Solar Power Basics

Solar Electric Systems Training

For 12 Volt DC systems

RIAL BAAI SOLAR

"Bringing light to the community"

South Sudan

Revision 14.8

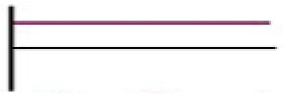
Glossary

Electricity

Electricity happens when electrons flow from one material to another. Electricity can do work like make light, make heat, turn motors, send radio waves, and turn on magnets.

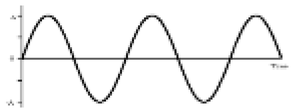
There are two types of electricity: AC and DC.

DC (Direct Current)



Direct current has a steady voltage with a positive wire and a negative wire. The positive wire is always positive voltage.

AC (Alternating Current)



Alternating current sources switch the voltage back and forth in time between positive and negative wires. The number of times the voltage is switched back and forth each second is called the “frequency”.

AC and DC should never be directly mixed. Special equipment can convert one type of electricity to the other. Devices powered by electricity use only AC or only DC; they cannot be used in the other or they will break.

Voltage

Voltage is the amount of force pushing the electrons to move. Electrons always flow from a high voltage to a low voltage.

Units: Volt (V)

Current

Current is the amount of electrons that are flowing. Electrons always move at the same speed, there are either more or less electrons flowing.

Units: Amps (A), or Ampere

Power

Power is the combination of voltage and current. It is how much work the electricity is doing.

Units: Watt (W)

Energy

Is the amount of electric energy that can be used over time. It can be stored in a battery (like a fuel tank).

Units: Watt hour (Wh)

Resistance

Resistance is the limits of a conductor that restrict the current flow. Bigger wires have less resitance and allow more electrons to flow. Everything has resistance to electrical current. Resistance causes heat. When small wires flow too many electrons, the resistance causes the wire to get hot. Resistance causes the voltage to drop.

Units: Ohm (Ω)

Mathematical Relationships in Electricity

Power (W) = Voltage (V) x Current (A)

Voltage (V) = Power (W) ÷ Current (A)

Current (A) = Power (W) ÷ Voltage (V)

Energy (Wh) = Power (W) x Time (h)

Time (h) = Energy (Wh) ÷ Power (W)

Resistance (Ω) = Voltage Drop (V) ÷ Current (A)

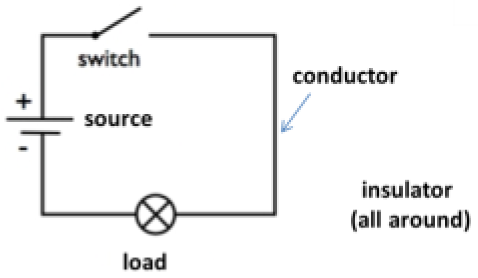
Voltage Drop from Resistance (V) = Resistance (Ω) x Current (A)

Heat Generated from Resistance (W) = Resistance (Ω) x Current (A) x Current (A)

Hour (h) = 60 Minutes

Circuits

The circuit is the path that electricity follows. The image below shows a typical circuit.



Source

The source provides the electrons. It produces the voltage (V) force. It has a maximum amount of current flow (A) that it can release. Examples of sources are generators and batteries.

NEVER MIX SOURCES. When sources of different voltage are put together, the source with the higher voltage forces current into the source with the lower voltage. This usually causes the sources to burn up. It is how electrons are put back into rechargeable batteries.

Conductor

Conductors allow electrons to flow through them. Conductors connect the components of an electrical system together. Good conductors are metals, salt water, and human insides.

Insulator

Insulators do not allow electrons to flow through them. Insulators prevent electricity from flowing where you do not want it to go. Insulators are plastic, rubber, air, wood, and human skin.

If the Voltage gets high enough, it will force electrons through an insulator. Electricity will pass through skin above 50 Volts. Electricity will flow through sweat, blood, or mucus on skin at 6 volts.

