discussion on common trouble and troubleshooting are also useful for participants. Exercises should be used to improve the level of understanding.	• Lecture • Exercise	• Electricity from Solar Energy • Feature of Solar PV System • Site selection • SHS (Solar Home System) • BCS (Battery Charge Station) • Centralized System (Mini, 10kW ~) • Available Power • Peak Load and Daily Power Consumption • Common Trouble & Trouble Shooting • Exercise
Topic 2 Basic of Electricity	This topic covers the knowledge on basic electricity and basic calculation skill of electrical circuit. The trainer will explain the meaning of units (V, A, W, Wh) and how to use circuit laws such as "Ohm's Law" and "Kirchoff's Law" showing examples. These basic knowledge are required for a PV engineer. Also the trainer will explain the meaning of the voltage drop and how to calculate it. In a small PV system which is designed at low voltage such as 12V and 24V, the voltage drop has to be taken into consideration. Exercises should be used to improve the level of understanding.	• Lecture • Exercise	• Voltage, Current, Resistance, Power • AC and DC • Ohm's Law, Power Law • Kirchhoff's Law • Power and Energy • Peak load and Daily Power consumption • Voltage Drop • Calculation of Voltage Drop • Specification of Voltage Drop • Exercise
Topic 3: Solar Energy	This topic covers the knowledge on solar energy. The trainer will explain the meaning of technical terms such as Insolation, Peak Sun Hours and Irradiance. Also the trainer will explain the no-shade time and effect of tilt angle.	• Lecture	• Insolation • Peak Sun Hour • Tilt Angle • Example of effect by various tilt angle • No-Shade Time

Topic 4: PV Module & IV and PV Curve	This topic covers the knowledge on PV module and I-V curve. The trainer will explain the type and feature of PV module. I-V curve is the most important data needed when acquiring a PV module. The trainer will explain the characteristic of I-V curve in details. Series & parallel connections and effect of shadow will further expand the PV engineer's knowledge. Trainer will explain the role of Bypass diode and blocking diode. Exercises should be used to improve the level of understanding.	• Lecture • Exercise	• PV module • Type of PV Module • I-V and P-V Curve • Characteristic of IV Curve • Series & Parallel Connection • Output of PV Module • Bypass Diodes & Blocking Diodes • Effect of shadow • Operation point • Exercise
Topic 5: Battery	This topic covers the knowledge on battery. The trainer will explain the type and features of lead-acid battery. The profile of battery is an important data to understand the state of charge of the battery. Also, the trainer will explain the battery capacity, cycle life, how to read capacity and how the cycle life is pre-determined. In addition, the trainer will explain the maintenance and usage method of battery. Battery is a key component in a PV system. To understand the maintenance and usage method correctly is necessary to a PV engineer. Exercises should be used to improve the level of understanding.	• Lecture • Exercise	• Common Sense • Type of Lead-acid Batteries • Profile of Battery Voltage • Indicator of State of Charge • Charging Efficiency • Cycle Life, Capacity, Discharge Rate • Maintenance of Electrolyte • Maintenance of Electrode • Maintenance of Cell Voltage • Battery Size vs Over Use • Series and Parallel, Inter-Connection • Exercise
Topic 6: Charge Controller	This topic covers the knowledge on charge controller. The trainer will explain the type, features and function of charge controller. There are three types of charge controller and the PWM type is currently the most widely used. Set point voltage such as HVD and LVD and status of C/C at set point voltage should be understood. Exercises should be used to improve the level of understanding.	• Lecture • Exercise	• Function of Charge Controller • Type of Charge Controller • Status of C/C, Set point voltage • Connecting Sequence • Additional functions • Do you know? • Exercise
Topic 7: DC Light	This topic covers the knowledge on DC Light. The trainer will explain the type and features of DC Lights such as CFL, CCFL, halogen light and LED.	• Lecture	• Compact Fluorescent Light • DC Fluorescent Light • Do you know?
Topic 8: Inverter	This topic covers the knowledge on Inverter. The trainer will explain the type and features of inverter for SHS.	• Lecture	• Inverter for SHS • Output Waveform • Do you know?

Topic 9: Maintenance	This topic covers the knowledge of Maintenance. The trainer will explain the general maintenance of PV system.	• Lecture	• General Maintenance
Topic 10: Inspection & Monitoring	This topic covers the knowledge on Inspection and Monitoring. The trainer will explain the necessity of inspection and how to inspect PV system. Understanding system parameters are necessary to inspect PV system correctly and the skill to analyze PV system condition using the system parameters is required in a PV engineer. Also the trainer will show the example of system condition and let trainee think. Exercise should be used to improve the level of understanding. (Exercise 8)	• Lecture	• Inspected & Approved, Why?? • System Parameters • Measuring equipment • Status of C/C • Status of system • How much is the load power (W)? • Measuring points (Centralized) • Specific Gravity • Daily Usage Time of loads (SHS) • Overuse • Peak load & Total load (Centralized) • Exercise
Topic 11: Troubleshooting	This topic covers the knowledge on troubleshooting. The trainer will explain the examples of normal troubles and causes of troubles occurring in each PV system. It is necessary to find the right cause or causes of trouble in order to administer the right troubleshooting procedure. To discuss the causes and the countermeasures in the group activity is an effective way to expand trainee's knowledge. Also, the trainer will explain how to check and countercheck the causes of troubles.	• Lecture • Group activity	• IV and PV Curve • Characteristic of IV Curve • Series & Parallel Connection • Effect of shadow • How to measure I-V Curve • How to draw I-V and P-V Curve • Operation point • Exercise
Topic 12: Procurement	This topic covers the knowledge on Procurement. The trainer will explain the specifications of main components and measuring instruments to be used in a PV project and how to read data sheet of materials.	• Lecture	• Inspection & Monitoring • Inspected & Approved, Why?? • Status of C/C • Exercise
Topic 13: Design of PV system	This topic covers the knowledge on system design method of PV system. The trainer will explain what data is needed to design and how to design a PV system. Exercise of system design is more effective.	• Lecture • Exercise	• Inspection & Monitoring • Inspected & Approved, Why?? • Status of C/C • Exercise
Topic 14: User training	This topic covers the knowledge on User Training. The trainer will introduce the training materials used in actual project and explain the key points of user training. Role-playing of user training is effective to expand the level of understanding of the trainees.	• Lecture • Role playing	• Inspection & Monitoring • Inspected & Approved, Why?? • Status of C/C • Exercise

2. Hands-on Training

Topics	Session Guide	Training Approach	Handouts
Topic 1: How to use Measuring Instruments	This topic covers the skills on how to use measuring instruments. The trainer will explain the specification of measuring instruments and how to use them. After explanation, the trainee will measure the parameters using the instruments individually and record the data into the data sheet.	• Individual activity • Measuring	• Data sheet
Topic 2: Measuring of Electrical Circuit	This topic reviews the circuit laws and voltage drop learned in basic of electricity. The trainees will calculate the values at the designated points by using circuit laws, and then trainees will measure the values at the same points to confirm if both values are the same.	• Group activity • Calculation • Measuring	• Data Sheet
Topic 3: Function Check of C/C	This topic reviews the functions and operation condition of C/C. The trainers will explain how to check function of C/C. After explanation, trainees will check the protective function of C/C by using test instruments. It is important to understand how switches change when the C/C has reached HVD or LVD.	• Group activity • Measuring	• Data Sheet
Topic 4: Inspection of SHS	This topic reviews the inspection method of a PV system. The trainers will explain how to inspect a PV system. After explanation, trainees will check the PV system by measuring the system parameters during operation. It is important to understand the meaning of system parameters.	• Group activity • Inspection	• Data sheet
Topic 5: Monitoring of existing PV system	This topic covers monitoring method of existing PV system. The trainees will be instructed how to conduct monitoring using the monitoring sheet. The trainees will conduct monitoring of existing PV system at the site and evaluate the system status from monitoring results.	• Group activity • Monitoring	• Monitoring sheet
Topic 6: Measuring of I-V Curve	This topic covers measurement of I-V curve and what are the parameters affects I-V curve. The trainers will instruct how to measure I-V curve. The trainees will measure I-V curve using test instrument and record the data into data sheet. After measuring, the trainees will arrange and process the data.	• Group activity • Measuring	• Data sheet • Graph paper
Topic 7: Measuring of PV module output	This topic covers the characteristic of PV output. The trainees will measure PV output by changing direction and tilt angle of PV module and understand how PV out put changes by those affects.	• Group activity • Monitoring	• Data sheet
Topic 8: User training	This topic covers how to conduct user training at the site The trainer and/or trainees will prepare the materials for user training in advance and conduct user training at the site.	• Practical training	• User training text

ANNEX 2 : Standard Training Curriculum for PV Trainer and PV Engineer

Standard Training Curriculum for PV Trainer

Date	Type of Training	min.		Subject	Syllabus	Text page	Place
1st	Lecture & Hands-on	30		Introduction	Purpose of training, Contents of training, Notice, Self-introduction		Room
		60	L1	Basic of solar PV system	Type of solar PV system, Case example Introduction of PV systems introduced at BEP	P.1-16	
		40	L2	Safety	Risk assessment, Hazard Safety management	P.17-24	
		150	L3	Basic of Electricity	Electrical term, Electrical law, Power & Energy Voltage drop	P.25-44	
		120	H1	Measuring of Electrical Circuit	Measuring of voltage and current Check the voltage drop		
		60	L4	Solar Energy	Irradiance, Insolation, Peak sun hours Tilt angle, affect of shading		
2nd	Lecture & Hands-on	20		Review of previous day's lesson			Room
		140	L5	PV module & I-V Curve	Type, I-V curve, Output, Bypass diodes and blocking diodes, Effect of shadow	P.55-78	
		100	L6	Battery	Type, Profile of battery voltage, Indicator of state of charge, Specific gravity, Maintenance	P.79-104	
		100	L7	Charge Controller	Function, Type, Status of C/C, Set point voltage, Connecting sequence, Additional function	P.105-115	
		10	L8	DC Light, Inverter	Characteristic, specification	P.116-119	
		5	L9	Inverter	Characteristic, specification	P.120-123	
		5	L10	Maintenance	General maintenance	P.124-125	
		80	H2	Function check of C/C	Confirmation of switching operation		
3rd	Lecture & Hands-on	20		Review of previous day's lesson			Room
		160	L11	Inspection & Monitoring	Inspected & Approved, System parameters Measurement instrument, System status	P.126-153	
		120	L12	Troubleshooting	Common trouble in a PV system, Troubleshooting Procedures, Case study of troubleshooting	P.154-172	
		40	L13	Procurement	Battery, PV module, Inverter etc.	P.173-184	
		120	L14	User Training	Technician training for BCS & SHS User training for BCS & SHS		
4th	Hands-on	300	H3	Monitoring of existing system	How to check PV system, How to arrange data, How to analyze monitoring data		Site
		120	H4	Performance check of PV module	Measuring of Isc and Voc of PV module		
5th	Lecture & Review	100	L15	Design of centralized PV system			Room
		200	R1	Summarization and review of Training	Group activity, Summarize the results of hands-on training and lecture		
		60	R2	Presentation of training results	Present the training results by group or personal		
		100	R3	Q & A, Free discussion	Q & A on overall PV training		
6th	Examination	30		Explanation of examination			Room
		180	T1	Examination			
		15		Closing			

Standard Training Curriculum for PV Engineer

Date	Type of Training	min.		Subject	Syllabus	Text page	Place
1st	Lecture & Hands-on	30		Introduction	Purpose of training, Contents of training, Notice, Self-introduction		Room
		120	T1	Confirmation test	Check knowledge level of participants before training		
		50	L1	Basic of solar PV system	Type of solar PV system, Case example Introduction of PV systems introduced at BEP	P.1-16	
		20	L2	Safety	R1sk assessment, Hazard Safety management	P.17-24	
		150	L3	Basic of Electricity	Electrical term, Electrical law, Power & Energy Voltage drop	P.25-44	
		90	H1	Measuring of Electrical Circuit	Measuring of voltage and current Check the voltage drop		
2nd	Lecture & Hands-on	20		Review of previous day's lesson			Room
		60	L4	Solar Energy	Irradiance, Insolation, Peak sun hours Tilt angle, affect of shading	P.45-54	
		100	L5	PV module & I-V Curve	Type, I-V curve, Output, Bypass diodes and blocking diodes, Effect of shadow	P.55-78	
		100	L6	Battery	Type, Profile of battery voltage, Indicator of state of charge, Specific gravity, Maintenance	P.79-104	
		100	L7	Charge Controller	Function, Type, Status of C/C, Set point voltage, Connecting sequence, Additional function	P.105-115	
		80	H2	Function check of C/C	Confirmation of switching operation		
3rd	Lecture & Hands-on	20		Review of previous day's lesson			Room
		15	L8	DC Light	Characteristic, specification	P.116-119	
		15	L9	Inverter	Characteristic, specification	P.120-123	
		10	L10	Maintenance	General maintenance	P.124-125	
		200	L11	Inspection & Monitoring	Inspected & Approved, System parameters Measurement instrument, System status	P.126-153	
		150	L12	Troubleshooting	Common trouble in a PV system, Troubleshooting Procedures, Case study of troubleshooting	P.154-172	
		50	L13	Procurement	Battery, PV module, Inverter etc.	P.173-184	
5th	Lecture & Review	20		Review of previous day's lesson			Room
		120	T2	Confirmation test	Check the level of understanding after training		
		120	R1	Review of confirmation test	Answer & Question		
		180	L14	User Training	Technician training for BCS & SHS User training for BCS & SHS		
		20		Explanation of Hands-on Training			
4th	Hands-on	300	H3	Monitoring of existing system	How to check PV system, How to arrange data, How to analyze monitoring data		Site
		120	H4	Performance check of PV module	Measuring of Isc and Voc of PV module		
6th	Examination	120	R1	Summarization and review of Training	Group activity, Summarize the results of hands-on training and lecture		Room
		60	R2	Presentation of training results	Present the training results by group or personal		
		45	R3	Q & A, Free discussion			
		15		Closing			

ANNEX 3　: Solar PV Technology Training Text

ANNEX 3

DOE-JICA Project

Rural Electrification Project

For

Sustainability Improvement of Renewable Energy Development

In Village Electrification

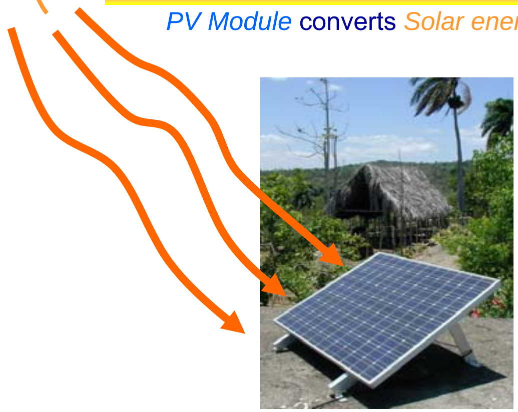
Solar PV Technology Training Text

Basics of Solar PV System

- Features of Solar PV System
- Components of system
- Type of System
  - SHS, BCS, Centralized PV
- General output power

Electricity from Solar Energy

PV Module converts *Solar energy* into *Electricity(DC)*



- Less *Solar Energy*
  Less *Electricity*
- More *Solar Energy*
  More *Electricity*

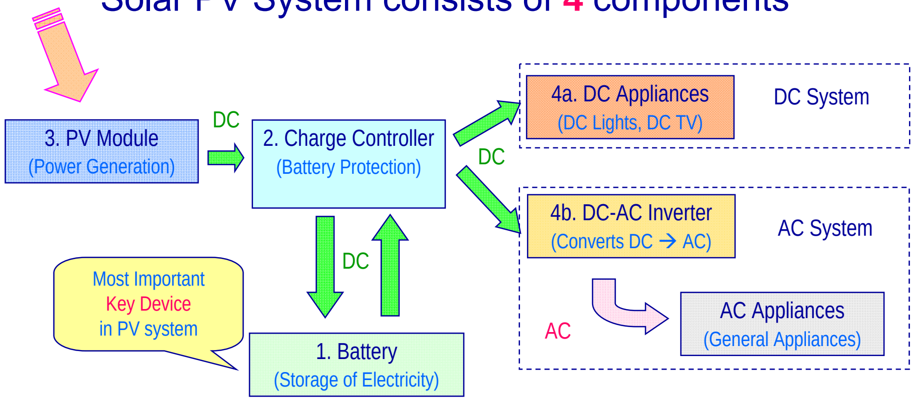
Power generation changes daily

Solar Energy → *PV Module* → *Electricity* (DC)

Input *Conversion* *Output*

Solar PV System

Solar PV System consists of 4 components



Basic Components

- PV Module
  - PV Module converts Solar energy into Electricity
  - Power generation is during daytime only
  - Long life for 20 years
- Battery
  - Battery stores electricity
  - Mainly used during night time
  - Easily damaged if over discharged
- Charge Controller
  - Charge controller protects battery from over charge and over discharge
- DC-AC Inverter
  - Inverter converts DC to AC
  - Not necessary for DC system
  - AC system is more convenient for users, but less efficiency.
- DC Light
  - DC fluorescent light (built-in inverter) is used for DC system

Features of Solar PV system

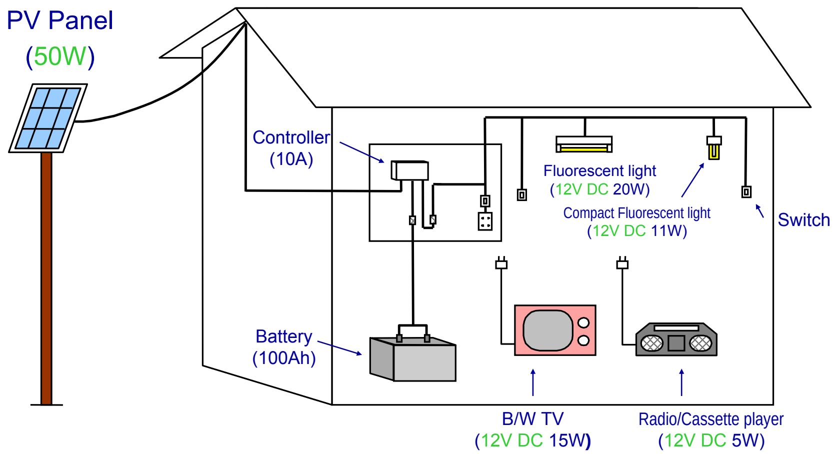
- Clean
  - No exhaust gas
- No mechanical moving parts
  - Quiet
  - Less maintenance work
- Fuel supply is not necessary
  - Very low running cost
- Last resort to supply electricity
  - Can be installed where no other energy sources are available
- Expensive and limited power supply
  - Small appliances use only
- Battery problems
  - Most users/operators fail to maintain batteries
  - Most users abandon systems when the end of battery life

Site selection

- No other potential sources
  - No hydro potential, No wind potential
  - Solar PV system is the last resort where no other energy sources are available
- Far away from Grid
  - Difficult areas to supply fuels during rain season
- Need open space
  - No tall trees
  - No shadows between 8am till 4pm
- Target group is mid-rich income level group
  - Make sure users can afford to replace battery every 2 – 3 years
  - Not recommended for low income group. They can NOT maintain the systems.
    → Requires lots of subsidies to maintain systems.
    → Systems are easily abandoned even a minor fault due to critical cash flow.
  - Not recommended to use electricity from PV system for livelihood activities.
    Electricity from PV system is expensive and electricity do not generate income.
    If electricity could generate income, no poor people exist in energized areas.

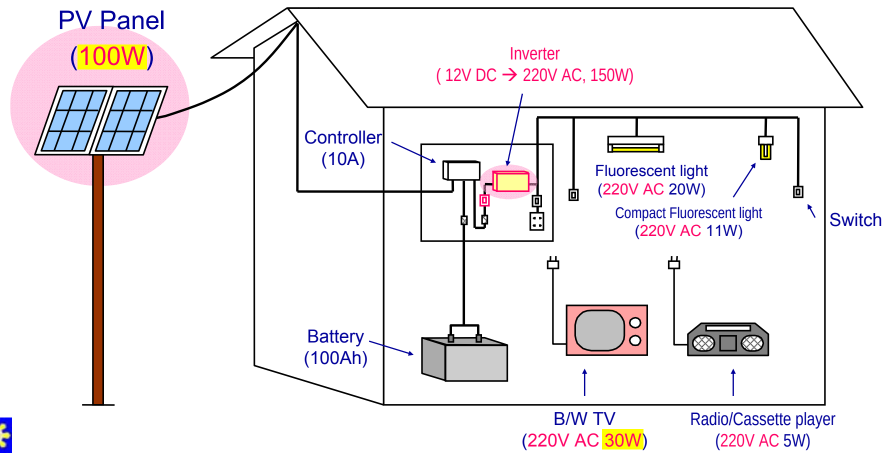
SHS (Solar Home System)

- SHS is Small, independent DC system
- Most efficient and economical system
- DC Fluorescent Lights are not easily available in local market



SHS (AC)

- AC system is convenient for users because of easy availability of appliances
- Less efficient and higher cost than DC system



BCS (Battery Charging Station)

- Users share PV modules
- One station can charge one battery in a day.
- Users have to carry heavy batteries to the BCS.
  - Heavy labor for women and children
- Available power per day is smaller than SHS
- Short battery life compare to SHS
  - Batteries are easily over discharged at user's houses
  - Long term cost is higher than SHS

PV Array (300Wp)

Battery (70Ah)

Charging schedule

Max. Number of Users are limited by Charging Interval + Spare day

Ex. Charging once / 7 days + 2 spare day = 5 users

Ex. Charging once / 10 days + 1 spare day = 9 users

Available power / day becomes less if charging interval is increased

Charged power = 64 Ah (300Wp BCS, (300Wp x 0.8 x 4h / 12V) x 0.8 = 64Ah)

Available power/day = 64 Ah / 7 days = 9.1 Ah (2 light for 6.0 hour per day)

Available power/day = 64 Ah / 10 days = 6.4 Ah (2 light for 4.5 hour per day)

Charging schedule

Mon	Tue	Wed	Thu	Fri	Sat	Sun
A	B	Spare	C	D	E	Spare

Schedule shift to spare days

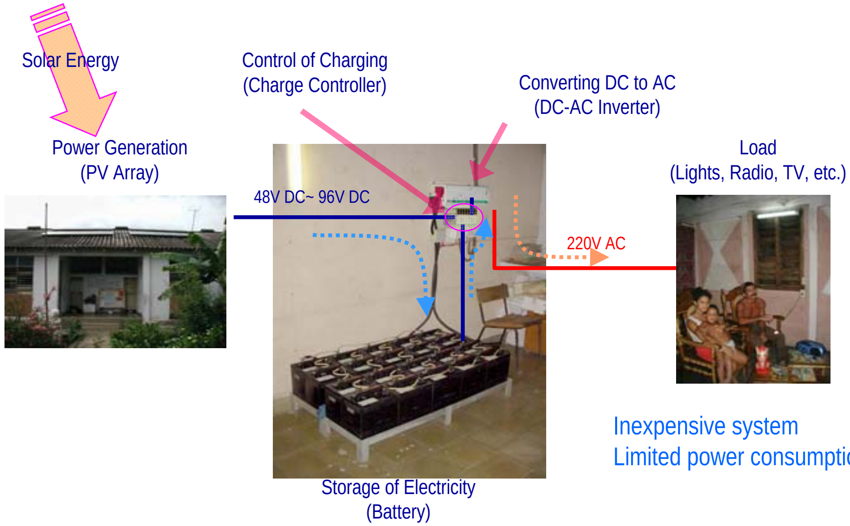
Cloudy day (Tue) — Cloudy day (Fri)

Mon	Tue	Wed	Thu	Fri	Sat	Sun
A	B	B	C	D	E	D

Cost and Power of BCS

	No. of PV	No. of users	Cost per user	Power per user (Peak hours=4)	Cost per Power
SHS	50Wp	÷	= $1.00	10.7Ah 1.00	(1.00)
BCS	150Wp	÷ (Charging interval : 7 days)	= $1.10	32Ah / 7 = 4.5Ah 0.42	(2.62)
		÷ (Charging interval : 7 days)	= $0.55	32Ah / 7 = 4.5Ah 0.42	(1.31)
	300Wp	÷ (Charging interval : 7 days)	= $1.10	64Ah / 7 = 9.1Ah 0.85	(1.29)
	300Wp	÷ (Charging interval : 10 days)	= $0.66	64Ah / 10 = 6.4Ah 0.60	(1.10)

