

Sandec Technical Fact Sheet

No. 01 (07/17)

Installing a Solar Electric Setup

Sandec
Sanitation, Water and Solid
Waste for Development

This document is not intended to replace help from a professional electrician. Its aim is to assist people with little or no knowledge of solar powered energy in how to set up a solar power installation in the field. Online resources or professional advice might still be advisable depending on the project.

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Part I: Electricity

Current

Electric current can be either direct or alternating. In direct current (DC), the electric current flows in one direction at all points in time. In an alternating current (AC), the flow changes direction periodically.

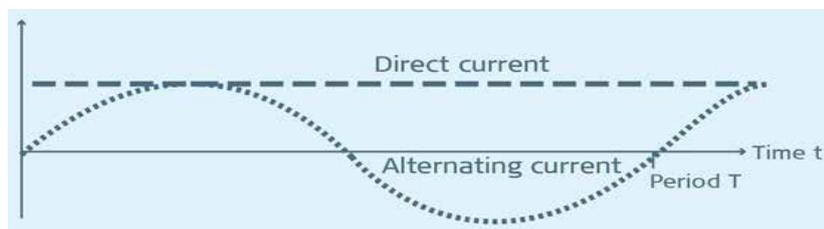


Figure 1: Representation of visual difference between DC and AC currents¹

AC (symbol: ) is the form in which electric power is typically delivered in the wall sockets of residences.

DC (symbol: ) is produced by sources, such as batteries or solar cells. The solar setup described in this brief provides DC current.

Measurement units

Unit	Ampere	Volt	Watt
Symbol	[A]	[V]	[W]
Definition	Unit of electric current.	Unit of electric potential or voltage.	Unit of power. For DC currents: [W] = [A] * [V]
Waterfall analogy	Amperage represents the volume of water going over the edge of the fall.	Voltage is the height of the waterfall.	Watts are the force of the water hitting the bottom.

Unit	Ampere hour	Watt hour
Symbol	[Ah]	[Wh]
Definition	Unit of electric charge. Charge transferred by a current of one ampere in one hour.	Unit of energy quantity. Energy equivalent to one watt of power sustained for one hour.
Application	Usually used to measure the capacity of a battery (amount of electricity that can be stored and provided).	To know the energy consumed by a device, its power (W) can be multiplied by the duration of use (h).
Example	A battery of a capacity of 50[Ah] can provide 50[A] over 1 hour, or 25[A] over 2 hours, etc.	A 1[W] device used during one hour uses an energy of 1[Wh]. A 6[W] device used during 10 minutes also uses an energy of 1[Wh].

Part II: Field solar supply system

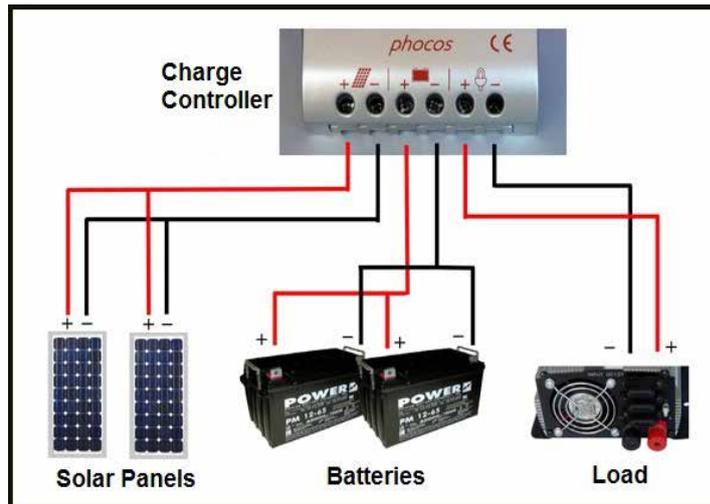


Figure 2: Standard solar wiring diagramⁱⁱ

Components

Solar panel is a photovoltaic panel absorbing the sun's ray as the source of energy for generating electricity.

Load is the equipment you supply power to through your solar setup (a lamp, an incubator, etc.).

Battery stores the energy generated from the solar panel. The stored energy can be discharged to use at night. There are various types of batteries. In the field, the most common are: lead acid, which are the ones found most frequently and are inexpensive, and lead-gel batteries, which have a longer life cycle, but are more expensive.

Charge controller (also called charge regulator) is the interface part between the solar panel, the battery and the load. It controls the rate at which electric current is added to or drawn from batteries. Charge controllers are useful to protect battery life because they prevent overcharging or deep discharging.

Converter converts a voltage to another (DC/DC converter). In a solar setup, a DC/DC converter could be typically used to convert 12/24V battery DC voltage to a 5V DC voltage (e.g. for USB charging).

Inverter converts one type of current to another (DC to AC). In a solar setup, the inverter typically converts the DC power from the solar panel/battery to AC power. The AC power can then be used to power laptops, TVs, and other typical electrical appliances.