Load

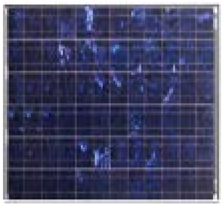
The load is the part of the circuit that we want to do work. Examples of loads are lights, TVs, motors, cell phones, battery chargers and computers.

Switch

The switch allows a person to open the circuit and stop the flow of electrons. This turns off the electrical system. Safe circuits also have a "fuse" or "circuit breaker" that opens automatically when the circuit has a bad problem. The fuse or circuit breaker opens a switch to protect the system or a person from getting hurt by the problem.

<u>Solar Equipment</u>

Solar Panel



The solar panel converts sun rays into electricity. The solar panel will collect the most rays when facing the sun. The important features about a solar panel are the 1. Power Rating (W), 2. Nominal Voltage (V), and 3. Maximum Current (A). The Power Rating is the maximum amount of power the solar panel will harvest when facing full sun at noon; most of the time, the panel will produce less than the rating.

Charge Controller

The charge controller makes sure the batteries are not overcharged and prevents electrons from going from the batteries back into the panel at night. The important features about charge controllers are the 1. Type (Diode, PWM or MPPT), 2. Maximum voltage, and 3. Maximum current.

Battery

The battery stores electricity like a tank stores fuel. It is a source of electricity. The most common battery for 12V solar equipment is the rechargeable "Lead Acid" type with "Deep Cycle" capability. The automobile uses a different kind of lead acid battery that is not good for solar equipment. The important features about batteries are the 1. Type (lead acid, NiCd, NMH, many others), 2. Nominal voltage and 3. Capacity (Ah).

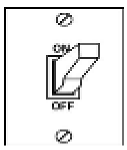
Inverter

The inverter converts the DC electricity from the battery to the AC current that runs many loads. The important features about the inverter are the 1. Type (Square Wave or True Sine Wave), 2. Input voltage, 3. Output voltage, and 4. Maximum power output.

Wire

The wires are the conductors that connect the components of the system. The wires must be large enough to carry the maximum amount of current for the system. Wires must be secured to a structure. Wires must be put where children cannot touch or pull on them. The important features about wires are the 1. Wire size and 2. Insulation type.

On/Off Switch



The On / Off switch opens the circuit conductor to stop the flow of electricity. The circuit should always be shut off with the switch when not in use so that electricity is not wasted. The important features of a switch are the 1. Voltage rating and 2. Current rating.

Connections

The connections are where the wires connect to the other wires from components or direction to the components. Bad wire connections cause the problems in most electrical systems. Wire connects must be tight, strong, insulated and protected from people touching them.

Fuses

A fuse is a safety device to prevent fires, equipment damage and injury to people. It is an automatic switch that opens (shuts off) the circuit when the current (A) gets larger than the fuse rating. If the fuse gets opened (off) the fuse must be replaced to get the circuit working again. Usually there is a problem that must be fixed before replacing the fuse. The important feature about the fuse are the 1. Maximum current rating and 2. socket type that holds the fuse.

Circuit Breaker

A circuit breaker is an automatic protection device just like the fuse. However, it can be opened and reclosed manually. If a high current opens the circuit breaker, it can be closed again with a manual switch. Usually there is a problem that must be fixed before re-closing the circuit breaker switch. The important feature about the circuit breaker are the 1. Maximum current rating, 2. socket type that holds the fuse, and 3. Type of electricity that the circuit breaker is made to open, AC or DC.

Tools

Voltmeter

The voltmeter will tell the voltage between two points where the wires from the meter are touched. If the meter has many other functions, it is called a "multimeter". Wires should always be measured with a voltmeter before working with them to make sure the circuit is off. Wires and connections should always be measured to make sure the voltages match before making connections.

Screwdriver

The screwdriver has a special shaped end that will fit in the top of screws to turn them. Turning a screw clockwise will move the screw in and tighten it. Turning a screw counter-clockwise will loosen and take a screw out.