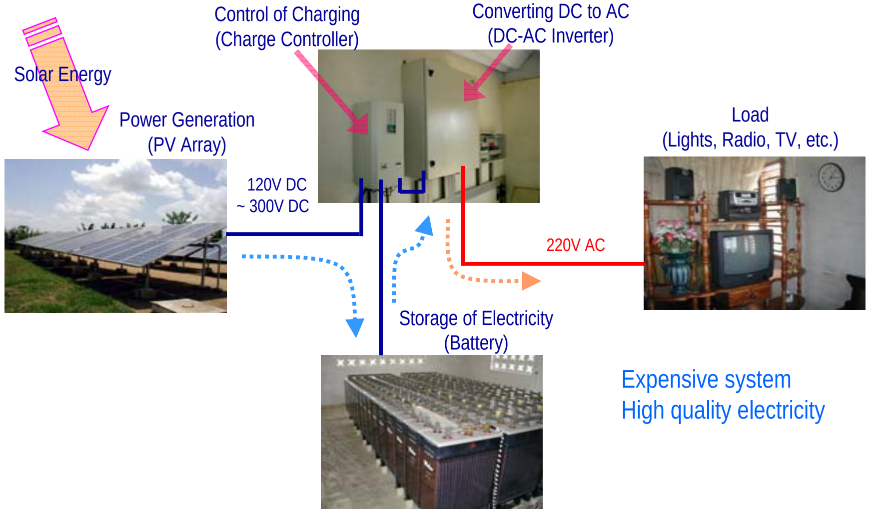
Mini Centralized System (~ 5kW)



Inexpensive system

Limited power consumption

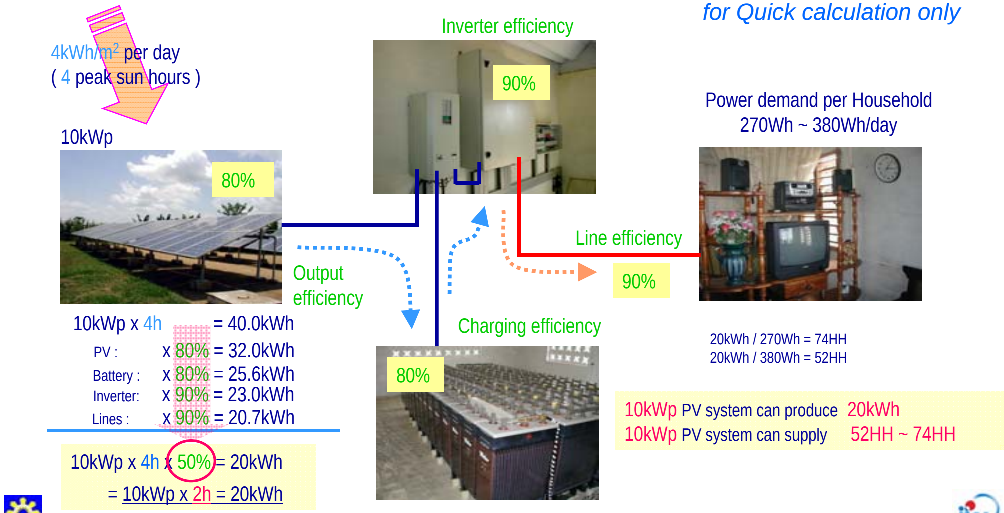
Centralized System (10kW ~)



Expensive system
High quality electricity

Available Power

for Quick calculation only

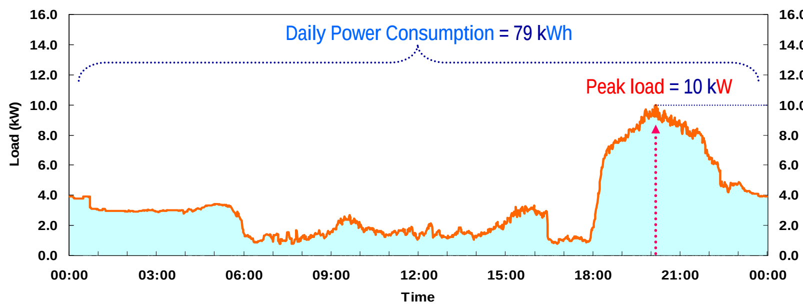


Peak Load and Daily Power Consumption

- ✶ Peak Load is a maximum load power (W)
  → Limited by Inverter Capacity
- ✶ Daily Power Consumption is a total energy that is consumed in one day (Wh)
  → Limited by PV array capacity (Daily Power Generation)

Peak Load does not mean Power Consumption

Power Generation > Power Consumption



Available Power

- ✶ Installed Capacity does NOT mean available power
- ✶ Available no. of households are limited by
  Peak Load for Non-battery system (Diesel and Micro-Hydro)
- ✶ Available no. of households are limited by
  both Peak Load and Daily Consumption for Battery-based system
  (Solar PV and Wind)

Type of Power Source	(a) Installed Capacity	(b) Duration of energy source (h)	(c) Performance Ratio	(d) Power Factor	a x b x c (x d) Available power (kWh)	Available households: by Daily consumption (380Wh/hh)	Available households: at Peak load (50Wh/h)	Available households: Maximum
Diesel Generator	10 kVA	5	0.8	0.7	28.0	73	140	140
Micro-Hydro	10 kVA	24	0.5	0.7	84.0	221	140	140
Solar PV *	10 kWp	4	0.5	0.7	20.0	52	140	52
Wind *	10 kW	24	0.2	0.7	48.0	126	140	126

*: with 10kVA inverter

Exercise

Safety

★ Risk Assessment

- There is a scorpion under every stone.
- It is recommended that a risk assessment is conducted before starting any on-site work.

★ Hazard

- Physical Hazard
- Electrical Hazard
- Chemical Hazard

★ Safety Management

- On the basis of risk assessment, it is recommended that safety measures are devised.

Risk Assessment

Risk assessment process

1. Identification of all possible risks
2. Study on the measures to remove the risk or to minimize the risk if it can not be removed
3. Assessment of the risk exposure
4. Reflection to on-site work

[Example]

In the cable replacement
*Electrical shock *Cuts
*Falling from ladder *Insects

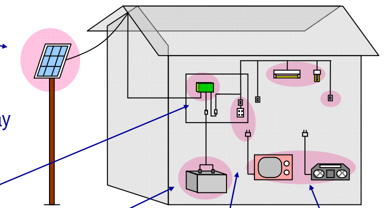
<Electrical shock>
1) Check voltage before work
2) Wear gloves
3) Use insulated tools
4) Don't work with wet hands
5) Work without power source

To keep items 1), 3), 4) and 5) can reduce the risks.

Preparation of insulated tools
Inform workers about precautions

Risk Assessment

What risks are there in on-site work?



1. PV
- Electrical shock
- Fire
- Fall of PV module
- Destruction of PV array
- Cut and bump

2. C/C, Inverter
- Electrical shock
- Fire

3. Battery
- Electrical shock
- Fire
- Chemical burns
- Explosion

4. Cables
- Electrical shock
- Fire
- Cut

5. Appliances
- Electrical shock
- Fall
- Burns

6. On-site work
- Electrical shock
- Falling from roof & ladder
- Cuts and Bumps
- Fire
- Chemical burns
- Insects, Snakes etc.

Hazard

(Physical Hazard)

★ Exposure

- Sun damage → *Wear a hat and long-sleeved clothes*
- Symptom of dehydration → *Drink plenty of fluids, never alcohol*
- Heat stroke → *Take regular breaks in the shade*

★ Injury

- Falling from roof or ladder
  → *Wear comfortable shoes,*
  → *Have a partner to hold the ladder and assist with handling equipment*
- Cut finger with sharp edge of metal and metal slivers → Wear gloves
- Bump head on the low beams and PV frame → Wear a safety helmet
- Back strain by lifting and carrying heavy equipment
- Burn caused by contacting hot metal.

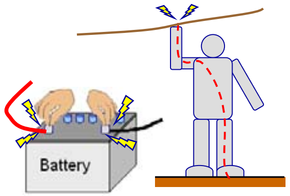
★ Insects, Snakes

- Spiders and insects often move in and inhabit junction boxes and other enclosures.

Hazard
(Electrical Hazard)

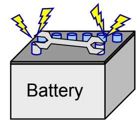
- Electrical shock
  - The human body acts like a resistor and allows current to pass.
  - The value of resistance varies with condition. (Wet: 1,000 Ω – Dry: 100,000 Ω)
  - The amount of current that will flow is determined by Voltage and Resistance in the current pass.
  - Current greater than 20mA may give a serious damage to the body.
    → *Always check the voltage between any conductor and any other wires, and to ground.*
    → *Do not touch conductive part by wet hand*

Current [1s contact]	Physiological Effect	Voltage required to produce the current	
		100,000 Ω	1,000 Ω
1 mA	Threshold of feeling, tingling sensation (No pain)	100V	1V
5 mA	Accepted as maximum harmless current	500V	5V
10 – 20 mA	Beginning of sustained muscular contraction	1000V	10V
100-300mA	Ventricular fibrillation, fatal if continued.	10000V	100V

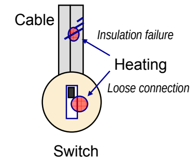


Hazard
(Electrical Hazard)

- Electrical sparks and burns
  - Electric sparks are caused by short circuit, and it can lead to fire.
    Especially, short circuit of battery is extremely hazard.
    It may give a serious damage to person and PV system.
    → *Use insulated tools (spanners etc).*
    → *Put covers over the battery terminals.*
    → *Install fuse.*

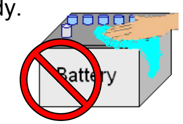


  - Loose connection increases resistance at the connecting part.
    The connecting part becomes the heating element and can cause a fire.
    → Check contact and voltage drop at the connecting part.
    → Tighten up screw and clean up contact.
  - Insulation failure can cause electric leak and short circuit.
    → Check cable and terminal block periodically.



Hazard
(Chemical Hazard)

- Chemical burns by acid
  - The lead-acid type battery uses sulfuric acid as the electrolyte.
  - Sulfuric acid is extremely hazardous. Chemical burns will occur if the acid makes contact with an unprotected part of the body.
    → *Wear non-absorbent gloves and protective glasses.*
    → Wash out with plenty of water in case of contact.



- Gas explosion
  - Most battery releases hydrogen gas as a result of the charging process.
  - Hydrogen is flammable gas and has an explosion hazard.
    → *The battery should be installed in a well-ventilated area.*
    → *All flames and equipment that could create a spark should be kept away from the battery.*

Safety Management

- Clothes
  - Wear proper clothes for on-site work and ambient environment.
    (Long-sleeved clothes, Hat, Shoes etc.)
- Safety Equipment
  - Prepare safety equipment.
    (Gloves, Protective glasses, Safety helmet, Appropriate ladder, insulated tools, Proper measuring equipment etc.)
- Work plan
  - Check specification and diagram of PV system
  - Make work plan which reflect results of the risk assessment.
  - Inform the workers about work plan in advance.
- Work at site
  - Confirm risks and safety measures before starting work.
  - Conduct work complying with work plan.

Basics of Electricity

- Basic elements of electricity
  - Voltage, Current, Resistance, Power, AC and DC
  - Parallel and Series connection
- Calculation
  - Ohm's Law
  - Power Law
- Wattage and Watt hour
- Daily power consumption and Peak load

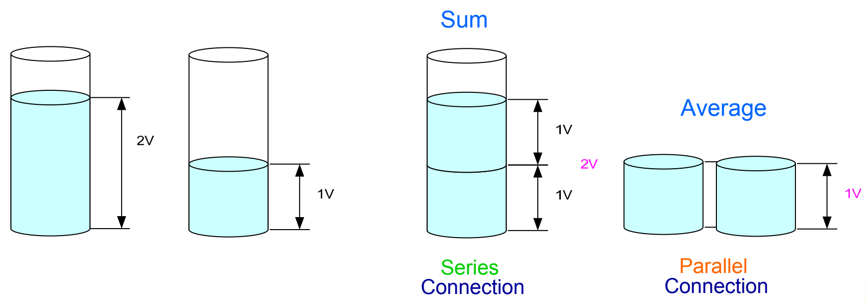
Voltage

Voltage is the degree of strengths of electricity.

AC mains uses 220V and SHS uses 12V.

The symbol is V. The unit is V (volt).

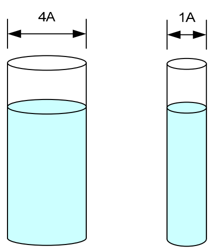
Series connection sums voltage, Parallel connection averages voltage.



Current

Current is the quantity of electricity flowing inside wires.

The symbol is I. The unit is A (ampere)

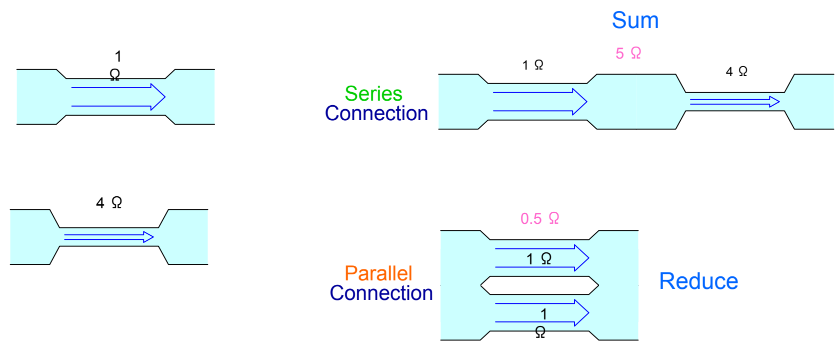


Resistance

Resistance is the degree of difficulty of current flow in a wire.

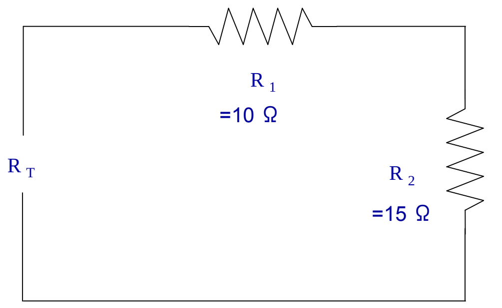
The symbol is R. The unit is Ω (ohm).

Series connection sums resistance, Parallel connection reduces resistance



Resistance

Series Connection



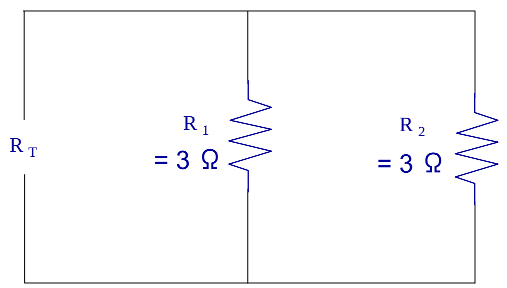
$R_T = R_1 + R_2$

$= 10\ \Omega + 15\ \Omega$

$= 25\ \Omega$

Resistance

Parallel Connection



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_T} = \frac{1}{3\,\Omega} + \frac{1}{3\,\Omega}$$

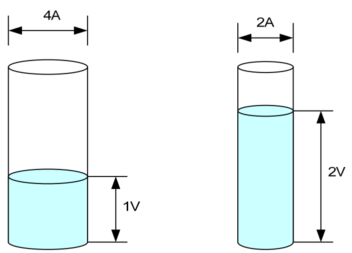
$$\frac{1}{R_T} = \frac{2}{3\,\Omega}$$

$$R_T = 1.5\ \Omega$$

Power

Power is derived from voltage multiplied by current.

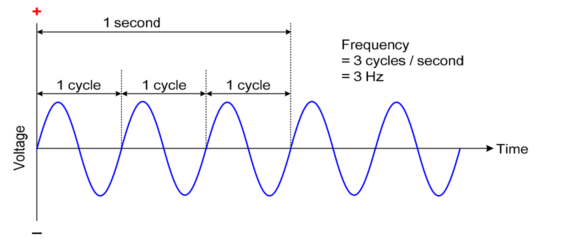
The symbol is P. The unit is W (watt).



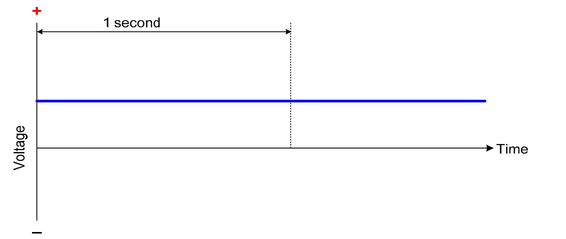
P = V x I　　1V x 4A = 4W　　2V x 2A = 4W

AC and DC

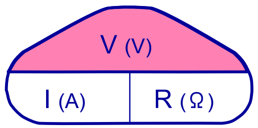
Alternative Current
Polarity changes
(No Polarity)



Direct Current
Fixed Polarity

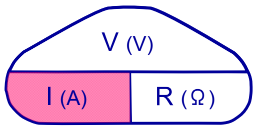


Ohm's Law



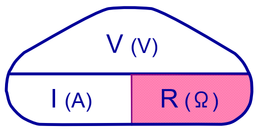
V = I x R

2.0 A x 0.1 Ω = 0.2 V
20.0 A x 0.1 Ω = 2.0 V



I = V / R

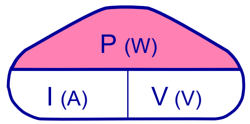
12.0 V / 2.0 Ω = 6.0 A



R = V / I

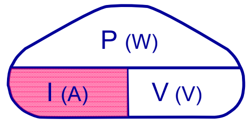
12.0 V / 1.0 A = 12.0 Ω

Power Law



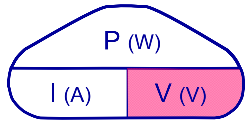
P = I x V

5.0 A x 12.0 V = 60.0 W



I = P / V

240.0 W / 12.0 V = 20.0 A
240.0 W / 120.0 V = 2.0 A



V = P / I

110.0 W / 0.5 A = 220.0 V

Kirchhoff's Law 1 (Current Law)

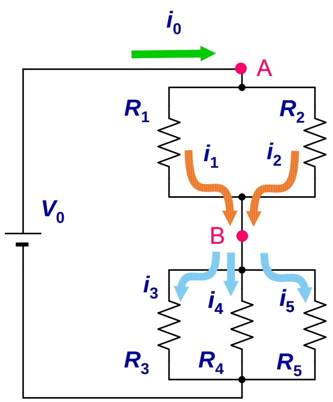
- The algebraic sum of all the currents meeting at a point is zero.

i_0 – $(i_1 + i_2)$ =0 — **Point A**
incoming outgoing

$(i_1 + i_2)$ – $(i_3 + i_4 + i_5) = 0$ — **Point B**
incoming outgoing

In other words,
The sum of incoming currents
is equal to
the sum of outgoing currents.

$i_0 = i_1 + i_2 = i_3 + i_4 + i_5$



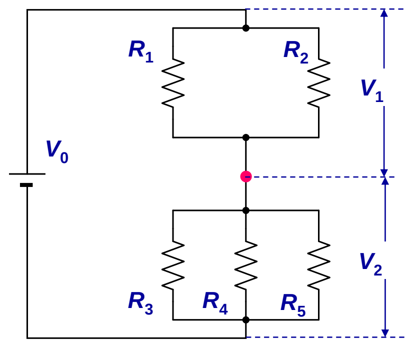
Kirchhoff's Law 2 (Voltage Law)

- The algebraic sum of voltage drops in any closed path in a circuit and the electromotive force in that path is equal to zero.

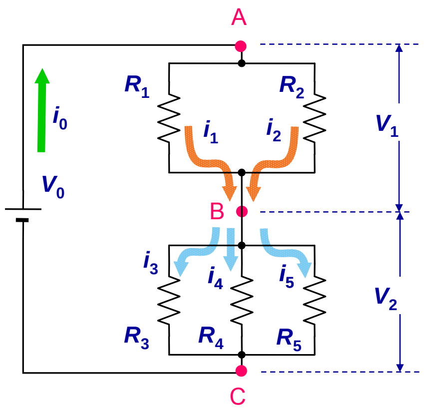
(V_0) – $(V_1 + V_2) = 0$
Source Voltage drops

In other words,
The sum of voltage drops
is equal to
the voltage source

$V_0 = V_1 + V_2$



Use of Kirchhoff's Law



Equations:

$i_1 + i_2 = i_3 + i_4 + i_5$ (Current Law)

$V_1 + V_2 = V_0$ (Voltage Law)

Known parameters:

$R_1, R_2 \dots R_5 = 1\ \Omega$, $V_0 = 10$ V

$i_1R_1 = i_2R_2 = V_1 \rightarrow i_1 = i_2$

$i_3R_3 = i_4R_4 = i_5R_5 = V_2 \rightarrow i_3 = i_4 = i_5$

$i_1 + i_1 = i_3 + i_3 + i_3 \rightarrow i_3 = 2/3\ i_1$

$V_1 + V_2 = i_1R_1 + i_3R_3 = i_1R_1 + 2/3 i_1R_1 = 10$

$5/3 i_1 = 10$, $i_1 = 30/5 = 6$

$i_1, i_2 = 6A$, $i_3, i_4, i_5 = 4A$

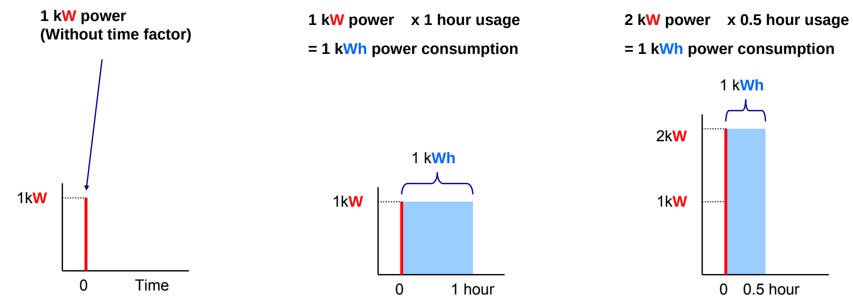
$V_1 = 6V$, $V_2 = 4V$

Exercise

Power and Energy

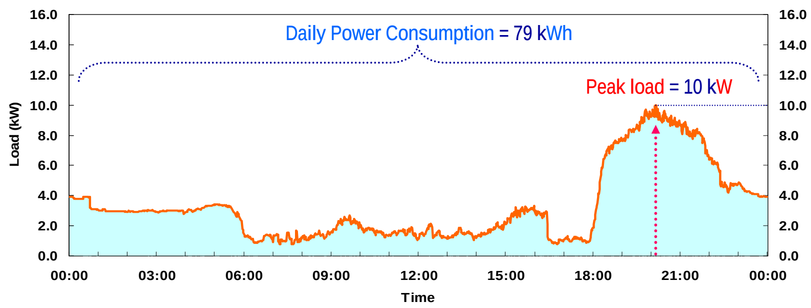
- W (Watt) is a power that indicates ability (strength) of energy.
- Wh (Watt hour) is an energy that is consumed in one hour (power consumption).
- When a 1 kW appliance is used for one hour, the energy used is 1 kWh.
- W and Wh are different unit. Don't mix their usage.
- In DC (battery) system, Ah is used.

Small letter : k , h
Capital letter : W, A
Do NOT mix.
Kw, wH, WH, wh, AH → Wrong!