Wiring: For DC current, power cables have two wires, red and black. By convention, red is the positive lead, black is negative.

Material technical specifications

Solar panels: On solar panels, you will find indications about the maximum power provided, P_{max} [W], Current at P_{max} [A] and Voltage at P_{max} [V]. P_{max} is the maximum power that can be delivered by the solar panel under optimal conditions.

Load: You need to know the power requirements of your load (equipment). If you do not have access to the technical specifications, measure the current [A] and the voltage [V] with a multimeter. Information about laptops and mobiles can easily be found online.

Battery: On batteries, you will find indications about Capacity [Ah], Cycle use [V], Standby use [V] and Initial current (max) [A]. Cycle use is the charging voltage that should be used when the battery is cyclically used (regular power source - discharged and re-charged repeatedly). Standby use is the charging voltage that should be maintained when the battery is not in use (standby).

Charge controller: On a charge controller, you can find different types of indications, such as: Normal voltage [V], Max input current [A], Max load current [A], Over charge [V], Over discharge [V], and Max solar input [A]. They indicate the maximum inputs and outputs of the controller.

Inverter: On an inverter, you will find information about the Input [V], the voltage coming in the inverter; Output [V], the resulting voltage that can be used; and Power [W].

Setup options

Solar panels and batteries can be set up in a series or parallel combination to increase the capacity of the power supply system. Depending on the need, two setups are possible.

In a **series** combination, the capacity [Ah] stays constant, and the voltage [V] adds up. Use a jumper (wire) between the negative of a battery (or panel) to the positive of another battery. Plug the device to the positive wire of the open connector from the first battery and the negative of the open connector on your last battery.

In a **parallel** combination, the capacity [Ah] adds up, and the voltage [V] stays constant. Connect the positive poles together with jumpers, and also connect the negative poles of the batteries (or panels) together. Connect positive and negative wires of the last battery to the device.

In both cases, the resulting power is the multiplication of the current and voltage: $[W] = [A] * [V]$.

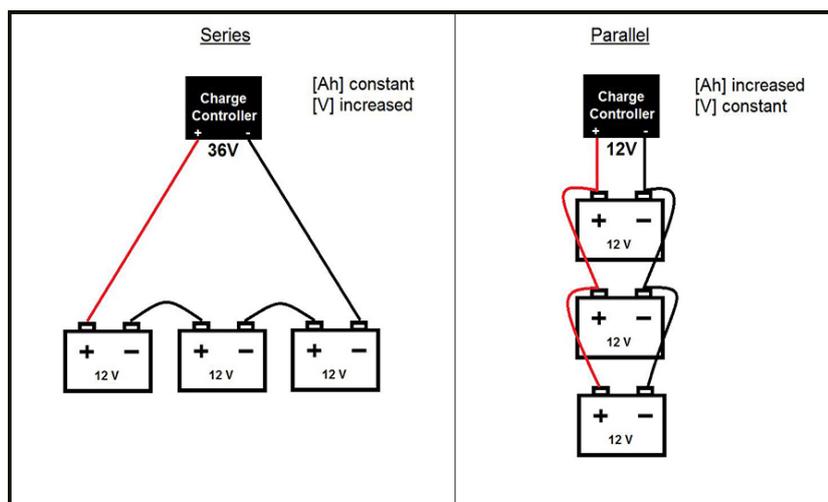


Figure 3: Series and parallel wiring

When connecting batteries in a combination, the capacities should match as much as possible. Also, jumpers between batteries and from batteries to the device should be of similar length. Otherwise, one of the batteries would be overused and wear down quickly.

The amount of current that can be transported depends on the wire gauge. A wire that is too small in diameter for the amount of current can overheat. You can find tables or calculators online that calculate the wire gauge required according to the voltage, amperage and length of wire you are using.

(Example: <http://www.energymatters.com.au/climate-data/cable-sizing-calculator.php>)

Field tips

- Check the voltage of the batteries you buy in the field. For a 12[V] battery, do not buy one with a voltage lower than 10[V].
- Always first plug the negative pole, then the positive pole. Always unplug first the positive pole, then the negative pole.
- When plugging the battery, there can be small sparks, which is normal.
- Batteries and more importantly wire must always be kept at ambient temperature. If they get warm, it is a sign of an over-current. Unplug your system immediately.
- Always connect your batteries/solar panels together (in series or in parallel) before connecting to the charge controller.
- Always plug the solar panels last to the charge controller.
- Regularly clean the solar panels with a soft cloth or brush. It is especially important in dry areas, as dust and other substances build up over time and reduce the amount of energy generated.