Wire Cutter and Stripper

A wire cutter is scissors that are made of a special hard metal that can cut through electrical wires. The wire cutter is not strong enough to cut through fence wire, security cables, or metal sheets. A wire stripper will cut through the insulation around a wire without cutting the metal of the wire. It is used to remove a portion of the insulation at the end of a wire so that a connection can be made.

How to size a solar/ battery system

Step 1. Determine the load power and time

List all of the appliances with their running Watts and surge/starting Watts. Appliances with motors (refrigerator, washing machine, AC etc.) have a surge in power when they start up that is two to three times higher than the continuous power draw.

Estimate how many hours each appliance will run during the day. Multiply the running watts times the hours to get the energy (Wh) used each day.

Step 2. Size the Inverter

Add up the continuous Watts and surge Watts of all the appliances that could be running at the same time. This is the maximum power requirement (kWc and kWs).

Select an inverter with an output that exceeds the total continuous wattage requirement and surge wattage requirement. Most high quality solar inverters have a surge capacity that is double their continuous output rating. However, the lower quality (and lower price) inverters often don't meet their maximum and a larger size is needed.

Inverters come in True Sine (expensive) or Modified Sine (cheap). Appliances and lights generally work better and last longer on True Sine. Some electrical equipment will not work on Modified Sine. The best way is to test the loads and make sure they work on Modified Sine.

Step 3. Size the Solar Array

Add up the energy used each day for all of the appliances to get the total energy consumed by the system each day. This is the daily energy requirement (kWh/day). Take the total energy need for each day (kWh) and divide by 6 full hours of sun in a day (a number good for South Sudan). This will give you the size (kW) of the solar array that you need. Pick a module size (i.e. 100 W) and determine how many modules you need to make up the solar array size calculated.

Find a Charge Controller that matches the solar panel voltage and will handle the total current with all of the modules together. A Pulse Width Modulated (PWM) charge controller just lets the panel voltage match directly with the battery. A Maximum Power Point Tracking charge controller converts the optimum operating panel voltage to the battery voltage and is more efficient, and much more expensive.

Step 4. Size the Battery Bank

Determine the length of time in hours that the batteries must provide back-up power without solar charging. If the user is going to run the batteries until they are completely dead on a daily basis, the battery bank must be sized for one day to prevent undercharging of the batteries and continuous low capacity cycling.

For South Sudan, we found what works best is to have 6 kWh of battery per kW of solar panels. Or, for a 12V system, to have half the Amp-hour battery as the array size in watts. For example, a 200 W solar array should have a 100 Ah battery at 12V.

Determine a battery type. Small battery back-up systems do best with AGM, which are maintenance free. Large off-grid systems typically use flooded lead acid batteries and require service every three months (equalize charge and a water refill).

Find a battery size that will string together to match the inverter DC input voltage (i.e, 12, 24, or 48 V), and meet the required battery capacity without exceeding 3 parallel strings. Large systems prefer 48 V to reduce the wire size.

Verify that the module voltage matches the battery voltage and charge controller voltage.

Solar Sizing Calculation

Customer Name: | **Date:**

Location: | **Analyst:**

Customer Phone Number:

Description of the Loads Used Daily	Continuous Power (W) per Unit	Quantity	Running Power (W) together	Operating Time (hrs/day)	Energy Consumption (Wh/day)
Additional Motor Starting Power					

Total AC Load for Inverter Size (W)		*Round Up to nearest size* Inverter Size (W)	
Total Energy Consumption per Day(Wh)		*Divide by 6h of sun per day* Solar Size (W)	
Energy Storage Needed		*Divide by 12V (voltage of battery used)* Battery Size (Ah)	

Other Items Needed:

NOTES:

Examples of Load Power Consumption					
Cell Phone	10	W	Fan - Small	*80*	W
Laptop computer	70	W	Fan - Medium	150	W
TV - 14"	70	W	Fan - Large	230	W
TV - 28"	150	W	CF Light Small	40	W
TV - 32"	200	W	CF Light Medium	65	W
Refrigerator 50-60 liter	100	W	CF Light Large	115	W
Refrigeratror ~150 liter	200	W	AC - small	1000	W
Refrigerator ~ 500 liter	500	W	AC - large	5000	W