Peak load and Daily Power consumption

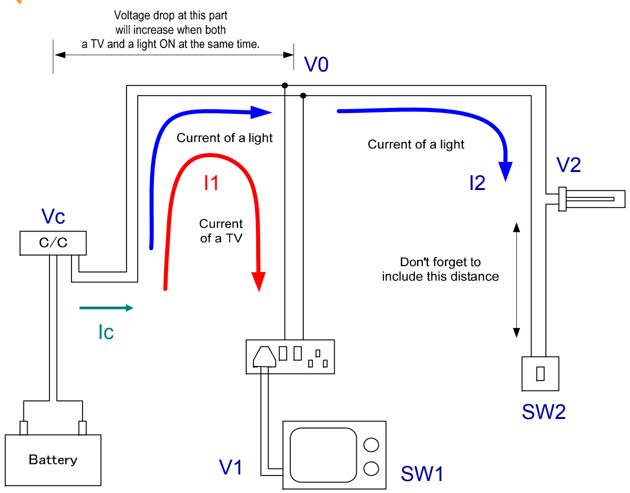
- **Peak load** is a maximum load power (**W**)
- **Daily Power consumption** is a total energy that is consumed in one day (**Wh**)
- System design must consider both
  Peak load (W) and **Daily Power consumption (Wh)**
- Capacity of **Generator** must be greater than **Peak load** (Micro hydro/Genset)
- Capacity of **DC/AC Inverter** must be greater than **Peak load** (Battery based system)



Voltage Drop

- Voltage Drop = Current x Cable Resistant
- Voltage Drop is a power loss in cable
  Current=10A, Vdrop=1V ---- 10W loss
  Current=20A, Vdrop=2V ---- 40W loss $P_{(W)} = I_{(A)} \times E_{(V)} = I^2_{(A)} \times R_{(\Omega)}$
- Cable Resistance is determined by Size and Length
- Current is determined by
  [PV capacity or Load] / [System Voltage]
  1kW / 12V = 83.3A, 1kW / 120V = 8.3A
- To reduce voltage drop
  - Use of thicker cable
  - Minimize the cable length
  - Use of higher system voltage to reduce current
- Voltage Drop is critical in low voltage system, especially 12V system

Voltage Drop depends on Current



SW1:OFF, SW2:OFF
Vc = V2 = V3 Ic = 0

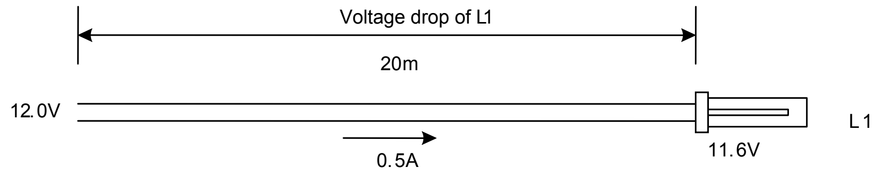
SW1:ON, SW2:OFF
Vc > V0 > V1 Ic = I1
Vc > V0 = V2

SW1:OFF, SW2:ON
Vc > V0 = V1 Ic = I2
Vc > V0 > V2

SW1:ON, SW2:ON
Vc >> V0 > V1 Ic = I1+I2
Vc >> V0 > V2

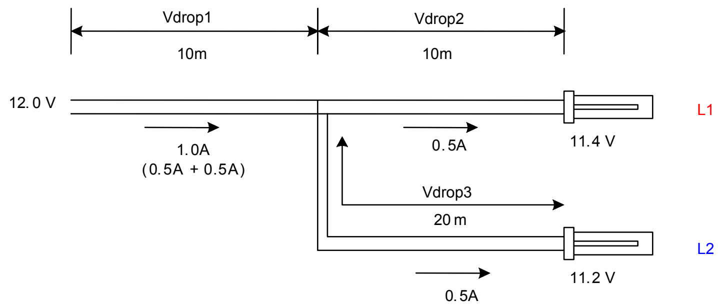
Calculation of Voltage Drop

Resistance of wire : 0.02 Ω / m *Current consumption : 0.5 A / light*



Voltage drop of L1 = I (A) x R (Ω)
= 0.5 A x (20 m x 0.02)
= 0.2 V per wire
= 0.2 V x 2
Total = 0.4 V

Calculation of Voltage Drop



Vdrop1 = 1.0 A x (10 m x 0.02 Ω) x 2 = 0.4 V
Vdrop2 = 0.5 A x (10 m x 0.02 Ω) x 2 = 0.2 V
Vdrop3 = 0.5 A x (20 m x 0.02 Ω) x 2 = 0.4 V

Voltage drop of L1 = Vdrop1 + Vdrop2
= 0.4 V + 0.2 V
= 0.6 V

Voltage drop of L2 = Vdrop1 + Vdrop3
= 0.4 V + 0.4 V
= 0.8 V

Specification of Voltage Drop

- ✶ Voltage Drop between Battery and C/C is critical
- ✶ Limitation value should be stated by V instead of % for SHS
  5% is 0.56V at 11.1V, 0.60V at 12V, 0.72V at 14.4V
  → These are critical for 12V system

Exercise

Example of 12V System

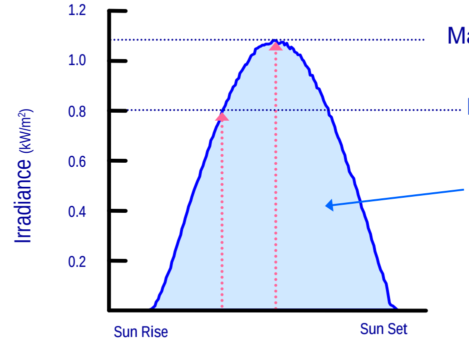
Section	Max Vdrop (V)	Remarks
PV – C/C	0.5	Larger voltage drop may cause not enough PV output voltage to charge battery
Battery – C/C	0.1	C/C controls battery voltage precisely
Load – C/C	0.5 - 1	To ensure appliances works till LVD *Ex:* LVD=11.5V, Vdrop=1V, Load=10.5V at LVD

Solar Energy

- ✶ Irradiance and Insolation
- ✶ Peak Sun hours
- ✶ Insolation pattern
- ✶ Actual insolation data
- ✶ No-Shade time

Insolation

Irradiance : Intensity of Solar energy kW/m²
Insolation : Quantity of Solar energy kWh/m²
(Irradiation)



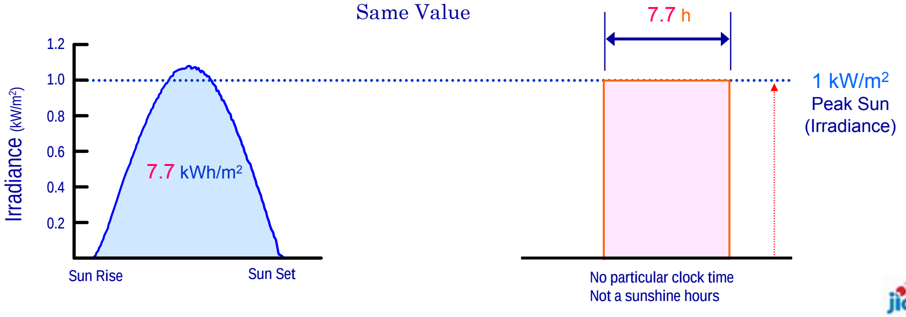
Peak Sun Hours

Peak Sun Hours is used to calculate power generation of PV modules

Insolation (kWh/m² per day) → Peak Sun Hours (hours per day at 1kW/m²)

7.7 kWh/m² → 7.7 h

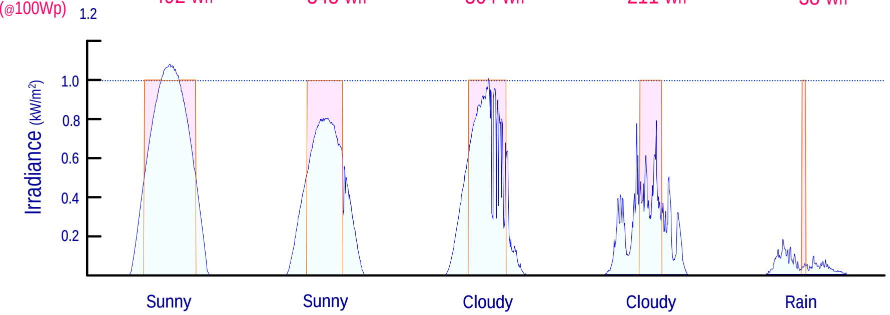
Same Value



Daily Insolation

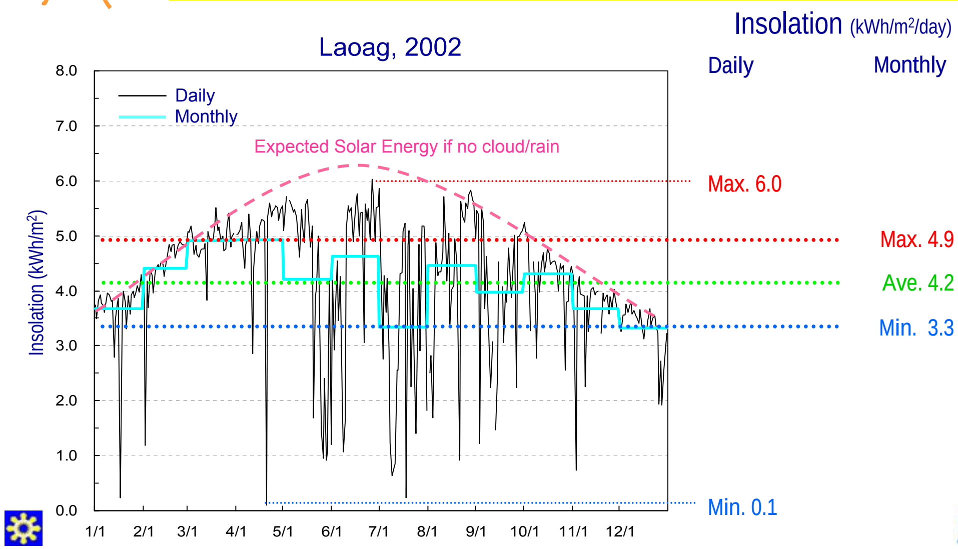
Solar Energy changes daily
→ *Power Generation changes daily*

Insolation	7.7 kWh/m²	5.4 kWh/m²	5.7 kWh/m²	3.3 kWh/m²	0.6 kWh/m²
Peak sun hours	7.7 h	5.4 h	5.7 h	3.3 h	0.6 h
Available power* (@100Wp)	492 Wh	345 Wh	364 Wh	211 Wh	38 Wh

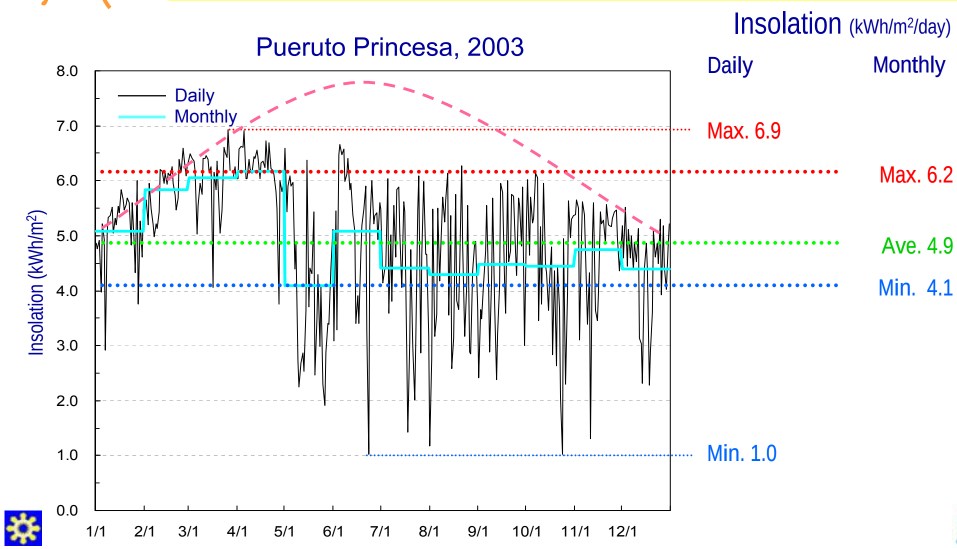


*: at 100Wp SHS (PV efficiency 80%, Battery efficiency 80%)

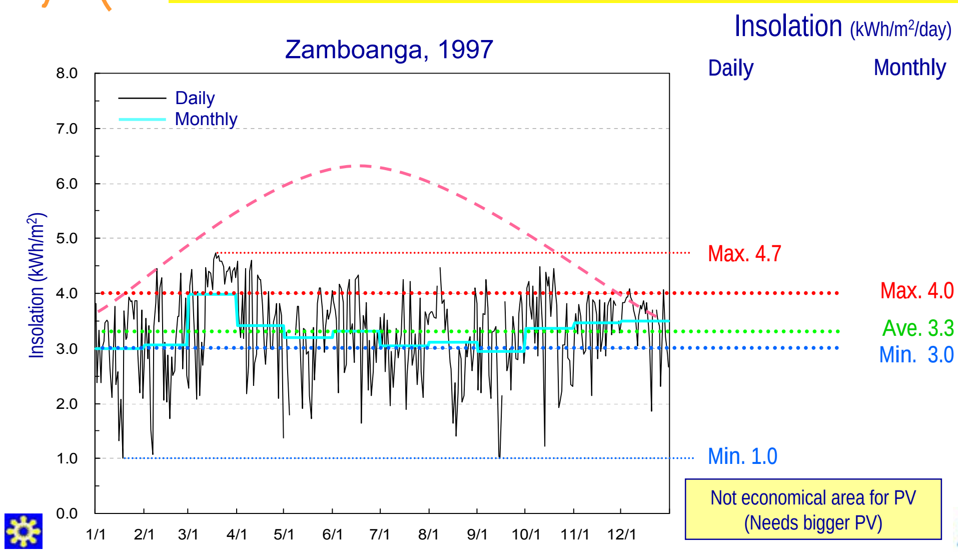
Daily Insolation (Actual data)



Daily Insolation (Actual data)



Daily Insolation (Actual data)

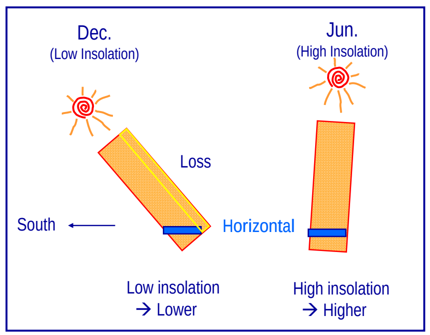


Not economical area for PV
(Needs bigger PV)

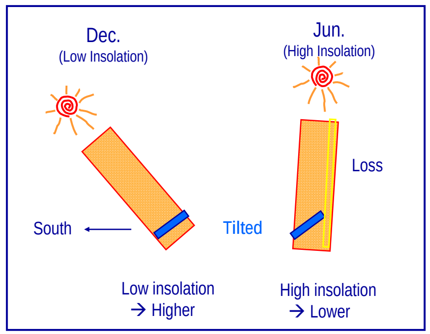
Tilt Angle

- The purpose of tilt angle
  - Optimize power generation throughout a year
- How to optimize?
  - Increase power generation at low insolation month
  - Decrease power generation at high insolation month

Minimum is 10º - 15º
to avoid dust accumulation



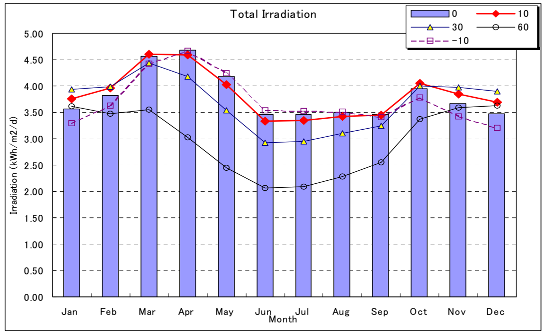
Not Optimized

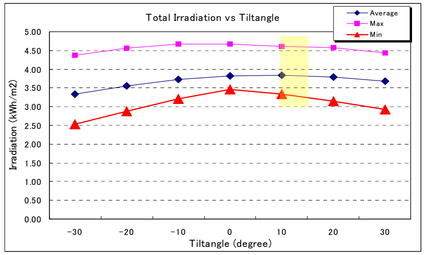


Optimized

Example of effect by various tilt angle

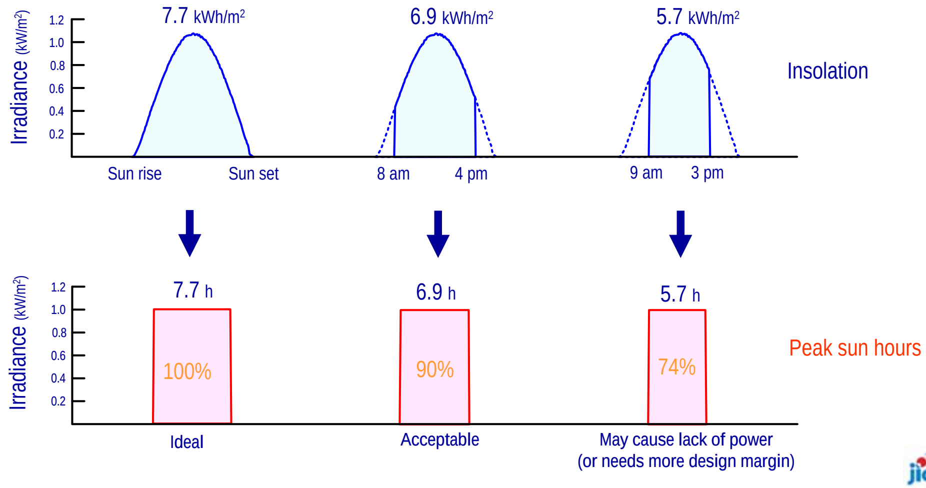
- ✶ Recommended tilt angle is 10º - 15º facing to equator in Philippines.
- ✶ Too much tilt angle reduces the energy.





Example at Cebu

No-Shade Time



PV Module

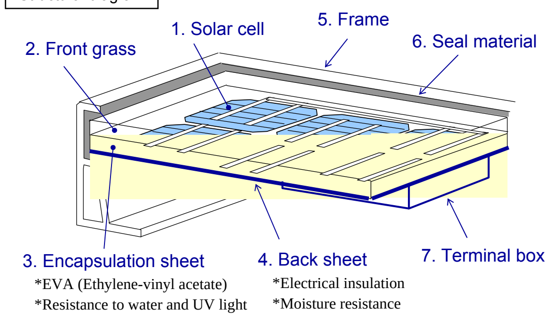
Always obtain data sheet.
No datasheet, No quality

- ✶ Role of PV module
- ✶ Type of PV module
- ✶ I-V Curve
  - – Voc, Isc, Vmp, Imp, Wp
- ✶ Output Power
- ✶ Protection Diodes

Role of PV Module

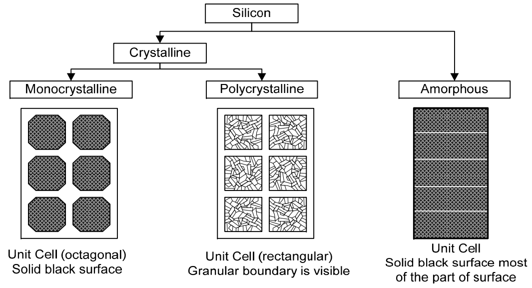
- ✶ PV module converts solar energy into electricity
- ✶ Most reliable component in solar PV system (lasts over 20 years)
- ✶ PV module consists of solar cells, front grass, frame, terminal box etc.
  - Power generation part in PV module is Solar cell.
  - Solar cell breaks easily and is sensitive to humidity.

Structural diagram



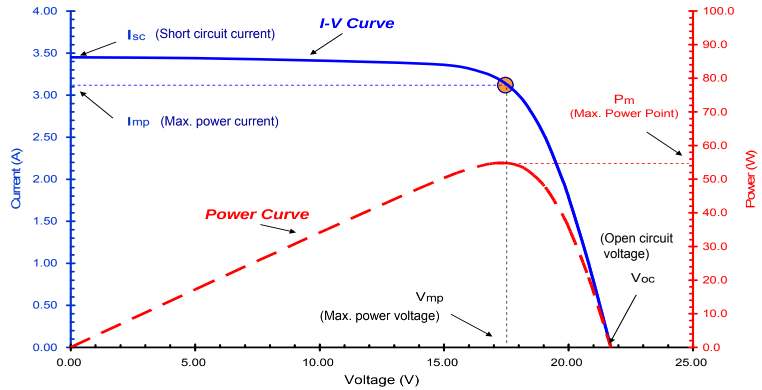
Type of PV Module

- Three types of PV module are used for power system generally.
- Crystalline type have been used and proven its reliability
- Efficiency of unit cell is not the matter of concern
  - Whatever the cell efficiency, the output of a PV module is rated as Wattage
  - Dimension of PV module is larger if low efficiency cells are used
  - Amorphous PV module is almost double of size compare to crystalline PV module
- One PV module has 36 series connected cells (for 12V system)



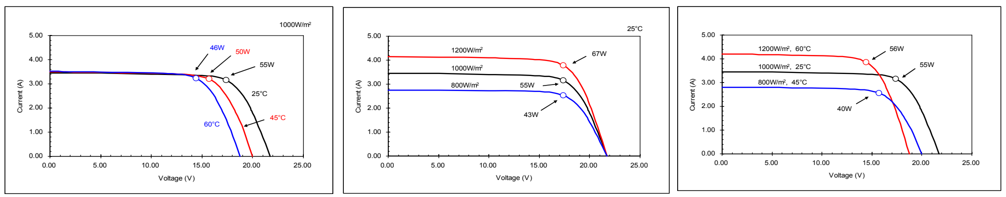
I - V Curve

- Unlike the other power generation devices, output voltage varies
- Output current depends on what output voltage is used
- Output power depends on what output voltage is used
- Max. output power (rated Wp) is available only at Vmp point under STC



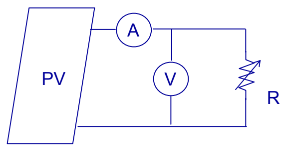
Output of PV Module

- Higher temperature reduces output voltage
  approx. – 2.2 mV / ºC per Cell
  approx. – 80 mV / ºC per 36-cell PV module
- Higher irradiance increases output current
- Rated output (Wp) does not mean actual output power at the site
  - Maximum power (P = I x V) depends on Irradiance (I) and Temperature (V)
  - Maximum power changes approx. – 0.5 % / ºC,
    100Wmp at 25 ºC → 85Wmp at 55 ºC

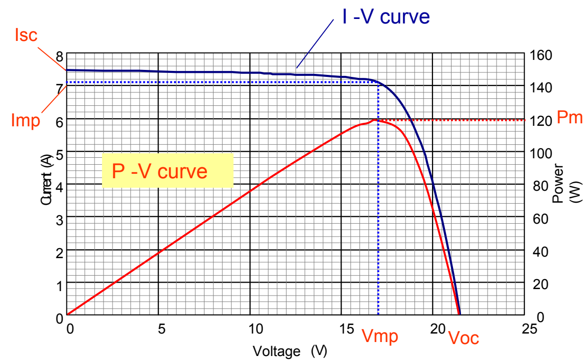


Characteristic of I-V curve

– I-V curve is the most important data for PV module



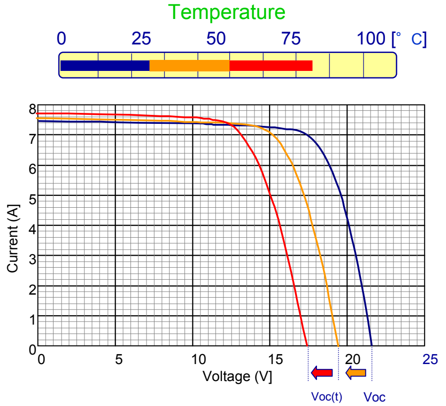
	Short				Open
R	0	→	R1	→	∞
V	0	→	Vmp	→	Voc
I	Isc	→	Imp	→	0



STC: Standard Test Conditions => AM = 1.5, t = 25° C, Irradiance = 1.0 [kW/m²]

Characteristic of I-V curve

– I-V curve changes depending on temperature



Voc(t) = Voc + α (t – 25)

α = -2.2 [mV/° C] x Number of cells

Voc(t) = ?
t = 75 ° C , 36cells, Voc = 21.7 [V]

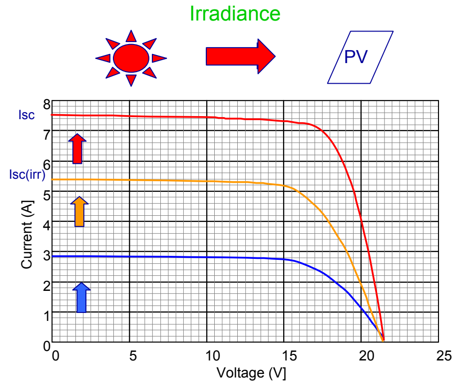
Voc(75) = Voc + α (75 – 25)

= 21.7 – 0.0022 * 36 * 50

= 17.74 [V]

Characteristic of I-V curve

– I-V curve changes depending on irradiance



Isc(irr) = Isc x irr / 1.0

(irr : irradiance [kW/m^2])