Part III: Measurements

Calculating power needs

Whenever energy undergoes a process, such as storage, transmission or transformation, there is a loss due to the yield of the material. The technical specifications of materials indicate their values in ideal conditions. When calculating the power needs and supply of your system, it is better to include an estimated loss to have a safety margin. In the following example, we will calculate the ideal scenario, then we will add in an estimated loss for a realistic scenario. Calculations of a solar powered energy supply system are, therefore, always approximate.

Power needs can be calculated in [Wh] or [Ah]. [Wh] will be used so that the capacities in [Ah] always relate to their corresponding voltage.

1. Energy requirement for equipment

We need to daily recharge 5 mobiles and 2 laptops, and to turn on the light 6 hours per day. They all work on 230 [V] AC. An inverter (DC/AC) is used to convert the supplied 12[V] DC power to the 230[V] AC requested.

Material: 1 laptop Acer: 4.85[Ah], 19[V] battery → $4.85[\text{Ah}] * 19[\text{V}] = 92.15[\text{Wh}]$
 1 mobile Samsung Galaxy S6: 2.5[Ah], 3.85[V] battery → $2.5[\text{Ah}] * 3.85[\text{V}] = 9.63[\text{Wh}]$
 1 lamp bulb: 230[V], 10[W] → 10[Wh] for 1 hour

Ideal: $(5 * 9.63[\text{Wh}]) + (2 * 92.15[\text{Wh}]) + 10[\text{W}] * 6[\text{h}] = \underline{292.45[\text{Wh}]}$ required

Realistic: Energy will be dissipated through the mobile and laptop chargers. We can estimate an 80% yield for the chargers.

1. $(5 * 9.63[\text{Wh}] / 0.80) + (2 * 92.15[\text{Wh}] / 0.80) + (10[\text{W}] * 6[\text{h}]) = 350.56[\text{Wh}]$ required, BUT

The (DC/AC) inverter also has a yield of 80%, it increases the amount of energy required:

2. $(350.56[\text{Wh}] / 0.80) = \underline{438.20 [\text{Ah}]}$ required

2. Energy generated by solar panels

To calculate the maximum power produced by a solar panel in a day, multiply the Pmax value indicated [W] by the estimated number of hours of sun exposure. We estimate 6 hours of sunlight daily.

Solar panel technical specifications: Pmax = 30[W], Voltage at Pmax = 18[V]

Ideal: $30[\text{W}] * 6[\text{h}] = \underline{180[\text{Wh}]}$ of maximum power produced in a day

Realistic: Pmax is the ideal value, when the sun is direct on the panel (no angle - 90°). In real conditions, the power provided (P) will depend on the solar panel quality (manufacturing, age, and condition), and on the sunlight conditions (clouds, angle of exposure, sunlight strength, etc.). To account for these, we can estimate lower values: P between 10-25[W], estimated hours of good sunlight 4-5[h].

$15[\text{W}] * 5[\text{h}] = \underline{75[\text{Wh}]}$ of maximum power produced

3. Storage capacity of the battery

The capacity of the battery is indicated in [Ah]. To know the quantity of energy available in [Wh], multiply the capacity by the battery voltage.

Battery technical specifications: Capacity = 50 [Ah], 12[V]

Ideal: $50[\text{Ah}] * 12[\text{V}] = \underline{600[\text{Wh}]}$ of capacity

Realistic: You cannot completely empty your battery, due to inherent limitations of the battery chemistry. The expected capacity is around one third lower than the one indicated.

On the batteries, the cycle use voltage is often indicated. It will not be entirely available when the battery is in use. Once it is plugged, the voltage will drop to around 12[V], which is the usage voltage.

$$600[\text{Wh}] * 2/3 = 400[\text{Wh}] \text{ of capacity}$$

Note: You can never withdraw all the power from a battery; this can also permanently damage a battery. For a 12[V] battery, it is recommended not to go below 10.8[V].

4. System calculation

Summary of realistic scenario: We need 438.20[Wh] per day for our equipment.
We have solar panels that can provide 75[Wh] per panel per day.
We have batteries with a capacity of 400[Wh] each.

One battery is enough to store the energy required by the equipment.
To fully charge one battery in one day, we need $400[\text{Wh}]/75[\text{Wh}] = 5.33 = 6$ solar panels.
To provide the daily energy required by our equipment, we need $438.20[\text{Wh}]/75[\text{Wh}] = 5.84 = 6$ solar panels.

If cloudy days are expected, we can consider having two batteries in a series setup, and 8 solar panels (or bigger panels) to charge the batteries.

Multimeter

A multimeter is an electronic measurement unit that can measure voltage, amperage and resistance. Always respect the type of current you want to measure (AC :  or DC : ) and the magnitude (μA , mA or A). Place the cables in the right position on your multimeter: the black cable goes in the COM position, and the red cable in the corresponding position (A for amperage or V for Voltage). Be careful not to create a short circuit while measuring: always set the wires far apart.