Solar Equipment Information

Battery Sizes and Charge

Lead Acid 12 V Deep Discharge Batteries

	Capacity	Energy	Dimensions (mm)			Weight
BCI Size	**Ah**	**Wh**	**L**	**W**	**H**	**kg**
U1	32	384	211	130	184	10
22NF	55	660	240	140	227	16
24	79	948	260	173	225	25
27	92	1104	306	173	225	28
30H	110	1320	343	173	235	33
31	105	1260	330	173	240	32
4D	200	2400	527	222	250	60
8D	245	2940	527	283	250	75

- There is about 8 Wh per kg of battery.
- Maximum charging rate should be 20% of rated capacity
- Maximum discharge rate of a deep discharge battery should be less than 50% of rated capacity.

Determining Charge Status of a 12V Lead Acid Battery

% Charge	Specific Gravity	Open Circuit Voltage
100%	1.27	12.6
75%	1.23	12.5
50%	1.20	12.2
25%	1.16	12.1
0%	1.13	11.9

Wire Sizing

Wire Size		Max Current	Voltage Drop Per amp meter
mm2	AWG	A	V/A/m
1	18	11	0.044
1.5	16	14	0.029
2.5	14	20	0.018
4	12	25	0.011
6	10	35	0.0073
10	8	45	0.0044
16	6	60	0.0028
25	4	80	0.00175
35	3	100	0.00125
50	2	120	0.00093
70	O	150	0.00063
95	OO	180	0.00046

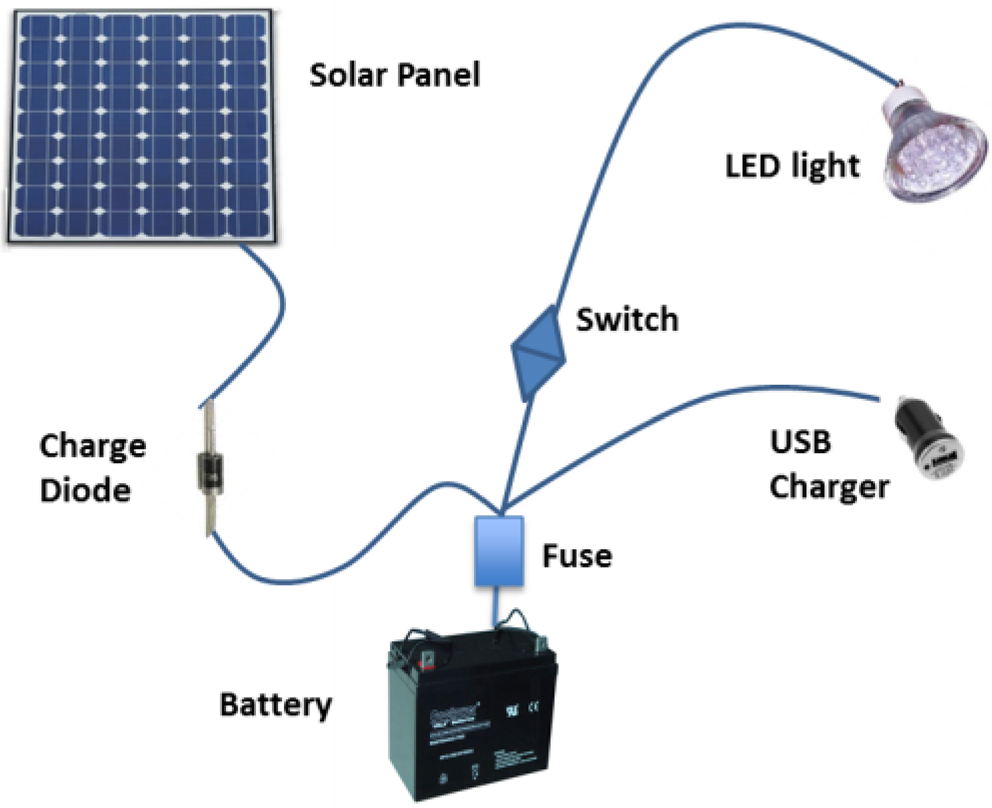
Wire Size Between Battery and Inverter
12 Volt System