Isc : Short circuit current at STC

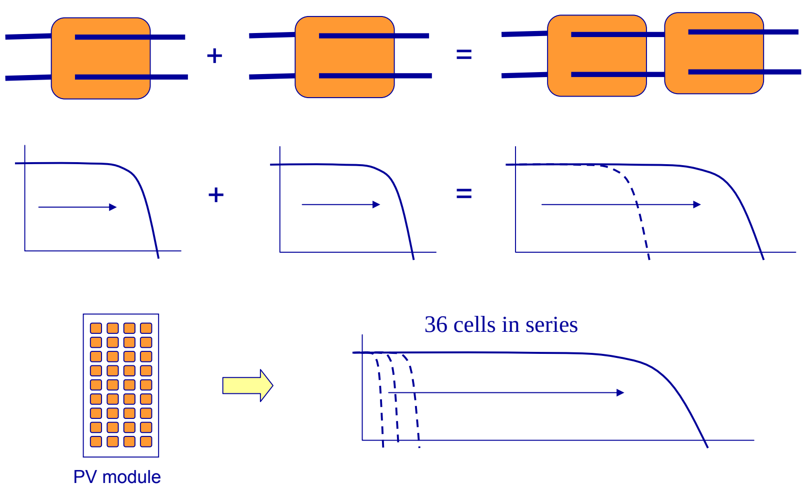
Isc(0.8) = ?
Isc = 7.5 [A], irr = 0.8 [kW/m^2]

Isc(0.8) = Isc x 0.8 / 1.0

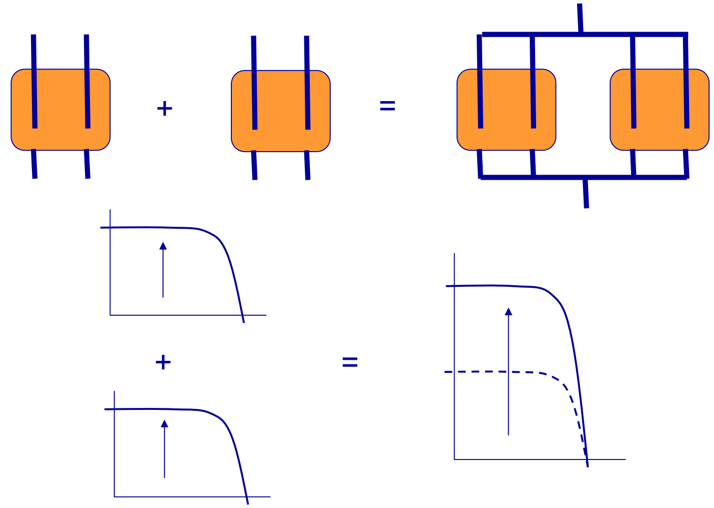
= 7.5 x 0.8

= 6.0 [A]

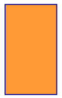
Series Connection

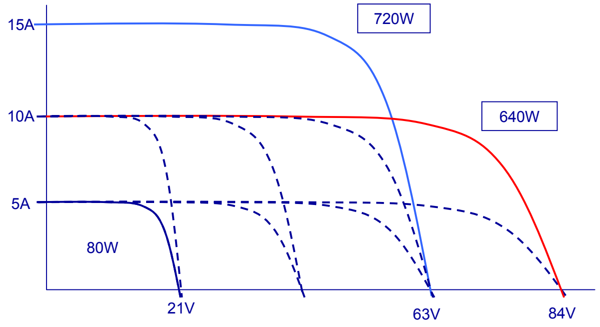


Parallel Connection



Series & Parallel Connection

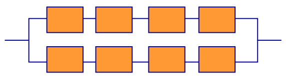


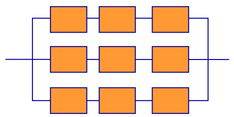


4 modules in series by 2 strings in parallel

3 modules in series by 3 strings in parallel

Circuit drawing

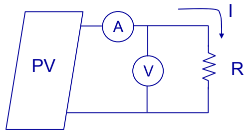


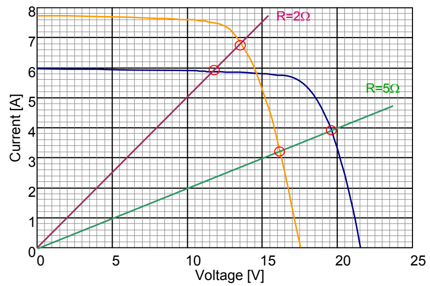


Operation point

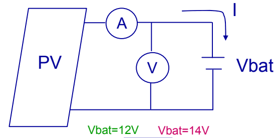
– Output voltage and current of PV module shall be on I-V curve

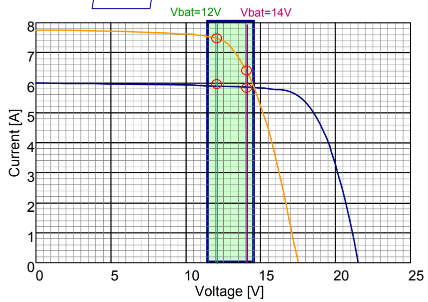
Case 1: Connection of load





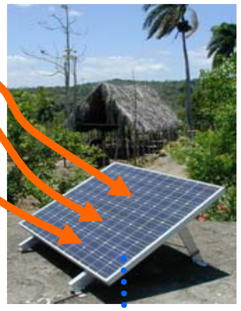
Case 2: Connection of battery





Output Power

7.7 kWh/m^2/day



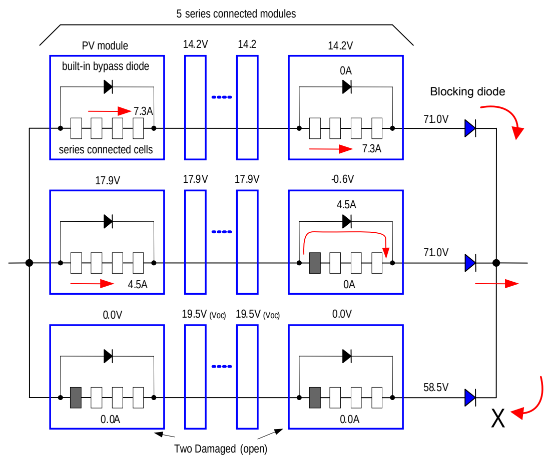
Output from PV module (DC Electricity)

Loss 20% (dust, heat, etc.)

7.7 h/day x 150W x 0.8 = 924 Wh/day

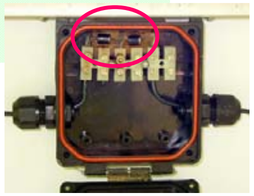
Peak Sun hours | Rated output of PV module | Output efficiency of PV module | Available PV Power

Bypass Diodes & Blocking Diodes

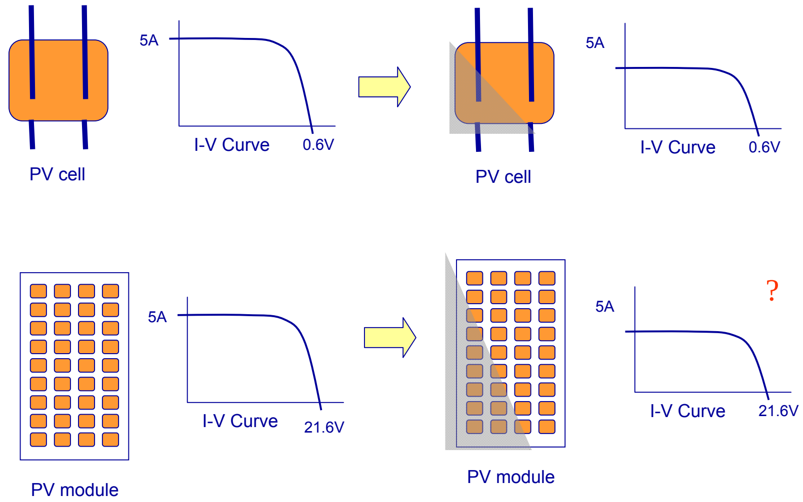


Bypass Diodes

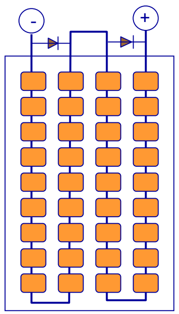
- ✶Bypass diodes are factory built-in each PV module
  - Normally 2 diodes. One per 18 cells.
  - Built-in diode is not blocking diode but bypass diode
- ✶Bypass diodes have no role at normal operation (under clean surface, no shading)
- ✶In case cell(s) have less output current such as shading, bird droppings, it will bypass the current.
- ✶In case a PV module has defective in series connection, the string may not have enough voltage to charge battery.
  - No bypass current → Bypass diodes have nothing to do.
- ✶When battery is connected in reverse, such as BCS, bypass diodes will be burned.
  - When diodes are burned, they will be shorted or opened.
  - If a diode is shorted, remove it. PV module works normally.



Effect of shadow



Effect of shadow



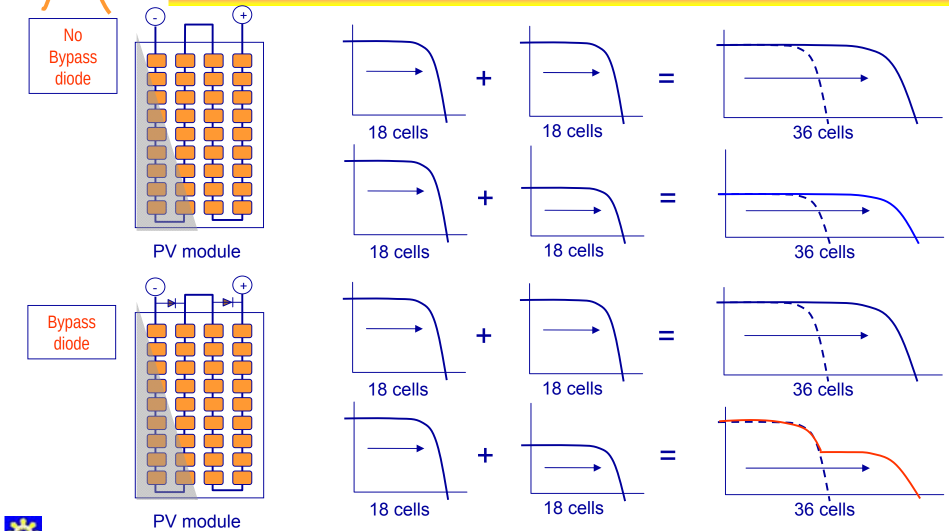
PV module

2 diodes are factory built-in each PV module

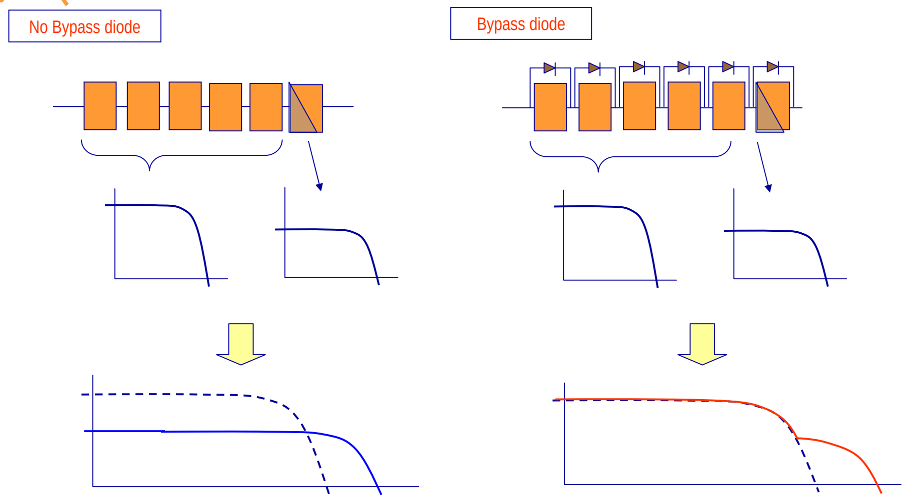
Bypass diode

- ✶Bypass diodes have no role at normal operation (under clean surface, no shading)
- ✶In case cell(s) have less output current such as shading, bird droppings, it will bypass the current.

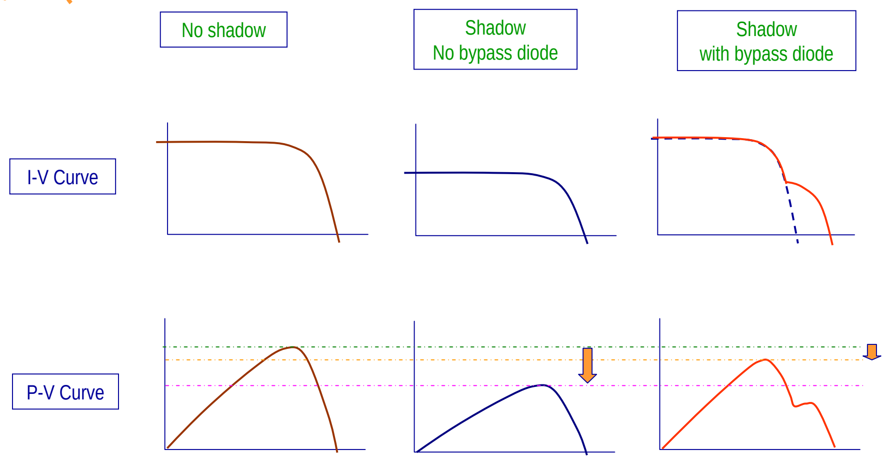
Effect of shadow



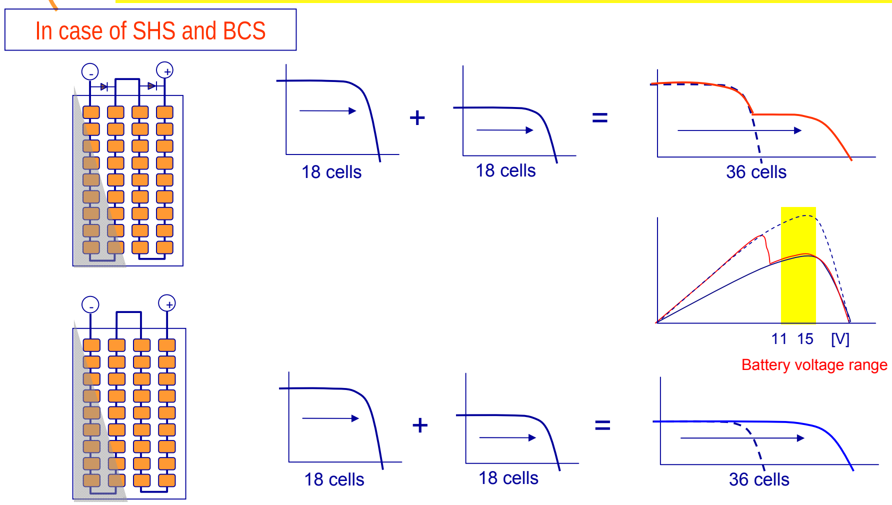
Effect of shadow



Effect of shadow

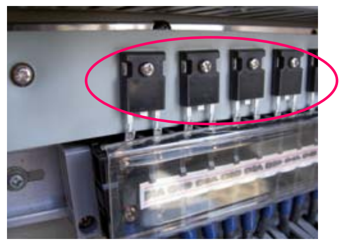


Effect of shadow



Blocking Diodes

- For Parallel connection, Blocking diodes are useful
  - Blocking diode prevents reverse current in case a string has damaged PV module.
  - Blocking diodes are not supplied with PV modules.
- There is a loss of 0.5 – 0.6V as threshold voltage of diode
  - If current is 10A, loss is 5W – 6W



Do you know?
(PV modules)

1. Mono-crystalline module has higher output power than Poly-crystalline module because of its higher efficiency.
2. PV module can generate rated power (Wp) at the site.

No!!

1. Modules are rated in Wp. As long as the same Wp are used, output power are same. If low efficient cells are used, simply the physical dimension (cell area) becomes bigger.
   - Mono-crystalline has advantage of its slightly smaller dimension of PV module
   - Poly-crystalline has advantage of its slightly lower cost.
2. The rated power is only available at Vmp under Standard Testing Condition (1kW/m², 25ºC).
   - At the site, temperature goes up around 60ºC and irradiance may vary. Roughly 80% of rated power is expected at the site around noon in sunny day.
   - In addition, operating voltage range of battery-based PV system is lower than Vmp. Therefore, rated power is not available even under STC.
   - Maximum power and Power at operation voltage are different !

OK

Do you know?
(Diodes)

1. Built-in diodes are Blocking diodes
2. Bypass diodes save series connected string in case a PV module has been damaged
3. Blocking diode is necessary at every PV module

No!!

1. Built-in diodes are Bypass diodes
   – Blocking diodes do not come with PV modules
2. If a PV module has been damaged, the whole string will not work because of lower voltage than other strings.
3. One blocking diode is enough in total series connection.

OK

Exercise

Battery

- ✶ Role of Battery
- ✶ Profile of charging and discharging
- ✶ Specific gravity, Voltage
- ✶ Charging efficiency
- ✶ Cycle life and Depth of Discharge
- ✶ Capacity
- ✶ Maintenance
  - Electrolyte : to keep Level, to prevent Stratification
  - Electrode : to prevent Sulfation
  - Cell Voltage : to keep Equal cell voltage
- ✶ Proper size
- ✶ Series and Parallel Connection

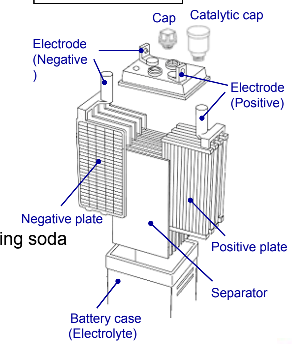
Always obtain data sheet.
No datasheet, No quality



Common Sense

- ✶ **Storage of electricity**
  - Does NOT generate electricity
- ✶ Unit cell is 2V
  - 2V means nominal voltage. Voltage range is around 1.85V to 2.40V
  - 12V battery has 6 unit cells in series connected
  - 6V battery has 3 unit cells in series connected
- ✶ Material
  - Electrode : Lead
  - Electrolyte : Diluted Sulfuric Acid
- ✶ Precautions
  - Electrolyte is high corrosive material
    - → Avoid any contact with skin, eyes, clothes
    - → Wash out with plenty of water in case of contact
  - Spilt acid does not evaporate
    - → must be neutralized with soda, if not available use baking soda
  - During charging, explosive gas will be released (Oxygen and Hydrogen)
    - → Air ventilation is necessary. No smoking!
  - Keep away from children

Structural diagram



Type of Lead-acid Batteries

HVD, LVD are example only

Forget about the terms "Deep Cycle type" and "Shallow Cycle type".
These will confuse you. The operation of solar PV system is *shallow cycle* operation.

	Automotive Type	Industrial Type
Flooded (Liquid) • Need to top up distilled water • Durable • Relatively strong against overcharge (HVD ~14.4V)	• Available • Low cost • Acceptable for small application • Limited range of capacity (~150Ah) • LVD: ~11.7V , HVD: ~14.4V	• Available • Durable • Wide range of capacity (~2000Ah, 2V unit) • LVD: ~11.5V , HVD: ~14.4V
Maintenance free (Liquid) • Easy to handle • Weak against over charge • Need to use lower HVD than flooded type (~14.1V) • No boost charging • Limited range of capacity (~150Ah)	• Available • Acceptable for small application • Good for maintenance free system • Need good charge controller to avoid overcharge • LVD: ~11.7V , HVD: ~14.1V	• Available • Recommended for small application • Good for maintenance free system • Need good charge controller to avoid overcharge • LVD: ~11.5V , HVD: ~14.1V
Maintenance free (Gel) • Sealed • Easy to handle • Weak against over charge • Need to use lower HVD than flooded type (~14.1V) • No boost charging • Limited range of capacity (~150Ah)	N/A	• Available • Recommended for small application • Good for maintenance free system • Need good charge controller to avoid overcharge • LVD: ~11.5V, HVD: ~14.1V

Battery

- Battery stores electricity
  - It does NOT generate electricity
- Most important key device for Solar PV, Wind systems
- Maintenance is very easy in theoretically because no mechanical maintenance such as lubrication, overhaul, etc.
  → Maintenance is extremely difficult in reality
- Technical maintenance

  Problem!

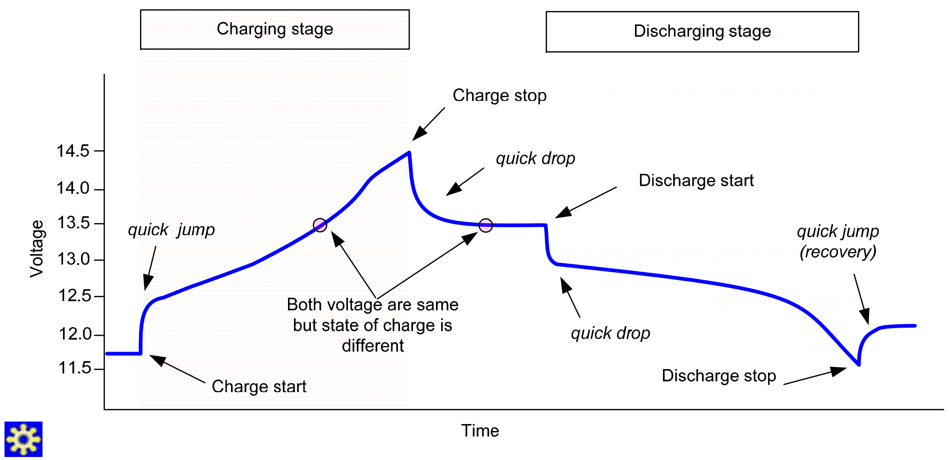
  1. Maintain electrolyte level (Topping up of distilled water)
     → Always forget. Use of unsuitable water (tap water, mineral water, well water, etc.)
  2. Maintain homogeneous electrolyte (Avoid stratification).

     Problem!
  3. Maintain healthy electrode (Avoid sulfation)
     → If no charge controller, easily over discharged because users want to use more power
  4. Maintain equal cell voltage (Periodical equalization).
     → Normally automatic by charge controller
- General maintenance
  - Maintain clean environment (Cleaning of terminals, cover, floor and air ventilation)

Most problematic device

Profile of Battery Voltage

- Voltage is always different at each stage



Indicator of State Of Charge

12.0V is relatively discharged level

Example ONLY: Values may change depends on Type and Model of Battery

State of Charge (%)	Specific Gravity (g/ml) at 20ºC	Open Circuit Voltage (V) at 25ºC (rest 24 hours)		End Voltage (V) at 25ºC	
		Cell	6 Cells	Cell	6 Cells
100	1.280	2.12	12.73	2.40	14.40
90	1.261	2.10	12.62		
80	1.241	2.08	12.50		
70	1.220	2.06	12.37		
60	1.198	2.04	12.24		
50	1.175	2.02	12.10		
40	1.151	1.99	11.96		
30	1.127	1.97	11.81		
20	1.101	1.94	11.66		
10	1.076	1.92	11.51		
0	1.051	1.89	11.35	1.85	11.10

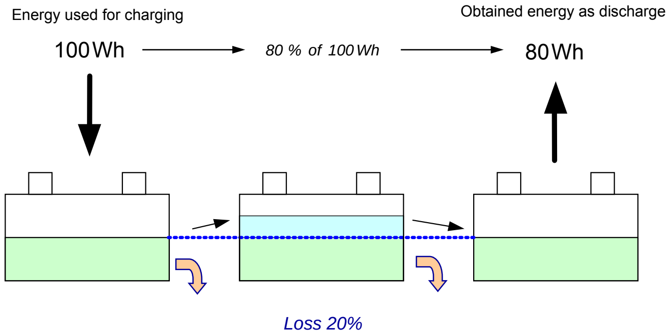
Non linear Different in Charging / Discharging

Charged 1.250

1.100 Discharged

Charging Efficiency

- Battery can store electricity
- However, there is a loss around 20%

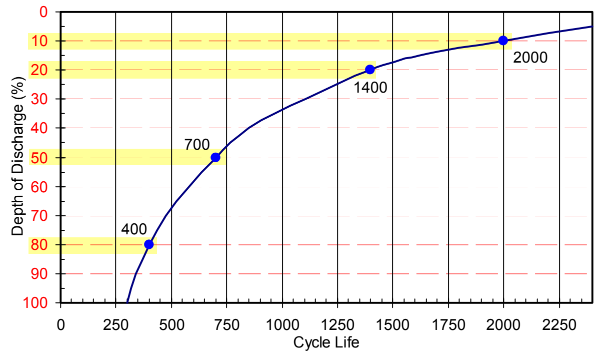


Cycle Life

- Shallow cycle operation prolong cycle life
- Higher operating temperature reduces cycle life

  Life becomes half every 10 °C higher than 20 °C

  6 years at 20 °C → 3 years at 30 °C → 1.5 years at 40 °C



Battery Capacity

- Batteries should come with data sheet
  - Always READ data sheet
  - No data sheet means substandard battery
- Capacity at each discharge rates shall be indicated
- Capacity is larger at longer discharge rate in same battery
  - Low discharge current → Longer usage hours
  - One by one load (less current) is recommended
  - Switch on many loads at same time (more current) reduces usage hours

How to read Capacity

A : 960Ah at 24h discharge rate [960Ah (C/24)]
= Can draw 40A for 24hours till voltage becomes 1.85V/cell

B : 1200Ah at 120h discharge rate [1200Ah (C/120)]
= Can draw 10A for 120hours till voltage becomes 1.85V/cell

Discharge rate *Duration of discharge (hours)*

Model No.