You can select the range you are measuring (for example: [A], [mA], [μA]). If you are not sure about your range, start high ([A]) and decrease if necessary to get a readable value ([mA] or [μA]). If you measure a high value on the position for a low measurement, the fuse of the multimeter will be overloaded and might break.

Always ensure that the multimeter is set on the right position (V for voltage measurement and A for current measurement).

Hold only the plastic insulation of the probes when measuring and not the metal pins to avoid electric shock.

Voltage

To measure the real voltage of a battery, unplug all devices from it, wait 5 minutes for the chemistry to settle, and simply touch the positive pole of the battery with your positive cable (red) and the negative pole with the black cable.

To measure the voltage of another type of device, unplug your device, remove insulation from a small part of the cables, plug in your device and touch the wires with your multimeter cables. The multimeter displays a negative value when you touch the wires with the wrong multimeter cable (black cable on positive wire and inversely).

Amperage

To measure the amperage, the current must pass through the multimeter. Remove insulation from a small part of one end of the wire (when the device is unplugged). Use the multimeter as an extension cord: plug in the device and place one multimeter cable on the end of the wire, and the other cable on the wire of the device.

(Fig. 4). If possible, disconnect your device before removing your multimeter cables from the wire.

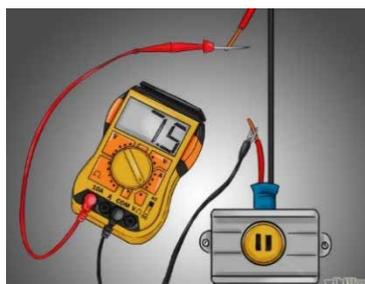


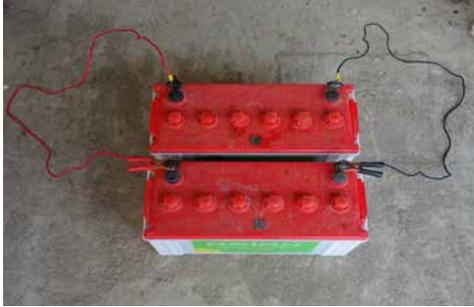
Figure 4: Amperage measurement with multimeterⁱⁱⁱ

Part IV: Step by step setup

Example of a setup to power an incubator, with solar panels connected in parallel and batteries connected in parallel.

System setup

1. Batteries setup in parallel



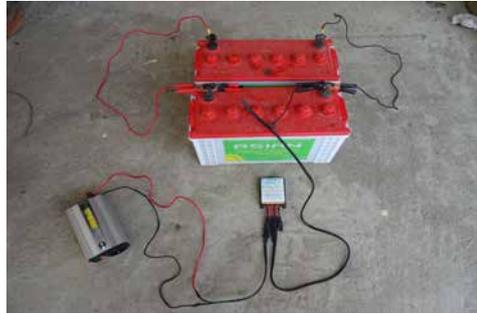
2. Batteries to charge controller



3. Option 1: Incubator charge controller



4. Option 2: DC/AC inverter to charge controller



5. Solar panel setup in parallel



6. Solar panels to charge controller



7. Overall system



Measurements

1. Voltage of battery



2. Amperage of battery (battery to controller)



3. Voltage coming out of charge controller (controller to incubator)



4. Amperage coming out of charge controller (controller to incubator)



5. Voltage of solar panels (out of multiple plug)



6. Amperage of solar panels (solar panels to charge controller)



Photos by: Dorian Tosi Robinson

Part V: Security

Working with electricity always presents risks. A voltage of 12[V] is generally used, but depending on the setup, the voltage might be higher, and if you are using an inverter, it might work with 230[V]. In the field, the following safety principles should also be observed:

- Always respect the polarity of components.
- Batteries must be placed in a well-ventilated area.
- Never use or connect batteries in the presence of petrol cans.
- Never connect the positive and negative poles from a battery together as this will create a short circuit and a risk of explosion. In the case of a short circuit, protect yourself from battery vapour emissions.
- Do not recharge batteries without a regulator.
- Lead batteries are harmful to the environment; please dispose of waste properly.

References

ⁱhttps://www.swissgrid.ch/swissgrid/en/home/grid/technologies/ac_dc.html

ⁱⁱhttp://www.smsolar.net/solar_non-grid_system_wiring_diagram.html

ⁱⁱⁱ<http://fr.wikihow.com/mesurer-l'intensit%C3%A9-d'un-courant-%C3%A9lectrique>

Sources

<http://www.solartechology.co.uk/support-centre/calculating-your-solar-requirements>

<https://geoffthegreygeek.com/using-a-multimeter/>

Further reading

Solar Information: http://www.smsolar.net/solar_library.html

DIY OFF GRID SOLAR SYSTEM: <http://www.instructables.com/id/DIY-OFF-GRID-SOLAR-SYSTEM/>



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July 2017

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