Final voltage *Discharge is stopped at this voltage (Empty)*

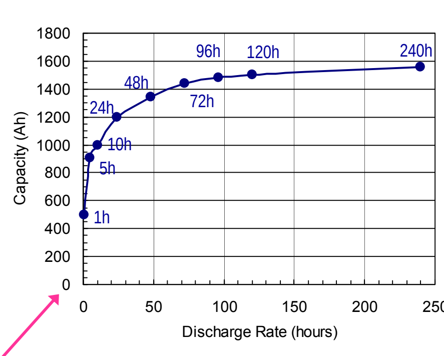
Capacity at each discharge rate *(Ah)*

Long-term discharge capacities for VARTA OPzS Batteries

Type		Capacity							final voltage
		10 h *)	24 h	48 h	72 h	96 h	120 h	240 h	V/cell
4 OPzS	200	200	240	268	288	296	300	312	
5 OPzS	250	250	300	335	360	370	375	390	
6 OPzS	300	300	360	402	432	444	450	468	
5 OPzS	350	350	420	469	504	518	525	546	
6 OPzS	420	420	504	562	604	621	630	655	
7 OPzS	490	490	588	656	705	725	735	764	1.85
6 OPzS	600	600	720	804	864	888	900	936	
8 OPzS	800	800	960	1072	1152	1184	1200	1248	
10 OPzS	1000	1000	[illegible]	1340	1440	1480	[illegible]	1560	
12 OPzS	1200	1200	1440	1608	1728	1776	[illegible]	1872	
12 OPzS	1500	1500	1800	2010	2160	2220	2250	2340	
15 OPzS	1875	1875	2250	2512	2512	2700	2775	2925	

A B

Battery Capacity v.s. Discharge Rate



Long-term discharge capacities for VARTA OPzS Batteries

Type	Capacity							final voltage
	10 h *)	24 h	48 h	72 h	96 h	120 h	240 h	V/cell
4 OPzS 200	200	240	268	288	296	300	312	
5 OPzS 250	250	300	335	360	370	375	390	
6 OPzS 300	300	360	402	432	444	450	468	
5 OPzS 350	350	420	469	504	518	525	546	
6 OPzS 420	420	504	562	604	621	630	655	
7 OPzS 490	490	588	656	705	725	735	764	1.85
6 OPzS 600	600	720	804	864	888	900	936	
8 OPzS 800	800	960	1072	1152	1184	1200	1248	
10 OPzS 1000	1000	1200	1340	1440	1480	1500	1560	
12 OPzS 1200	1200	1440	1608	1728	1776	1800	1872	
12 OPzS 1500	1500	1800	2010	2160	2220	2250	2340	
15 OPzS 1875	1875	2250	2512	2512	2700	2775	2925	

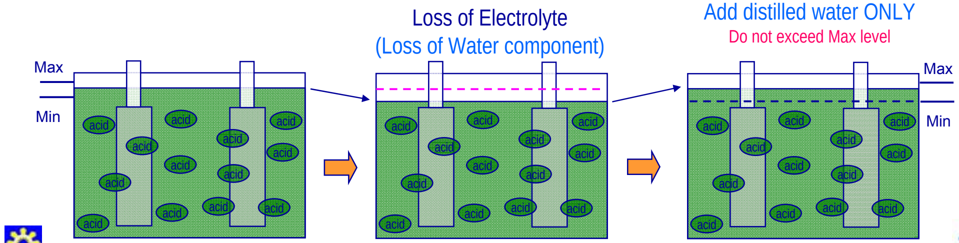
Capacity depends on Discharge rate

Maintenance of Electrolyte

(To keep Level)

- ✶ Loss of Electrolyte occurs during operation
  - Water component → Decrease
  - Acid component → No change
- ✶ To keep Electrolyte Level,
  - Compensate decreased water component
    - Add distilled water ONLY
    - Do NOT add acid

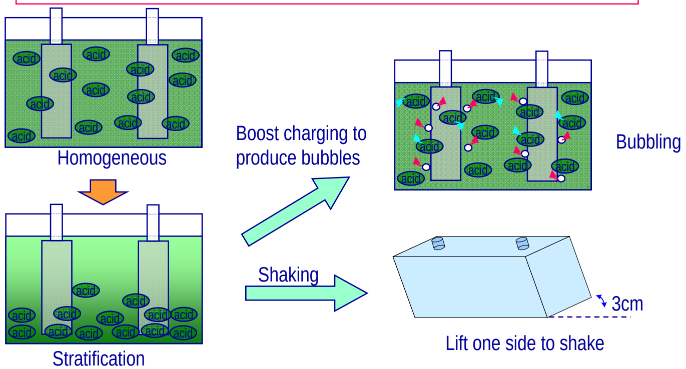
Dry up, Adding unsuitable water are Major Cause of DAMAGE



Maintenance of Electrolyte

(To Prevent Stratification)

- ✶ Acid tend to accumulate in bottom area (Stratification)
- ✶ To prevent Stratification,
  - Boost charging to mix electrolyte by bubbling
  - Shake battery to mix electrolyte (small battery only)

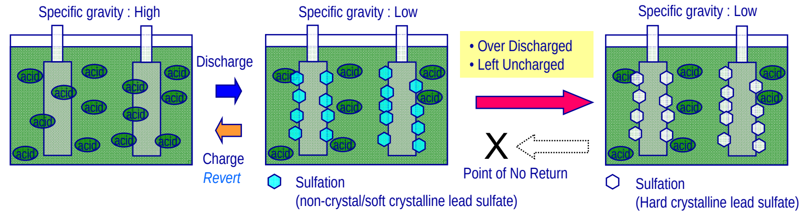


Maintenance of Electrode

(To Prevent Sulfation)

- ✶ Sulfation occurs during discharge, it reverts the state during charging
- ✶ When over discharged and/or left uncharged, sulfation develop crystals
  - Crystallized sulfation covers surface of electrode permanently
  - Active area of electrode is reduced → Less capacity
- ✶ To prevent Sulfation,
  - Do NOT over discharge
  - Do NOT leave battery uncharged
    - Charge battery immediately after discharge
    - Battery shall be fully charged daily

Major Cause of Short Life



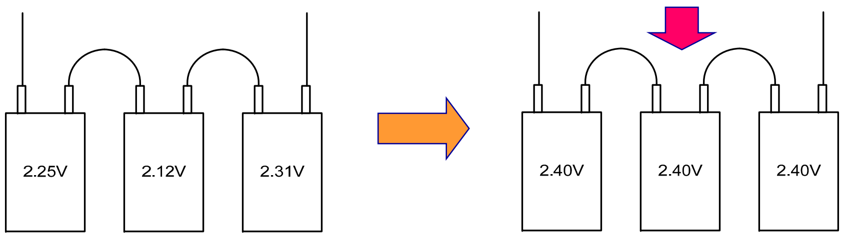
Maintenance of Cell Voltage

(To Equal voltage)

- ✶ In series connected batteries, cell voltages become different
- ✶ To do Equalization,
  - Force over voltage under controlled charging (Boost Charging)
  - Equalization is also effective to prevent Stratification and Sulfation
  - Charge controllers normally have this function
  - Do NOT do boost charging for sealed (maintenance free) type battery

After for a while…

Equalization
(Boost Charging over 2.5V~)



Overuse

- ✶ Electricity is generated by PV modules
- ✶ Battery only stores electricity
- ✶ Daily power consumption should be less than generated power
  - Daily power consumption is limited by PV module size and insolation
  - Battery capacity is not the matter
- ✶ Overuse
  - [Generated available power] < [Power consumption]
- ✶ Overuse occurs
  - Poor insolation (Cloudy, rain)
  - Larger Load (Additional load, longer usage hours)

How can I check overuse?

Case A : Charge controller does not show Full state during a day
- Accidental overuse. Cloudy or Rain, Special TV program, Party, etc.
- Reduce load usage time in half for a day

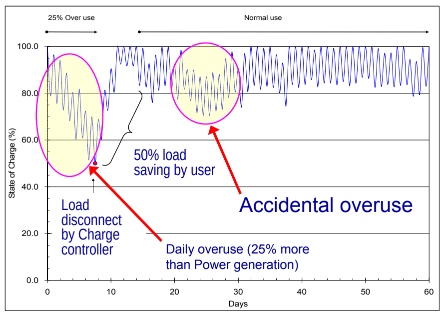
Case B : Charge controller cut off load
- Daily overuse. Battery is empty.
- Reduce load usage time in half till C/C shows Full state (at least for a week)

May need larger PV module

Battery Size vs Over Use

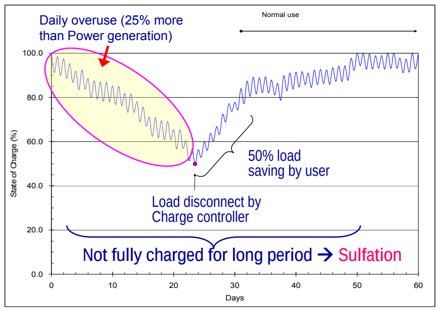
- ✶ Larger battery capacity allows shallower cycle operation → Prolong cycle life
- ✶ Larger battery capacity becomes disadvantage when over used

50Wp, 50Ah



Battery is too large compare to PV size

50Wp, 120Ah



Series and Parallel

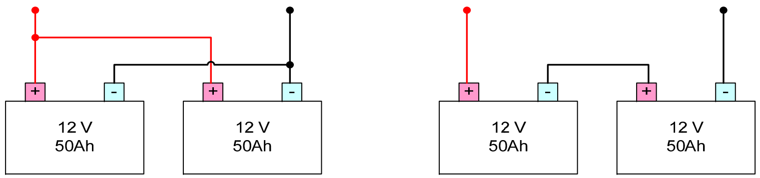
- ✶ Parallel connection sums Ah
- ✶ Series connection sums Voltage
- ✶ Total energy storage (Wh) is same
- ✶ Do NOT mix different type, model, age of batteries

<u>Parallel</u>

12V 100Ah
1200Wh

<u>Series</u>

24V 50Ah
1200Wh



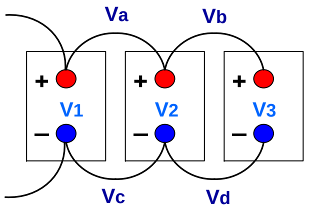
Balanced Connection

✶ Balanced wiring is important

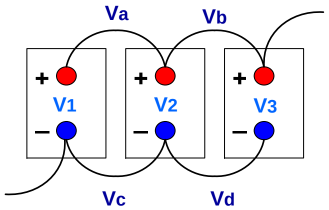
– Uniform each battery voltage

$V_1 = V_a + V_c + V_2$
$= V_a + V_b + V_c + V_d + V_3$

$V_1 + V_a + V_b = V_3 + V_c + V_d$
$= V_2 + V_c + V_b$



Va = Vc
Vb = Vd



Imbalanced : $V_1 > V_2 > V_3$ (Charging)
$V_1 < V_2 < V_3$ (Discharging)

No

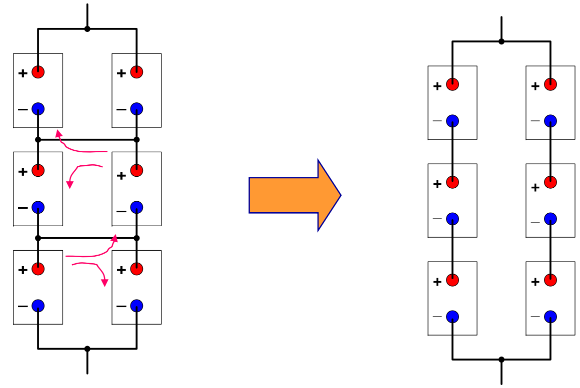
Balanced : $V_1 = V_2 = V_3$

OK

Inter-connection

No inter-connection among series connected string

- Cause complicated stray current network
- Difficult to equalize voltage



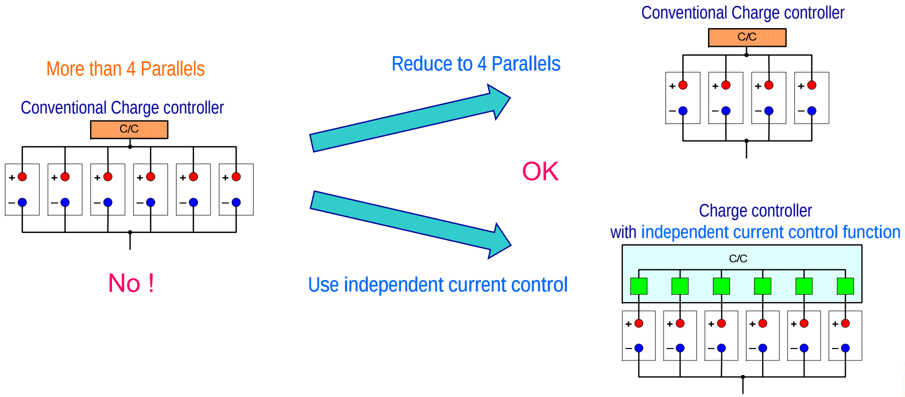
No

OK

Parallel Connection

✶ Maximum parallel connection need to be limited up to 4
  – Difficult to control equal charging current due to slight difference of voltage, internal resistance and capacity

✶ For more than 4 parallel connection, need independent current control function

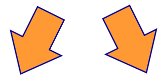


Do you know?

(Capacity)

100Ah battery can draw
- 1 A for 100 hours (1 A x 100 h = 100 Ah)
- 5 A for 20 hours (5 A x 20 h = 100 Ah)
- 20 A for 5 hours (20 A x 5 h = 100 Ah)
- 100 A for 1 hours (100 A x 1 h = 100 Ah)

No!!



OK

100Ah (C/20) battery can draw
- 8 A for ~10 hours (~80Ah @C/10)
- 5 A for 20 hours (100Ah @C/20)
- 1 A for ~120 hours (~120Ah @C/120)

OK

100Ah (C/100) battery can draw
- 8 A for ~8 hours (~64Ah @C/8)
- 5 A for ~16 hours (~80Ah @C/16)
- 1 A for 100 hours (100Ah @C/100)

You must specify discharge rate to purchase battery

Do you know?
(Voltage)

Battery is full at 12 V

No!!

OK

Full : ~14.4 V (~2.40V/cell x 6, depends on model)
LVD : ~11.4 V (~1.90V/cell x 6, depends on model)
Empty : ~11.1 V (~1.85V/cell x 6, depends on model)

12V = 2V/cell
→ around half discharged

Do you know?
(Discharge)

1. Battery is discharged deeply every day.
   This is the reason to use deep cycle battery.
2. When over used, a battery becomes empty in a night.
3. Even the battery is empty, it can be fully charged in next day.
4. Measuring of Specific Gravity is an important maintenance.

No!!

1. Daily depth of discharge is around 15%
   - Rest of capacity is reserved for autonomy.
   - Shallow cycle operation prolongs battery cycle life.
2. It takes a week or more to become empty.
3. It takes a week or more to recover (full charge).
   - It takes several weeks to recover in large system.
4. Measuring of Specific Gravity is monitoring of battery status.
   - You have nothing to do with those values.
   - You need NOT to maintain the value of specific gravity.

OK

Do you know?
(Discharge)

* Back up Diesel generator will work efficiently when battery voltage is low.

No!!

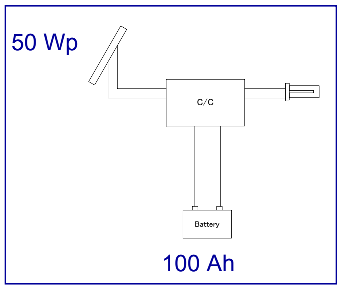
* In centralized system, it takes several weeks till batteries become empty.
  - This means "daily overuse" – load has been more than power generation for weeks.
  - If battery voltage has been monitored, this situation could be avoided.
* Low battery voltage means system operation is not in good condition
  - Possible development of sulfation
  - Check system performance
  - If system is OK, need severe load management
* It takes several weeks to recover battery status once it is empty.
  - Need to stop using batteries for at least a week to recover battery status.
* Back up Diesel generator is supposed to use :
  - Incase of System Maintenance
  - Incase of System Malfunction
  - PV systems are normally designed to work without back up diesel generator.

OK

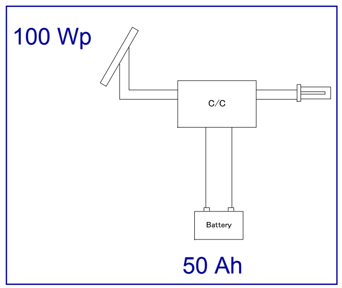
Do you know?
(Power)

Q : In which system you can use more electricity daily?

A



B



Exercise

Charge Controller

- ✶ Role of Charge controller
- ✶ Type of PV control
- ✶ Set point voltage
- ✶ Connecting sequence

Always obtain data sheet.
No datasheet, No quality

Functions of Charge Controller

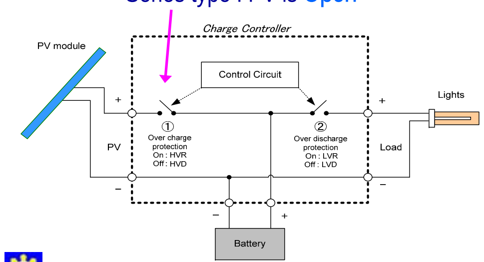
- ✶ Role of Charge controller
  - Charge controller protects batteries from Overcharge and Over discharge
  - Charge controller does NOT control/regulate current and voltage.
- ✶ Over charge protection :
  - Sense battery voltage
  - Battery voltage is high (fully charged, ~14.4V : High Voltage Disconnect, HVD)
    → Disconnect PV module from battery (Stop Charging)
  - While battery voltage is not high (not fully charged, below 13.5V : High Voltage Reconnect, HVR)
    → Always connect PV module to battery (Normal status for charging)
- ✶ Over discharge protection :
  - Sense battery voltage
  - While battery voltage is not Low (ordinary status, above 12.5V : Low Voltage Reconnect, LVR)
    → Always connect Load to battery (Normal status for discharging)
  - Battery voltage is Low (close to empty, below 11.5V : Low Voltage Disconnect, LVD)
    → Disconnect Load from battery (Stop Discharging)

Example of 12V system

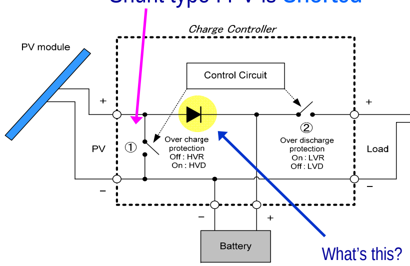
Type of Charge Controller

- ✶ Over charge protection :
  - Series Type : PV is disconnected as Open
  - Shunt Type : PV is disconnected as Shorted
  - PWM Type : PV is disconnected as Open/Shorted after controlling SW
- ✶ Over discharge protection : Load is disconnected (open)

Series type : PV is Open



Shunt type : PV is Shorted

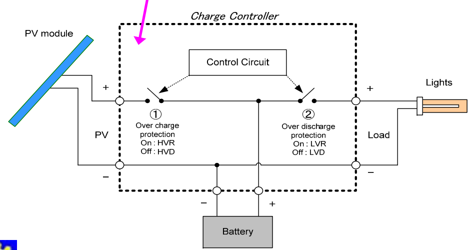


Type of Charge Controller

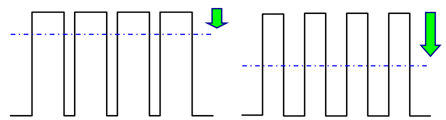
PWM (Pulse Width Modulation) Type

- Frequent switching on/off sequence (~100Hz ~) allow effective charging
- Average current from PV is reduced and Voltage is kept to setting value. (Pulse control)
- Series and Shunt type charge controller are commercially available.

PWM type : SW① is controlled for keeping the voltage .



Average current : I

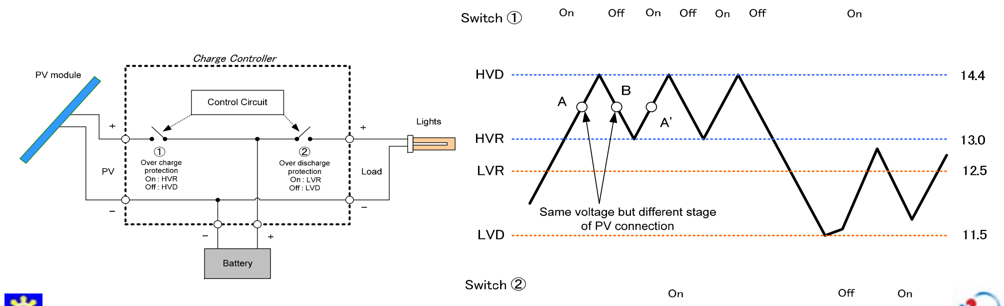


$V_{Bat} = V_0 + I \times R$

V_{Bat}: terminal voltage of battery
V0: Excitation voltage
I : Charging current
R: Internal resistance of battery

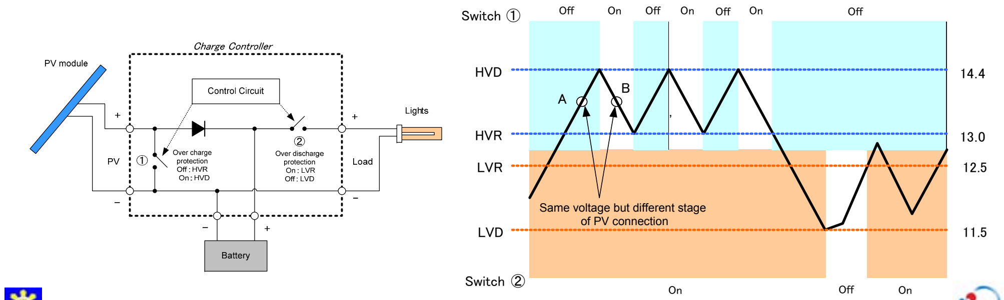
Status of C/C (Series type)

- Over charge Protection
  - When Battery voltage reached full (HVD), PV is disconnected
  - When Battery voltage decreased to HVR, PV is reconnected
- Over discharge protection
  - When Battery voltage decreased beyond LVD, Load is disconnected
  - When Battery voltage recovered above LVR, Load is reconnected
- Very important to know the status of C/C when monitoring/Troubleshooting



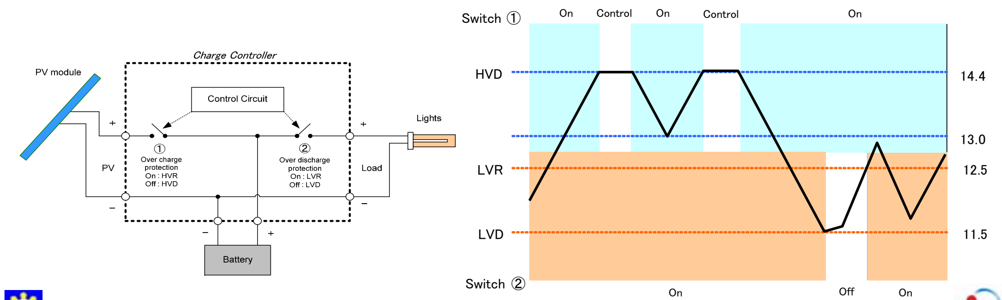
Status of C/C (Shunt type)

- Over charge Protection
  - When Battery voltage reached full (HVD), PV is shorted
  - When Battery voltage decreased to HVR, PV is reconnected
- Over discharge protection
  - When Battery voltage decreased beyond LVD, Load is disconnected
  - When Battery voltage recovered above LVR, Load is reconnected



Status of C/C (PWM type)

- Over charge Protection
  - When Battery voltage reached full (HVD), SW① is controlled
  - When Battery voltage decreased, SW① is ON (No HVR)
- Over discharge protection
  - When Battery voltage decreased beyond LVD, Load is disconnected
  - When Battery voltage recovered above LVR, Load is reconnected



Set point voltages

- Set point voltages are slightly differs by each model
  - Choose right set point voltage with battery
- Temperature compensation is necessary (built-in)
  - Approx. -3mV / ºC per cell
  - Approx. -0.18V at 12V battery when 10 ºC increased
- For accurate control, Voltage drop between Battery and Charge Controller shall be minimized (<0.1V, <0.05V per line)

Use proper model of charge controller (LVD) for each types of batteries

Use proper model of charge controller (HVD) for each types of batteries

Set Point @ 20 ºC	Automotive (Flooded)	Deep Cycle (Flooded)	Deep Cycle (Maintenance free)
HVD	14.4	14.4	14.1
HVR	13.0	13.0	13.0
LVR	12.6	12.6	12.6
LVD	11.7	11.5	11.5

Values are reference ONLY

Connecting Sequence

- ✶ Connecting / Disconnecting cables to C/C, *First Battery, Last Battery* is the rule of the thumb

Connecting Sequence

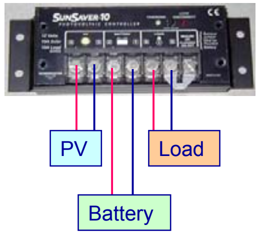
Battery → PV → Load

First Battery

Disconnecting Sequence

Load → PV → Battery

Last Battery



If battery is not connected, high voltage (18V) of PV module may damage Load (Max input is ~14.5V)

Additional functions

Some charge controller have additional function to prolong battery life and efficient charging

✶ Boost charging mode

- To equalize cell voltage, high HVD setting By changing HVD,
- Boost charging mode is triggered automatically (low battery voltage, after several charging cycles, etc.). Once boost charging is completed, it becomes normal mode automatically.
- Do NOT use this type of charge controller for sealed (maintenance free) battery

Do you know?

(Charge Controller)

1. Charge controller regulate charging current and voltage
2. Charge controller regulate (stabilize) voltage
   - PV module voltage (18V) became 13V when connected to charge controller. This is the evidence that charge controller regulate voltage.

No!!

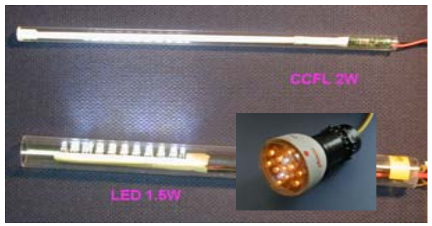
OK

1. Charge controller is to protect battery from over charge and over discharge by switching on/off.
   - It does NOT control current and voltage.
   - Some charge controllers use PWM and/or Independent sub array control. It looks like current is controlled, however, it is a result of switching on/off function.
2. Charge controller does not regulate voltage.
   - This example (18V to 13V) is the effect by connecting the PV module to the battery. Charge controller does not change voltage.
   - This misunderstanding might come from the other name of charge controller – "Regulator". The name of "Regulator" may not be adequate at this point (leads misunderstanding).

Exercise

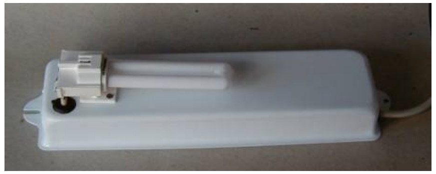
DC Lights

- ✶ For SHS and BCS, DC lights are necessary
  - Available power is very limited
  - Electricity is very precious
  - High efficiency lights are necessary
- ✶ Type of DC Lights
  - DC Fluorescent Light
    - Compact Fluorescent Light (CFL)
    - Cold Cathode Fluorescent Light (CCFL)
  - Halogen Light
  - LED



Compact Fluorescent Light

Typical DC light used in SHS and BCS



There is a built-in inverter that converts 12 V DC into some hundreds volts of AC.

The fluorescent lights need AC. The device used in DC fluorescent light "inverts" DC into AC. Sometimes the inverter is called "ballast". However, original meaning of "ballast" is the device normally used in conventional AC fluorescent light. It is a sort of choke coil. It does not change DC to AC.

DC Fluorescent Light

- CFL is the most recommended light at the moment
  - Low cost, Enough brightness at reasonable power consumption
  - The life of tube is around 1~2 years → problem of tube supply
- CCFL is developed as backlight of LCD display.
  - The life of tube is very long (~20,000 hours, more than 10years if used 4hours/day) .
  - Free from the problem of tube supply.
- Halogen lamp is easily available at automobile parts shop
  - Easily available but power consumption is higher than CFL.
- LED light are becoming popular.
  - Due to its high cost, only small light (1~2W) are available.
  - Brightness is not enough at this small type.
  - If the cost becomes low and 10W types are available, LED light mat become main stream for SHS

The combination of maintenance free battery and CCFL / LED lights will make SHS as maintenance free system

Lights	Current (A)	Illuminance at each distance from light (Lux)	
		1 m	2 m
CFL 9W	0.58	83.0	20.0
Halogen 10W	0.80	50.0	8.0
Candle	N/A	1.2	0.5

Do you know?
(DC Light)

1. Power consumption is rated at tube.
2. Halogen bulbs for car can be used as lights
3. DC light is much brighter than candle.
   This is good for reading at night. Children can do homework at night

No!!

1. Power consumption depends on built-in inverter and tube
   – Measure actual power consumption.
2. It consume more power than fluorescent light.
3. DC light is normally 9 ~ 11W. This gives only around 10~20lx that is not enough brightness for reading (150 lx or more). Reading under this dark condition may develop near sight especially for children.

OK

Inverter

Always obtain data sheet.
No datasheet, No quality

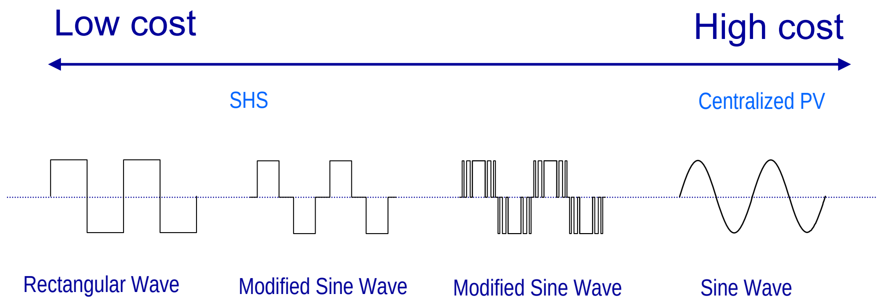
- Converts DC into AC
- Wide range of capacity
  - 100W ~ 300W ~1kW ~ 5kW (Easily available in market, Inexpensive)
  - 10kW~ 100kW (Production by order, Expensive)
- Inverters for car use are becoming popular at low price P1000~, 100W
- Use of inverter is very convenient for users
- Need larger PV panel due to low efficiency of AC system compare to DC system

Inverter for SHS

- Car use type is easily available at low price
- Check surge power tolerance
  - Some appliance such as TV, Fridge requires high current at start up.
  - Inverter must have tolerance of these surge current
    Example:
    Rated : 150W (continuous)
    Surge : 500W (within one minutes)
- Choose low self power consumption and high efficiency type

Output Waveform

- Sine wave output is ideal
- Due to cost limitation, modified sine wave types are common for small-scale application
- Rectangular wave type might have some problem with some appliances



Do you know?
(Inverter)

1. Inverter has low voltage shut off function to prevent over discharge.
2. Inverter can connect directly to battery.

No!!

1. Low voltage shut off function is to protect inverter itself and not for the over discharge protection of battery.
   Low voltage shut off is normally 10.5V that is too low to prevent over discharge of battery (~11.5V).
2. Inverter should connect to charge controller instead of direct connection to battery to avoid over discharge.

   → Direct connection is acceptable at only special case that the use of appliance is more important than protecting battery – such as Vaccine Fridge, Radio communication. Careful design and user instruction is required to avoid over-discharge.

OK

Maintenance

- Basically PV system is low maintenance system
- General Maintenance ("Keep Clean" is Common Sense)
  - Cleaning of PV module → Dust, Birds dropping
  - Cleaning of Battery terminal → Rust, Corrosion
  - Cleaning of Floor → Spilt acid
  - Cleaning of System → Dust, insects, web
- Maintenance of Battery
  1. Electrolyte (Maintain level) → Top up distilled water
  2. Electrolyte (Avoid Stratification) → Shake once a week (SHS)
     Automatic by C/C (Centralized)
  3. Electrode (Avoid Sulfation) → Maintain full charge (Avoid overuse)
  4. Cell Voltage (Equalization) → Automatic by C/C

Load Management

Sounds easy but extremely difficult to do

General Cleaning

- PV Module
  - Clean surface
  - Use water, soft cloth
  - Never use detergent
- Battery
  - Clean spilt acid
  - Avoid skin contact of acid
- Charge Controller
  - Remove insects & dust
- Lights
  - Clean diffuser cover
  - Remove insects & dust

Inspection & Monitoring

- Inspection & Monitoring are the KEY to ensure system reliability & sustainability
  - Should be conducted by doubting
  - Should be conducted by using measuring equipment
  - Should be conducted by using 6th sense
- Must understand Meaning of system parameters
  - Monitoring without understanding of system parameters is useless
  - Only qualified people can conduct proper monitoring

Inspected & Approved, Why??

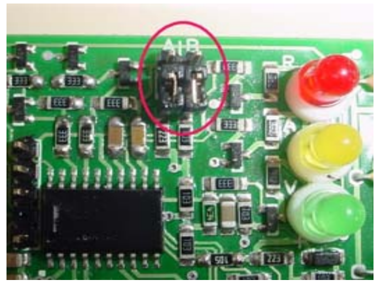
One is 30 degree, the other is flat??

PV panels are facing West

Inspected & Approved, Why??

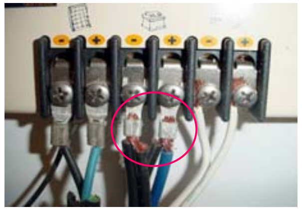
Inverter is connected to battery directly

Deep cycle battery is used, but battery selector of C/C is set to car battery



Inspected & Approved, Why??

Corrosion
(No grease)



High risk of short circuit

Temperature sensor was cut off

High risk of short circuit

Inspected & Approved, Why??

Installed behind a big baobab tree…

Why these are approved?
Because Inspectors did not know about solar PV system…..

How they could be inspectors?
Because ….. Why???

Inspectors should have :

- Proper Knowledge (Intermediate or Advanced level)
- Good Skills to check System Parameters
- Good Technical Sense

Need qualification of Inspectors

System Parameters
(Essential Knowledge)

✶ Electricity is invisible.
Need to measure several parameters to check system status

✶ System parameters

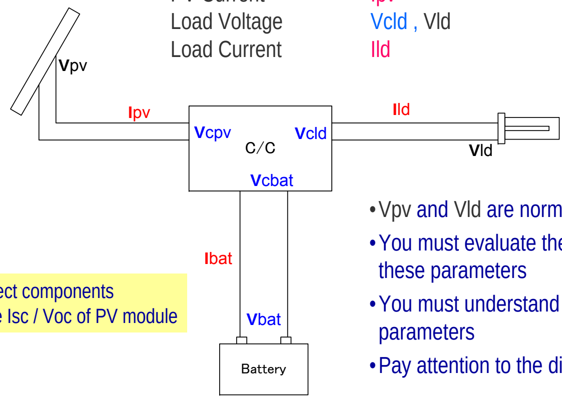
- Battery Voltage
- Battery Current
- PV Voltage
- PV Current
- Load Voltage
- Load Current
- Specific Gravity
- Battery Temperature
- Irradiance
- PV Temperature

Prime parameters for SHS (Battery Voltage to Load Current)

Must understand Meaning of Measured Values for Monitoring

Parameters to be measured at monitoring

Battery Voltage	Vcbat , Vbat
Battery Current	Ibat (Positive = Charging, Negative = Discharging
PV Voltage	Vcpv , Vpv
PV Current	Ipv
Load Voltage	Vcld , Vld
Load Current	Ild



Do NOT disconnect components
Do NOT measure Isc / Voc of PV module

- Vpv and Vld are normally difficult to measure
- You must evaluate the status of the system with these parameters
- You must understand the relations among parameters
- Pay attention to the direction of current flow

AC/DC Clamp Meter

Measurement:
AC/DC Voltage, AC/DC Current

<Required Specification>

- DC current to measure current
  - Max. : min. 10 A
  - Resolution : min. 0.01 A
- DC voltage to measure voltage
  - Max. : min. 600 V
  - Resolution : min. 0.01V
- Resistance to check contact failure of switches/terminals
  - Max. : min. 40MΩ
  - Resolution : min. 0.1Ω

One clamp tester is enough to measure prime parameters

Digital Multi Meter

Measurement:
AC/DC Voltage, AC/DC Current

Not necessary if AC/DC Clamp Meter is available

<Required Specification>

- DC current to measure current
  - Max. : min. 10 A Limited to 10A
  - Resolution : min. 0.01 A
- DC voltage to measure voltage
  - Max. : min. 600 V
  - Resolution : min. 0.01V
- Resistance to check contact failure of switches/terminals
  - Max. : min. 40MΩ
  - Resolution : min. 0.1 Ω

Not recommended to disconnect cable to measure current

Digital Illuminance Meter & Pyranometer

Digital Illuminance Meter
Measurement:
Illuminance as Irradiation

<Required Specification>

- Range
  - Max. : min. 200,000 Lx
  - Resolution : min. 0.1 Lx

Irradiance 1kW/m^2 = around 116,000 Lx ~ 120, 000 Lx

Pyranometer
<Required Specifications>

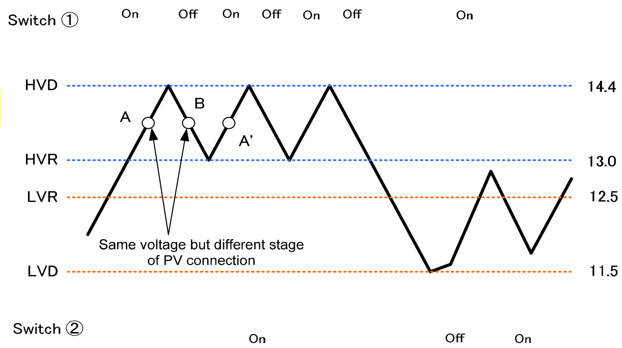
Use together with data logger

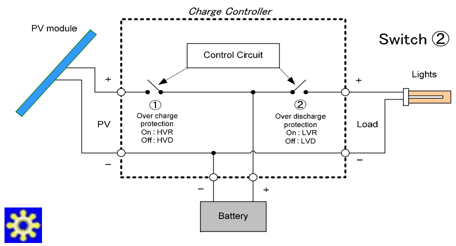
Measuring wave length: 0.3~2.8 μm

Sensitivity: 7μV / (7.0 mV / kW*m^{-2})

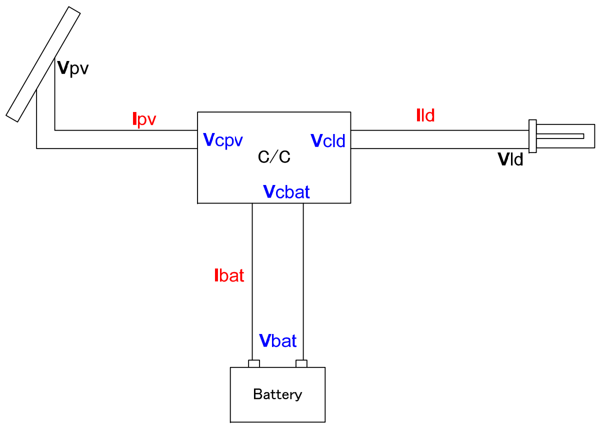
Status of C/C

Must understand status of C/C





Which relations are correct?



?

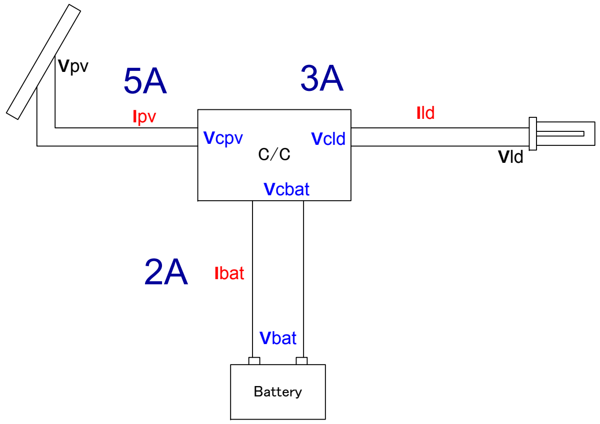
Vpv > = < Vcpv

Vbat > = < Vcbat

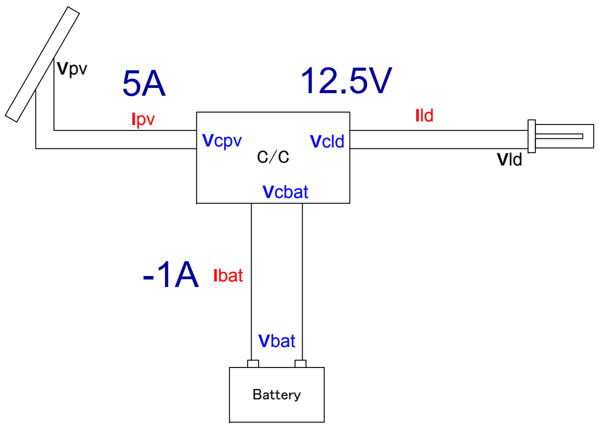
Vld > = < Vcld

Ipv > = < Ibat + Ild

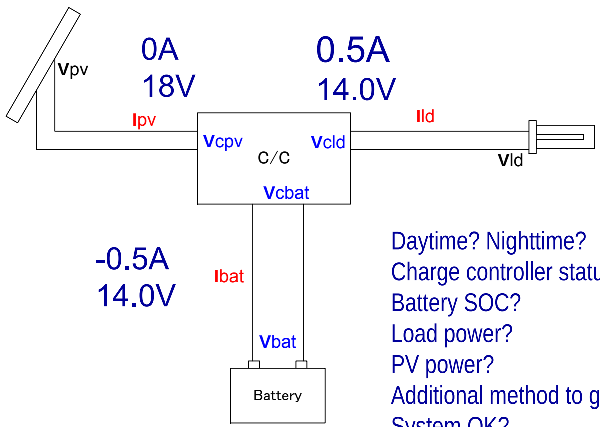
What is system status?



How much is the load power (W) ?

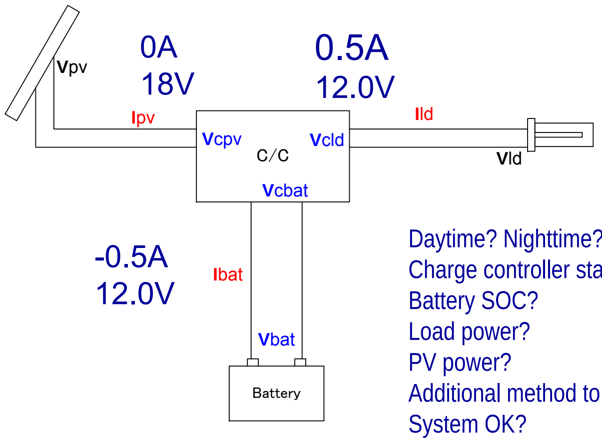


What is system status?



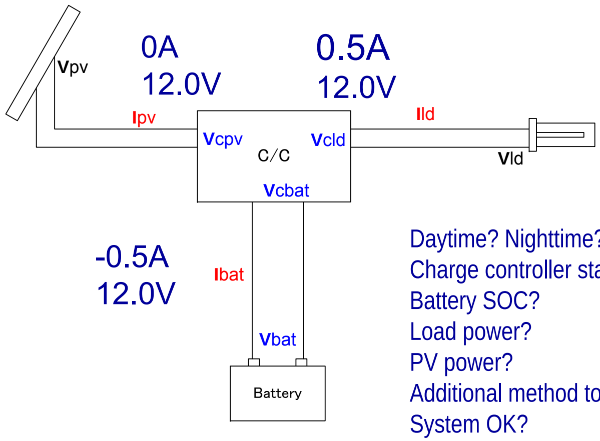
Daytime? Nighttime?
Charge controller status?
Battery SOC?
Load power?
PV power?
Additional method to get additional parameter?
System OK?

What is system status?



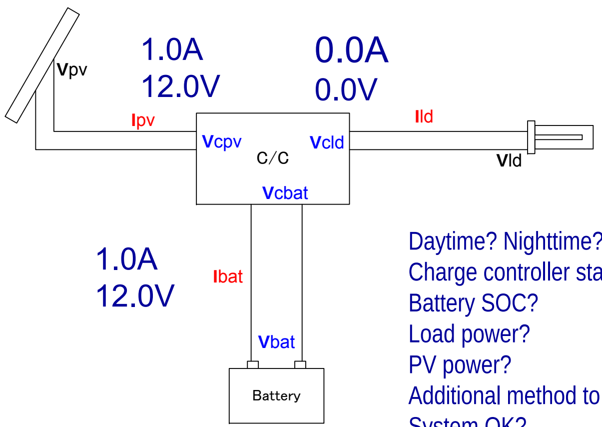
Daytime? Nighttime?
Charge controller status?
Battery SOC?
Load power?
PV power?
Additional method to get additional parameter?
System OK?

What is system status?



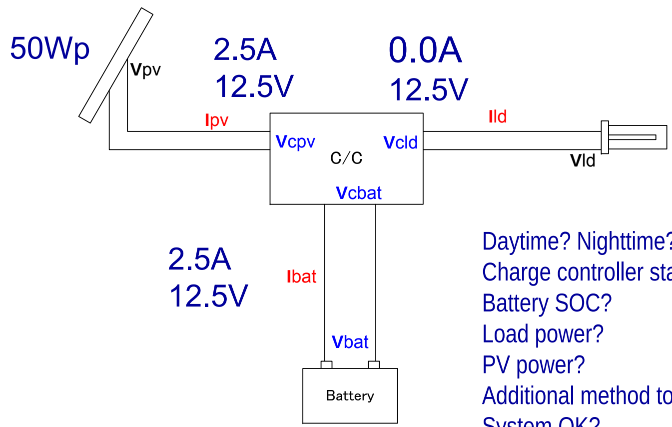
Daytime? Nighttime?
Charge controller status?
Battery SOC?
Load power?
PV power?
Additional method to get additional parameter?
System OK?

What is system status?



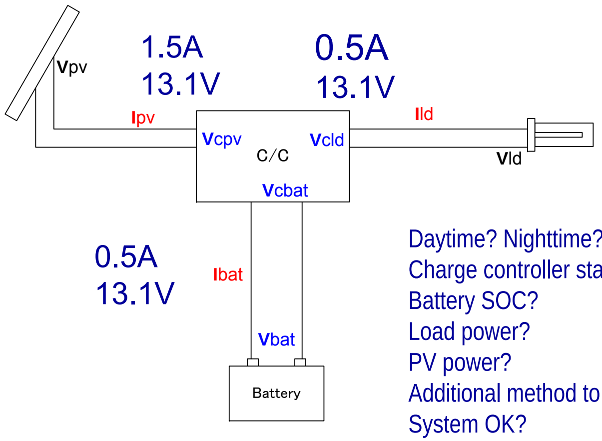
Daytime? Nighttime?
Charge controller status?
Battery SOC?
Load power?
PV power?
Additional method to get additional parameter?
System OK?

What is system status?



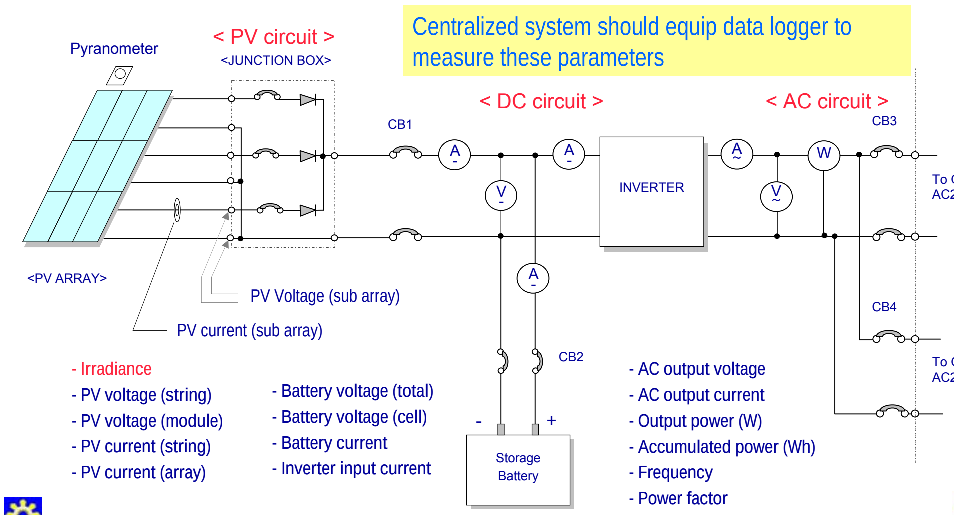
Daytime? Nighttime? Sunny day at 2pm
Charge controller status?
Battery SOC?
Load power?
PV power?
Additional method to get additional parameter?
System OK?

What is system status?



Daytime? Nighttime?
Charge controller status?
Battery SOC?
Load power?
PV power?
Additional method to get additional parameter?
System OK?

Measuring Points (Centralized)



Specific Gravity

Why do we need specific gravity?

- Voltage gives us result of electro-chemical reaction
- Specific gravity gives us condition of electro-chemical reaction

Specific Gravity changes at temperature

→ Need to calibrate at standard temperature 20 ºC

$S20 = St + 0.0007\ (t - 20)$

S20 = Electrolyte specific gravity at 20 ºC
St = Electrolyte specific gravity at t ºC
t = Electrolyte temperature ºC

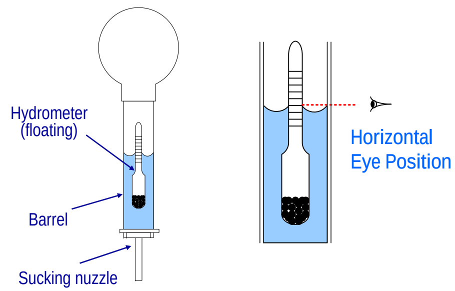
Standard condition
PV : 25 ºC
Battery : 20 ºC

Example:

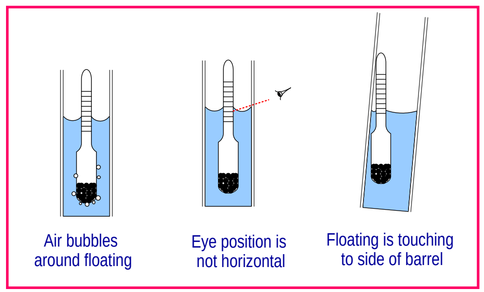
1. The specific gravity is 1.250 when the electrolyte temperature is 35 ºC
   The specific gravity at the standard condition 20 ºC :
   S20 = 1.250 + 0.0007 (35 – 20) = 1.260 → What battery voltage is expected?

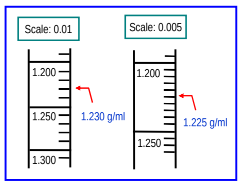
2. If battery voltage is 13.5V and specific gravity (at 20 ºC) is 1.180, what does this mean?

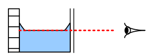
Measuring of Specific Gravity



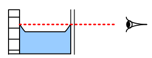
No!







Due to surface tension of liquid, normally, reading of plane liquid surface is used.



However, hydrometer for battery is normally designed (scaled) to read the point where surface of the liquid touches the hydrometer.
→ Check your hydrometer if your hydrometer is this type or not.

Why do we need system parameters?

Electricity is Invisible

↓

System parameters are only way
to understand system status

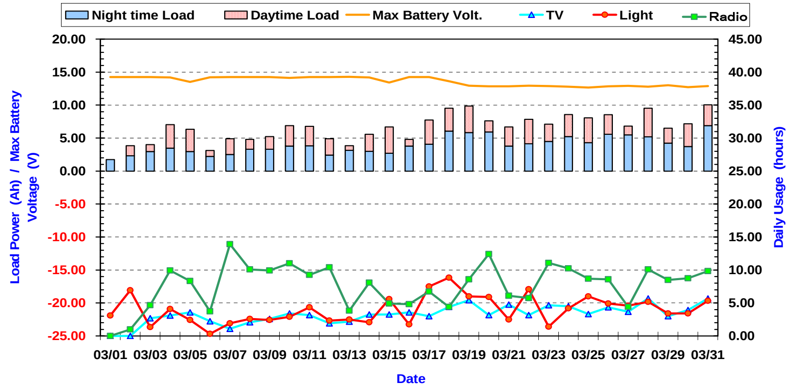
↓

Recorded data give us feed back
whether estimated values are reasonable or not

Daily Usage Time of Loads (SHS)

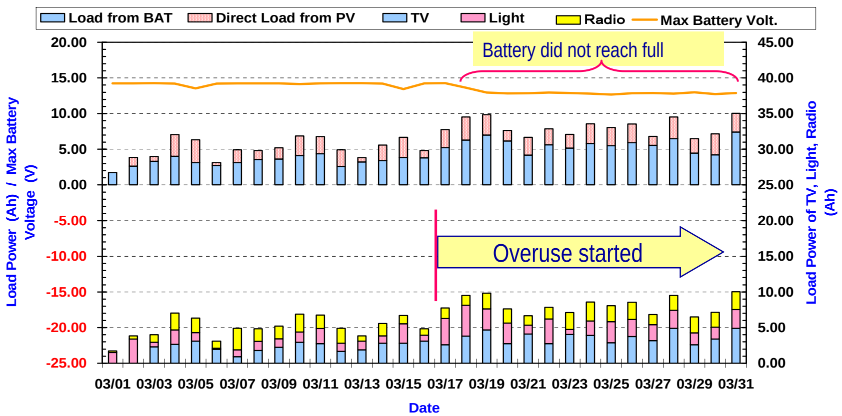
We normally instruct users "You can use TV for 2hrs, Light for 4hrs"
→ Actual usage time changes daily

Fig. 4 Load Analysis at Geja House (Mar. 1 - Mar. 31, 1999)



Overuse (SHS)

Users always tend to do overuse
because battery have excess storage of electricity for autonomy



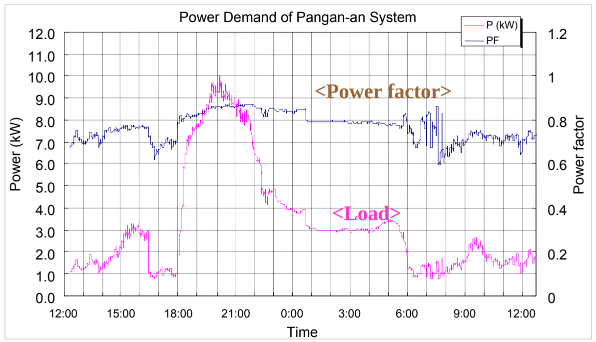
Peak load & Total load (Centralized)

(Pangan-an PV plant)

Pangan-an PV Power Plant Operation Data
< 2/22-2/23 >

TIME	V (V)	I (A)	P (W)	Q (Var)	PF (PU)	F (Hz)
18:00	237.9	10	1860	1470	0.784	60.02
18:01	238	10.1	1890	1490	0.785	60.03
18:02	237.9	11.1	2090	1610	0.793	60.03
18:03	237.8	12.4	2380	1730	0.809	60.03
18:04	237.8	12.5	2400	1760	0.806	60.02
18:05	237.8	14.1	2730	1960	0.812	60.02
18:06	237.7	15.7	3050	2140	0.819	60.03
18:07	237.6	16.8	3230	2360	0.808	60.03
18:08	237.6	17.5	3300	2530	0.794	60.03
18:09	237.5	18.4	3490	2630	0.799	60.03
18:10	237.5	20.6	3910	2940	0.799	60.02
18:11	237.3	21.6	4140	3040	0.806	60.02
18:12	237.3	21.6	4080	3100	0.796	60.03
18:13	237.2	23.5	4410	3390	0.793	60.03
18:14	237	25.8	4870	3690	0.797	60.03
18:15	236.8	27.4	5160	3920	0.796	60.02
18:16	236.8	28.6	5400	4070	0.798	60.03
18:17	236.7	29.7	5610	4220	0.799	60.03
18:18	236.7	30.8	5880	4320	0.806	60.03
18:19	236.7	30.4	5800	4270	0.806	60.02
18:20	236.6	30.9	5900	4300	0.808	60.03
18:21	236.5	33.1	6360	4570	0.812	60.03
18:22	236.5	33.4	6420	4590	0.813	60.02
18:23	236.5	33.5	6440	4600	0.813	60.02
18:24	236.5	33.8	6520	4630	0.816	60.03
18:25	236.4	34.3	6600	4700	0.815	60.03
18:26	236.4	34.7	6740	4680	0.821	60.03
18:27	236.4	34.4	6650	4680	0.818	60.02
18:28	236.4	35.7	6930	4800	0.822	60.03
18:29	236.3	35.9	7010	4800	0.825	60.02
18:30	236.3	36.3	7090	4830	0.827	60.03

Knowing Peak load & Power consumption is very important for load management



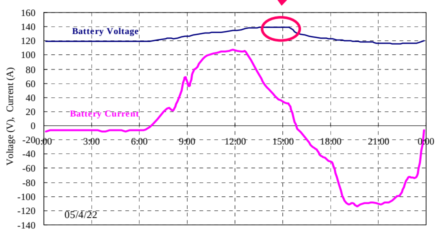
Power consumption a day: 79.2 kWh/day
Peak Load : 10kW

Found Overuse (Centralized)

(New Ibajay PV plant)

The record indicated Power demand is much higher than Power generation

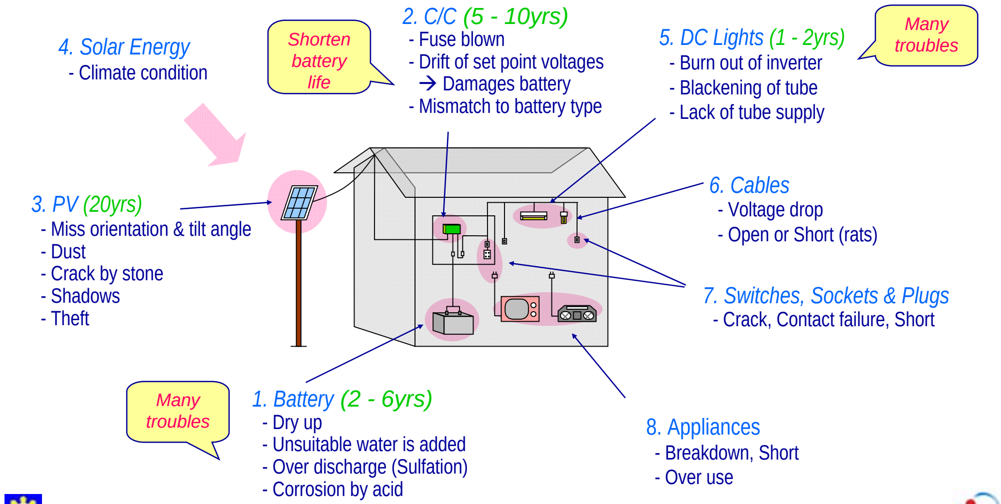
Battery is not fully charged during daytime
→ Overuse



DateTime	IVOLT	IPOW	IPF	BATVPC	BATV	BATA	RENA
2005/04/22 00:08	229	0.2	0.28	1.98	119	−8	0
2005/04/22 00:23	229	0.2	0.28	1.98	119	−6	0
2005/04/22 00:38	229	0.2	0.27	1.98	119	−6	0
2005/04/22 00:53	229	0.2	0.27	1.98	119	−6	0
2005/04/22 01:08	229	0.2	0.27	1.98	119	−6	0
2005/04/22 01:23	229	0.2	0.25	1.98	119	−6	0
*	*	*	*	*	*	*	*
2005/04/22 06:08	229	0.2	0.27	1.98	119	−6	0
2005/04/22 06:23	229	0.2	0.27	1.98	119	−5	0
2005/04/22 06:38	229	0.2	0.27	1.99	119	−2	1
2005/04/22 06:53	229	0.2	0.27	2.00	120	3	3
2005/04/22 07:08	229	0.2	0.27	2.01	121	9	8
2005/04/22 07:23	229	0.2	0.27	2.02	122	16	15
2005/04/22 07:38	229	0.2	0.27	2.04	123	23	23
2005/04/22 07:53	229	0.2	0.27	2.05	124	25	26
2005/04/22 10:08	229	0	0.24	2.15	131	98	104
2005/04/22 10:23	229	0	0.23	2.16	131	100	105
2005/04/22 10:38	229	0	0.25	2.17	132	102	106
2005/04/22 10:53	229	0	0.25	2.18	132	103	110
2005/04/22 11:08	229	0	0.25	2.18	132	105	111
2005/04/22 11:23	229	0	0.24	2.19	133	105	112
2005/04/22 11:38	229	0	0.26	2.20	134	106	114
2005/04/22 11:53	229	0	0.26	2.21	135	108	114
2005/04/22 12:08	229	0	0.24	2.23	135	106	114
2005/04/22 12:23	229	0	0.25	2.24	136	105	112
2005/04/22 12:38	229	0	0.25	2.25	137	105	111
2005/04/22 12:53	229	0	0.27	2.27	138	98	105
*	*	*	*	*	*	*	*
2005/04/22 17:08	229	4.4	0.70	2.06	125	−33	7
2005/04/22 17:23	229	4.4	0.70	2.04	124	−42	1
2005/04/22 17:38	229	4.4	0.69	2.04	124	−45	0
2005/04/22 17:53	229	4.6	0.68	2.02	123	−50	0
2005/04/22 18:08	229	4.8	0.66	2.02	123	−53	0
2005/04/22 18:23	229	6.4	0.62	2.00	121	−72	0
2005/04/22 18:38	229	7.8	0.60	1.98	121	−91	0
2005/04/22 18:53	229	9.4	0.62	1.97	120	−106	0
2005/04/22 19:08	229	9.6	0.60	1.97	120	−111	0
2005/04/22 19:23	229	9.4	0.60	1.96	119	−109	0

Exercise

Troubleshooting



Troubleshooting

Many people request to learn troubleshooting at early stage of training. However, you must learn system first. Once you could understand PV system very well, you already know Troubleshooting.

✶ Check all system parameters

- Users/Operators may report a trouble that is normal
- Users/Operators may report normal that is a trouble
- Must understand meaning of measured data
- Identify the cause of the trouble by analyzing measured data

✶ *THINK* solutions

- There are several ways to solve the problem
  → In most cases, there is no 100%-correct answer (no best solution)
- Consider advantages and disadvantages of each solutions
  → Choose Better solution at case by case.
  The better solution at the site A may not be the better solution at the site B.
- Explain them to the user for approval

You MUST understand meaning of system parameters for Troubleshooting.
You MUST be intermediate to advanced level

Common Troubles in a PV System

✶ PV Module

√ Low or no power output

Causes

√ Mis-orientation, Wrong tilt angle;
√ Accumulation of dust;
√ Crack in the glass lamination;
√ Shadow;
√ Climate condition;
√ Short circuit of bypass diode;
√ Loose connection of wires; and
√ Theft

Common Troubles in a PV System

✶Charge Controller
- √ No current is flowing to the battery;
- √ Signals fully charged though battery is just being charged;
- √ Keeps charging even when fully charged

Causes
- √ Blown-up fuse;
- √ Set point voltages are not within the set standards;
- √ Loose connection of wires;
- √ Malfunction of internal circuit

Common Troubles in a PV System

✶Battery
- √ Easily discharged;
- √ Cannot be charged;
- √ Unequal cell voltages

Causes
- √ Sulfation;
- √ Dried up battery solution;
- √ Stratification;
- √ Loose connection at the terminals;
- √ High temperature;
- √ Leakage of electricity;
- √ End of life

Common Troubles in a PV System

✶Balance-of-Systems (Cables, SW, Lights, etc.)
- √ No light even when battery is fully charged;
- √ Under-voltage at load end;
- √ No power at load end

Causes
- √ Open or Short circuit or Grounding;
- √ Inappropriate/undersize cables (large voltage drop);
- √ Burn-out DC light tube/inverter;
- √ Loose connection at the terminals;
- √ High resistance on the SW contact

Troubleshooting Procedures

✶PV Module
- √ Check, rectify orientation and tilt angle (must not be < 10º facing South)
- √ Check presence of dust and cracks,
- √ Clean PV with water, detergents not needed;
- √ Tighten loose connections at the terminal box;
- √ Check shadowing at PV module between 8am-4pm;
- √ Relocate PV module to a clear and unobstructed area;
- √ Remove/prune tree/s that is/are causing shadows at PV Module
- √ Check/replace/remove bypass diode

Troubleshooting Procedures

✶Charge Controller

- √ Check voltage at the terminal and output current;
- √ Check for loose connections at the terminals;
- √ Check/replace busted fuse;
- √ Check HVD and LVD settings, rectify settings as necessary.

If some trouble is remained, contact the supplier.
If under warranty, request for replacement.

Troubleshooting Procedures

✶Battery

- √ Check loose connection at the terminals;
- √ Clean terminals with steel brush and apply grease;
- √ Check level of battery solution, top up when necessary;
- √ Use appropriate terminal lugs/clamps only;
- √ Check presence of sulfates at the terminals;
- √ Slightly shake battery (not >10^{o} from the floor line at side) to avoid stratification;
- √ Check the installation condition, relocate if necessary;
- √ Check the battery performance

Troubleshooting Procedures

✶Balance of Systems (Cables, SW, Lights, etc.)

- √ Check voltage level at load end and voltage drop;
- √ Check for possible loose connections at the terminals;
- √ Check size of cable if the installed cable is the appropriate size, replace as necessary;
- √ Check continuity of cables, when open circuit, trace the line and connect the open circuit;
- √ Check possible short circuit and grounding in the line, re-insulate short-circuited/grounded line;
- √ Check operation of SW and voltage drop between input and output. Clean contact if necessary;
- √ Replace DC light when necessary and use brands with that passed the Philippine Standards (with PS Mark)

Case study of Troubleshooting

Battery can not charge fully in spite of fine day!

Possible Reason	Check point	Solution
Battery level is too low	Weather condition/Overuse	User retraining
Overuse of load	Usage condition of load	User retraining
Loose connection, Rust	Connector, terminal	Retightening /Cleaning
Dirt on PV module	Surface of PV module	Cleaning
Shadow on PV module	Surrounding condition	Removal of the source
Damage of cable	Condition of cable	Repair /Replacement
Damage of PV module	Condition of PV module	If bad, Contact engineer
Malfunction of C/C	Operation of C/C	If bad, Contact engineer
Battery is weakening	Performance of battery	If bad, replace it

Case study of Troubleshooting

C/C can not operate properly!

Possible Reason	Check point	Solution
Loose connection	Terminal	Reconnection /Retightening
Set voltage is shifted	HVD and LVD setting	Rectify setting
Malfunction of C/C	Operation of C/C	If bad, Contact supplier
Damage of PV module	Condition of PV module	If bad, Replace it
Damage of cable	Condition of cable	Repair /Replacement
Direct connection between battery and additional load	Connection of additional load	Remove User retraining
Effect of noise	Terminal voltage	Denoising/Grounding
Battery is weakening	Performance of battery	If bad, replace it
Type/voltage of battery is not matched with C/C	Specification of battery and C/C	Replacement of Battery or C/C

Case study of Troubleshooting

The usage hour of appliances is getting shorter than ever!

Possible Reason	Check point	Solution
Usage of appliance which is large consumption	Specification of appliances	Reduce power usage
Loose connection	Connector, terminal	Retightening
Shade on PV module	Surrounding condition	Removal of the source
Damage of PV module	Condition of PV module	If bad, Contact engineer
Rust of connector	Condition of connector	Cleaning (with sandpaper)
Battery is weakening	Performance of battery	If bad, Replace it
Malfunction of C/C	Operation of C/C	If bad, Replace it

Case study of Troubleshooting

Appliances can not use even with correct connection of battery!

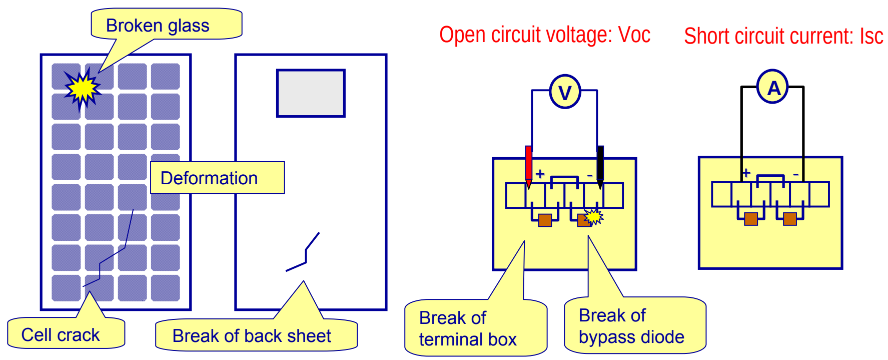
Possible Reason	Check point	Solution
Failure of appliance	Condition of appliance	Repair/Replacement
Loose connection	Connector, terminal	Retightening
Battery can not charge fully	Condition of battery, C/C	If bad, Contact supplier
Damage of cable, SW	Condition of cable, SW	Repair/Replacement
Malfunction of C/C	Operation of C/C	If bad, Contact engineer

The interval of water refilling is getting shorter than ever!

Possible Reason	Check point	Solution
Overcharge	Function of charge controller	If bad, Contact supplier
Leave battery at hot place	Ambient condition	Change in place
Leakage of electrolyte	Damage of battery case	If bad, Replace it
Battery is weakening	Performance of battery	If bad, Replace it

Troubleshooting

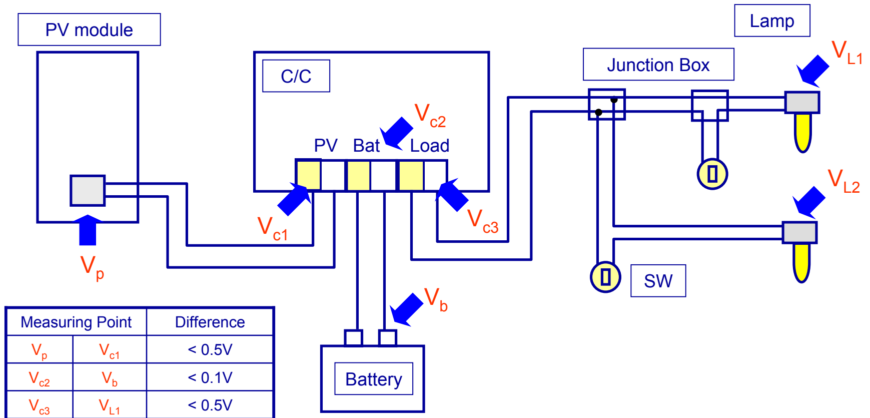
How to check PV module



Visual check → Measure Voc and Isc → Check operation

Troubleshooting

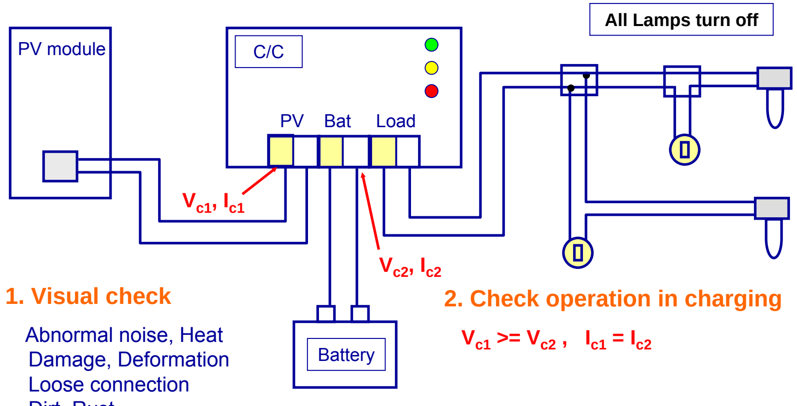
How to check voltage drop at SHS



Measuring Point		Difference
V_p	V_{c1}	< 0.5V
V_{c2}	V_b	< 0.1V
V_{c3}	V_{L1}	< 0.5V
V_{c3}	V_{L2}	< 0.5V

Troubleshooting

How to check C/C



1. Visual check

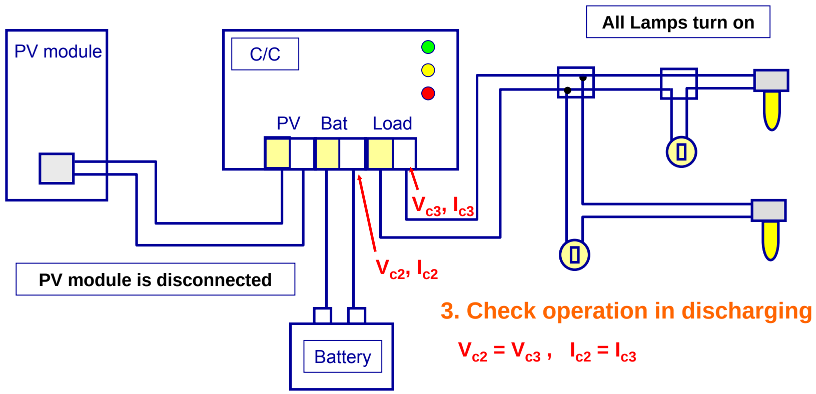
Abnormal noise, Heat
Damage, Deformation
Loose connection
Dirt, Rust
LED operation

2. Check operation in charging

$V_{c1} >= V_{c2}$, $I_{c1} = I_{c2}$

Troubleshooting

How to check C/C



3. Check operation in discharging

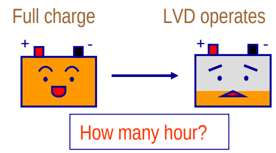
$V_{c2} = V_{c3}$, $I_{c2} = I_{c3}$

Troubleshooting

How to check battery performance

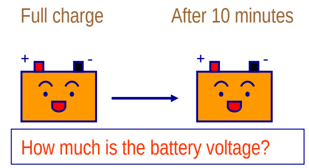
1) Check using hour of electricity

After charging battery fully, use electricity with constant load (example; two 11W CFL lamps)
Measure using hour of electricity until LVD operates and compare with designed hour.
If measured hour is less than 80% of designed hour, the battery almost reaches the end of its usefulness.



2) Check the battery voltage

After charging battery fully, leave the battery in the condition of charging stop.
After 10 minutes, measure the battery voltage.
If the voltage is lower than 12.5V, the battery almost reaches the end of its usefulness.



Procurement

- Procurement of reliable component is the KEY to ensure system reliability & sustainability
  - Use standard PV module
  - Use components of good brand
  - Do NOT use handmade type components
  - Check datasheet
- The success of Solar project is already determined around 90% at the time of procurement
  - If good components were procured, the project is almost successful.
  - If poor components were procured, the project is already failed.

Always obtain data sheet.
No datasheet, No quality

Standards, Specification does NOT ensure Quality

Battery

- Use good brand model
- Obtain datasheet (capacity at several discharge rate)
- Check the value of full voltage and discharged voltage
  - Select charge controller model based on these values
- Specify discharge rate
- Specific Gravity depends on Models / Manufactures
  → Do NOT specify it in the bidding document

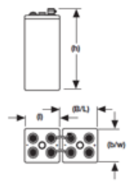
Battery
(Datasheet)

Always obtain datasheet

Check Ah capacity at each discharge rate
(C_{10}, C_{24}, C_{100} etc.)

Data of C_{10} is recommendable for system evaluation.

OPzS Solar 1320
up to
OPzS Solar 2500



Used for New Ibajay (El Nido) PV system

Type	Part number	Nominal voltage V	Nominal capacity C_{120} 1.85 V/C 25°C Ah	Length (l) max. mm	Width (b/w) max. mm	Height* (h) max. mm	Installed length (B/L) mm	Weight including acid approx. kg	Weight acid** approx. kg	Internal resistance mΩ	Short circuit current A	Terminal	Pole pairs	Capacities in Ah (C_6 - C_{240} at 25°C) C_6 1.75 V/C	C_{10} 1.80 V/C	C_{12} 1.80 V/C	C_{24} 1.80 V/C	C_{48} 1.80 V/C	C_{72} 1.80 V/C	C_{100} 1.85 V/C	C_{120} 1.85 V/C	C_{240} 1.85 V/C
OPzS Solar 1650	NVSL021650WC0FA	2	1650	215	235	695	225	73.2	21.7	0.26	7900	F-M8	2	1025	1174	1170	1290	1440	1540	1620	1650	1730
OPzS Solar 1990	NVSL021990WC0FA	2	1990	215	277	695	225	86.4	26.1	0.23	8900	F-M8	2	1230	1411	1405	1550	1730	1850	1950	1990	2090
OPzS Solar 2350	NVSL022350WC0FA	2	2350	215	277	845	225	108.0	33.7	0.24	8500	F-M8	2	1575	1751	1740	1910	2090	2200	2300	2350	2470
OPzS Solar 2500	NVSL022500WC0FA	2	2500	215	277	845	225	114.0	32.7	0.22	9300	F-M8	2	1670	1854	1845	2015	2215	2335	2445	2500	2600
OPzS Solar 3100	NVSL023100WC0FA	2	3100	215	400	815	225	151.0	50.0	0.16	12800	F-M8	3	2085	2317	2305	2520	2755	2910	3040	3100	3250
OPzS Solar 3350	NVSL023350WC0FA	2	3350	215	400	815	225	158.0	48.0	0.14	14600	F-M8	3	2275	2523	2510	2740	2985	3135	3280	3350	3520
OPzS Solar 3850	NVSL023850WC0FA	2	3850	215	490	815	225	184.0	60.0	0.12	17000	F-M8	4	2595	2884	2870	3135	3430	3615	3765	3850	4040
OPzS Solar 4100	NVSL024100WC0FA	2	4100	215	490	815	225	191.0	58.0	0.11	17800	F-M8	4	2785	3090	3075	3355	3650	3840	4000	4100	4300
OPzS Solar 4600	NVSL024600WC0FA	2	4600	215	580	815	225	217.0	71.0	0.11	18600	F-M8	4	3100	3450	3435	3765	4100	4300	4500	4600	4850

*The above mentioned height can differ depending on the used vent(s).

**Acid density d_N = 1.24 kg/l

Charge Controller

Always obtain data sheet.
No datasheet, No quality

- Use good brand model
- Obtain datasheet (HVD, HVR, LVR, LVD)
  - Set point voltage should match to the procured battery
- Check functions
- Use cycle charging type
  → Charge controller for UPS type is not suitable

DC Light

Always obtain data sheet.
No datasheet, No quality

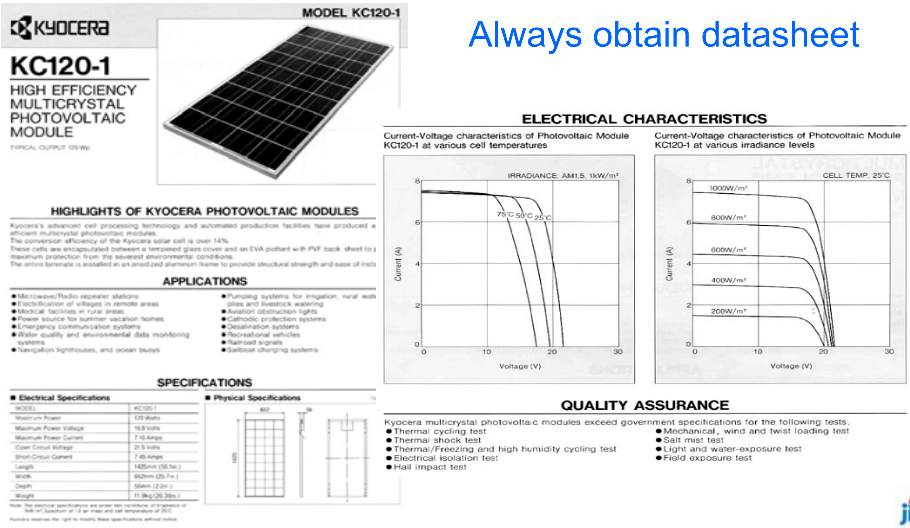
- ✶ Use good brand model
  - – Many cheep low quality lights are available → Do not use them
  - – Do not use handmade type light → low efficiency, low reliability
- ✶ Check input range
  - – 10.5V ~ 14.5V
  - – Minimum input voltage should be 1V lower than LVD to allow some voltage drop in cables.
  - – Maximum input voltage should be higher than HVD.
- ✶ Check radio interference
  - – Should be no interference to AM radio from 2 m
- ✶ Check inverter quality
  - – Should be 2 transistor type
  - – Remove tube while turning on. → Should not be burned

PV Module

- ✶ Normally, except Pangan-an case, PV modules are very reliable.
- ✶ Make sure 36 cells (Vmp : Min. 16.5V) for 12V system
- ✶ Make sure there is a label at back side
- ✶ Use same model No. for series and parallel connection
  (Pangan-an is a bad example)

PV Module

(Datasheet)



Always obtain datasheet

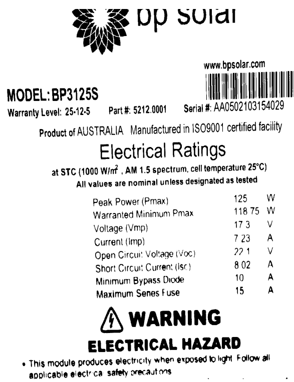
PV Module

(Label)

Always check label at backside

< Applied to El Nido system>

< Module surface >



< Label >

PV Module

(Third Party Certification)

Example of third party certification

By TÜV Rheinland

For reliable PV system, use certified PV module!

No.	Items	No.	Items
1	Thermal cycle test	7	Hail impact test
2	Humidity freeze test	8	Twist test
3	Damp heat test	9	Mechanical load test
4	Heat test	10	Static load test
5	Light exposure test	11	Robustness of terminations test
6	Salt spray test	12	Impulse voltage test

Inverter

(for centralized system)

Electrical specification:

Continuous output power : W, kVA
Allowable peak power
Efficiency
Rated input voltage : same as battery voltage
Input voltage range : same as battery voltage range
Rated output voltage (regulation), Rated output current
Frequency (regulation), Wave form, Power factor

Indication :

DC voltage, DC current, AC voltage, AC current, (Frequency)
Output power : W, Wh (*Watt-hour meter is necessary for a centralized PV system*

Data logging:

Data logging function is essential for to monitor system status.
Inverter with this function is highly recommended.

Others:

Charge control, Stacking connection etc.

Inverter

(for small-scale AC system)

Trace 2500 Series Inverters (60 Hertz Models)

Inverter Model Number	2512	2624	2232	2536	2548
Continuous Power*	2500 Watts	2600 Watts	2200 Watts	2500 Watts	2500 Watts
Surge Power**	8000 Watts	8000 Watts	6500 Watts	8000 Watts	8000 Watts
Efficiency	96% peak - greater than 85% from 50 watts to rated output				
No Load Current					
-Search Mode	.030 amps	.018 amps	.016 amps	.014 amps	.012 amps
-Full Voltage	.60 amps	.36 amps	.32 amps	.28 amps	.24 amps
Nominal Input Voltage	12 VDC	24 VDC	32 VDC	36 VDC	48 VDC
Input Voltage Range	8.8 - 15.6	14.9 - 30.7	19.9 - 42.9	19.9 - 47.0	22.4 - 62.6
Nominal Output Range	**120 VAC** (100, 220, 230, 240, VAC - 50 or 60 Hz models also available)				
Voltage Regulation	±2% RMS				
Frequency Regulation-60Hz	±.04% RMS				
Waveform	Modified Sine				
Power Factor	Power factor of load can vary from -1 to +1				
Stacking Option Available	YES				
Load Sensing Sensitivity	5 to 80W				
Inverter Protection Circuits:					
with Auto Reset	High battery, low battery, high temperature, instantaneous over-current with linear temp compensation.				
with Manual Reset	Extended over-current (more than 20 seconds), inverter output connected to grid or genset.				
Battery Protection Circuit	Load compensated, "smart" overdischarge protection				
Cooling	Thermally activated AC fan				
Dimensions (HxWxD)	9.5 x 11.5 x 13.5				
Weight	Product weight: 42 - 44 lbs. Ship weight: 47 - 49 lbs.				
Warranty	2 year parts and labor				
Other Voltage/frequency specs for export are as follows: (Example 2512 /NE)					
	/A = 240VAC/50Hz	/NE = 220VAC50Hz	/J = 100VAC/50Hz	/K - 100VAC/60Hz	
	/W = 220VAC/60Hz	/E = 230VAC/50Hz	/U = 240VAC/60Hz	(Two wire output only)	

Check
- Continuous power
- Surge Power

Measuring Equipment

In addition to components, Measuring equipment is also important to procure.

✶ SHS
- AC-DC Clamp meter
- Lux meter
- Emission thermometer
- Compass & Angle finder

✶ Centralized system
- AC-DC Clamp meter
- Emission thermometer
- AC Clamp Power meter
- Pyranometer
- Data acquisition system

Exercise 1

1-1 Fill in blanks

Feature of each PV system

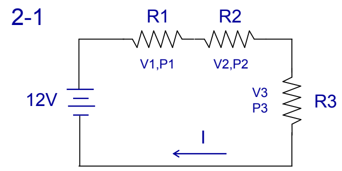
System	BCS	DC SHS	AC SHS	Centralized System
Capacity of PV array	300W	50W	100W	10kW
Charge controller	(Panel meter)	Need	Need	Need
Battery	Need	Need	Need	Need
Inverter	No	No	Need	Need
Distribution line	No	No	No	Need
Supply electricity	DC	DC	AC	AC
Number of user	Share (10)	1	1	More than 10

1-2 Answer following questions?

1) PV Module converts __solar energy__ into __DC electricity__ .
2) Peak load is a __Maximum__ load power. Unit: [W]
3) What is the device required the most special care in PV system? __Battery__.

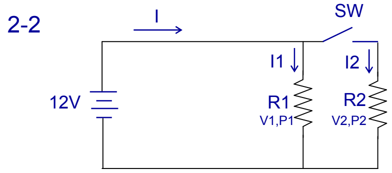
Exercise 2 Fill in blanks

2-1



1) (Series) connection
2) R1 = R2 = R3 = 1 Ω
   R_T = (3 Ω)
   I = (12 V) / R_T = (4 A)
3) R1 =1 Ω , R2 = 2 Ω , R3 = 3 Ω
   6 Ω 2 A
   R_T = (2 V), I = (12 W)
   V1 = ( ), P3 = ( )
4) P1 = 3W, P2 = 6W, P3 = 15W
   24 W 2 A
   P_T= (1.5 V), I = (3 V)
   V1 = (7.5 V), V2 = ( )
   V3 = ( )

2-2

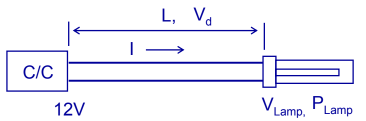


1) (Parallel) connection
2) R1 = R2 = 2 Ω , SW: OFF
   V1 = (12 V), V2 = (0 V)
   I1 = (6 A), I2 = (0 A), I = (6 A)
   P1 = (72 W), P2 = (0 W)
3) R1 =6 Ω , R2 = 4 Ω , SW: ON
   I1 = (2 A), I2 = (3 A), I = (5 A)
   V1 = (12 V), V2 = (12 V)
   P1 = (24 W), P2 = (36 W), P_T = (60 W)

Exercise 3 Fill in blanks

3-1

(Cable resistance: 0.01 Ω /m)

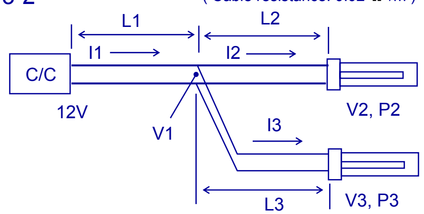


1) How to reduce voltage drop?
   (Use of thicker cable)
   (Minimization of cable length)
   (Use of energy-saving lamp)
2) I = 5A, L = 20m
   V_{drop} = I x R = (5) x (2) x (0.01) x (20)
   = (2V)
3)

Case	I	L	V_d	V_{Lamp}	P_{Lamp}
1	5A	20m	(2V)	(10V)	(50W)
2	5A	10m	(1V)	(11V)	(55W)
3	2A	10m	(0.4V)	(11.6V)	(23.2W)

3-2

(Cable resistance: 0.02 Ω /m)



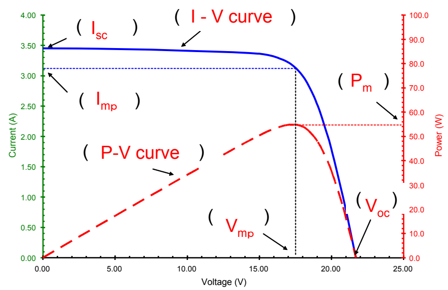
1) I2 = I3 = 2A, L1 = L2 = L3 = 5m
   I1 = I(2) + I(3) = (4A)
   V1 = (12V) – I1 x (2) x (0.02) x L1 = (11.2V)
   V2 = (10.8V), V3 = (10.8V), P2 = (21.6W)
2) I2 = 1A, I3 = 2A, L1 = L2 = 5m, L3 = 10m
   I1 = (3A)
   V1 = (11.4V), V2 = (11.2V), V3 = (10.6V)
   P2 = (11.2W), P3 = (21.2W)

Exercise 4

4-1 Answer following questions?

1) Higher irradiance increases output __current__.
2) Higher __temperature__ reduces output voltage.
3) What is the purpose of installing blocking diode? __To prevent reverse current from another string__.
4) What is the purpose of installing bypass diode? __To bypass the current in case cells have less output__.
5) What happen to the bypass diode when battery is connected in reverse?
   __Bypass diode will be broken (burned)__.

4-2 Fill in blanks



4-3 Fill in blanks with marks

Features of each type of PV Module

	Mono-crystalline	Poly-crystalline	Amorphous
Efficiency	H	M	L
Module Area (same output)	S	M	L
Cost (Same output)	H	M	L
Reliability	H	M	L

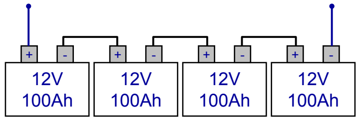
[Mark] (H:high, M:middle, L:low) or (L:large, M:medium, S:small)

Exercise 5

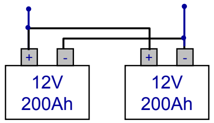
5-1 Answer following questions?

1) What is role of battery ? Storage of electricity.
2) What has close relation to the state of charge? Specific gravity.
3) If liquid level of battery is low, what should you do? Add distilled water (Do not add acid).
4) What affects the cycle life of battery? Depth of discharge, Temperature.
5) How to prevent sulfation? Avoid over discharge, Avoid leaving battery uncharged.

5-2 Fill in blanks



1) Series Connection
2) Total Voltage : 48 V.
3) Total Energy storage: 4800 Wh.
4) What for is the boost charge required?
To equal voltage of each battery.



1) Parallel Connection
2) Total Voltage : 12 V.
3) Total Energy storage: 4800 Wh.

Exercise 6

6-1 Answer following questions?

1) What does charge controller protect batteries from? Overcharge, Over discharge.

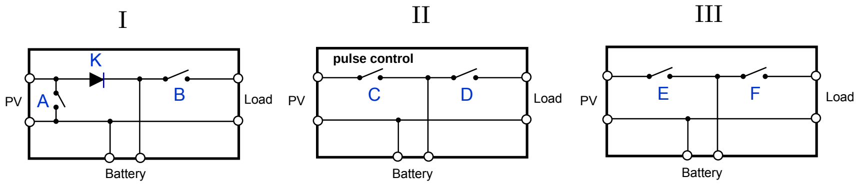
2) What function operates in the following case?

* When battery voltage reaches to LVD, load is disconnected.
* When battery voltage reaches to HVD at the series type C/C , PV is disconnected.
* When battery voltage recovers above LVR , load is reconnected.

3) In which order should the equipments be connected? 1) Battery > 2) PV > 3) Load.

Exercise 6

6-2 Fill in blank spaces



Status of switch (ON or OFF or Pulse) [ON = short, OFF = open]

	Controller I		Controller II		Controller III	
Battery voltage	SW A	SW B	SW C	SW D	SW E	SW F
V = HVD	ON	ON	Pulse/OFF	ON	OFF	ON
HVD > V > HVR	ON / OFF	ON	ON	ON	ON / OFF	ON
LVR > V > LVD	OFF	ON / OFF	ON	ON / OFF	ON	ON / OFF
V = LVD	OFF	OFF	ON	OFF	ON	OFF
Type	Shunt		PWM		Series	

* What is "K"? Blocking diode.

Exercise 7

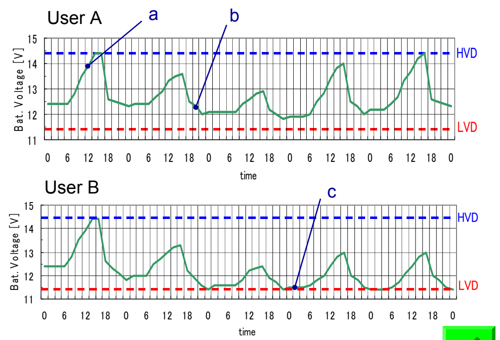
7-1 Answer following questions?

1) Write down the temperature correction formula of specific gravity S20 = St + 0.0007 * (t – 20).
2) Calculate the specific gravity (S20) at the following condition (t = 40 ℃ , S40 = 1.200)

[S20 = S40 + 0.0007 * (40 – 20) = 1.200 + 0.0007 * 20 = 1.214] , S20 = 1.214.

7-2 Answer following questions?

1) What is the status of battery at this point?
a. Battery is being charged.
b. Battery is being discharged.
c. Battery is disconnected from C/C (LVD).



2) Explain the status of use for each user.

User A
Status of Use is good.
System did not stop even bad weather day.

User B
Status of use is bad, overuse.
System stopped a few times in night time.
Battery could not recover even fine day.

ANNEX 4　: Examination Evaluation Sheet

Evaluation Sheet for PV trainer's Training

No.	NAME	Background	Company	Result	Examination score at each page																Training evaluation			Score ratio at each subjects							Number of subject			Calc ability
					Charge controller			Battery			PV Module			System			Basic Electricity			Exam Total	Lecture	Hands-on	Total	CC	Bat	PV	System	Elec	Training	Ave %	>70	>80	>90	
																							100	100	100	100	100	100	100	100	70	80	90	
1																																		
2																																		
3																																		
4																																		
5																																		
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11																																		
12																																		
13																																		
14																																		
15																																		

A : Qualified [2 subjects >= 90, 4 subjects >= 80]

B : Qualified Assistant Trainer (Basic) [3 subjects >= 80, 4 subjects >= 70]

C : Follow-up Training (Lecture) is necessary

D : Follow-up Training (Lecture & Hands-on) is necessary

E : Follow-up Training (Lecture & Hands-on + Basic Electricity) is necessary

F : Additional Training (Beginner's level) is necessary [Ave. score below 50]

As for grading C, D and E
C:Average ≧60 and lack of one subject to be qualified. D:Average≧60 but not C. E:Average≧50 and ＜60.

Evaluation Sheet for PV Engineer's Training

No.	NAME	Organization		Examination score at each page														Score ratio at each subjects						
				Basic Electricity		Battery		C/C		PV Module		PV system		Monitoring & troubleshooting			Exam Total	Electricity	Bat	C/C	PV	System	Monitoring	Ave %
				10	24	13	12	11	7	18	13	15	11	13	15	9	171	100	100	100	100	100	100	100
1			Pre																					
			Post																					
2			Pre																					
			Post																					
3			Pre																					
			Post																					
4			Pre																					
			Post																					
5			Pre																					
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6			Pre																					
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7			Pre																					
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8			Pre																					
			Post																					
9			Pre																					
			Post																					
10			Pre																					
			Post																					
																	Pre							
																	Post							

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