Inverter Watts	Current Amps	Wire Size AWG	mm2
300	28	#8	6
500	46	#6	16
750	69	#4	25
1000	93	#2	35
1500	139	O	50
2000	185	OO	70
3000	278	OOOO	135
4000	370		

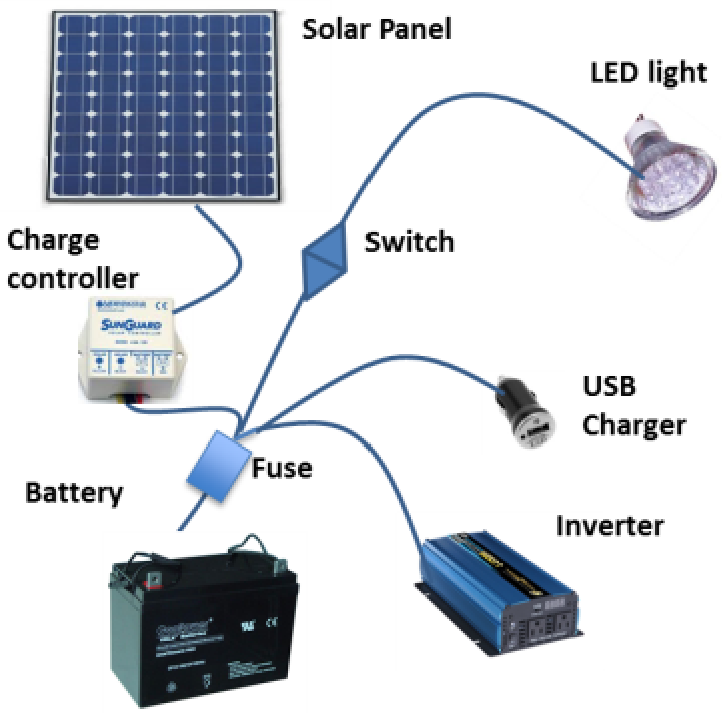
Example Systems

Solar Light Kit

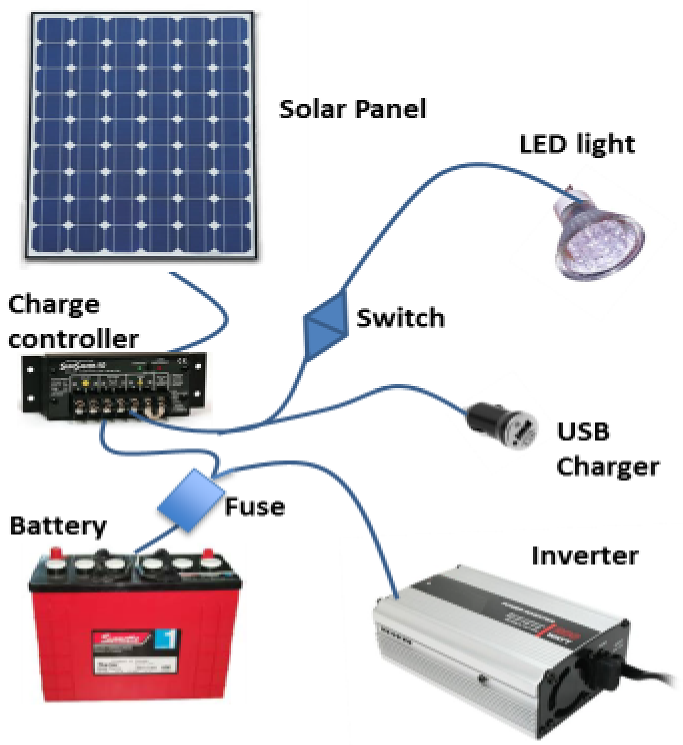
Solar Light and Phone Charger



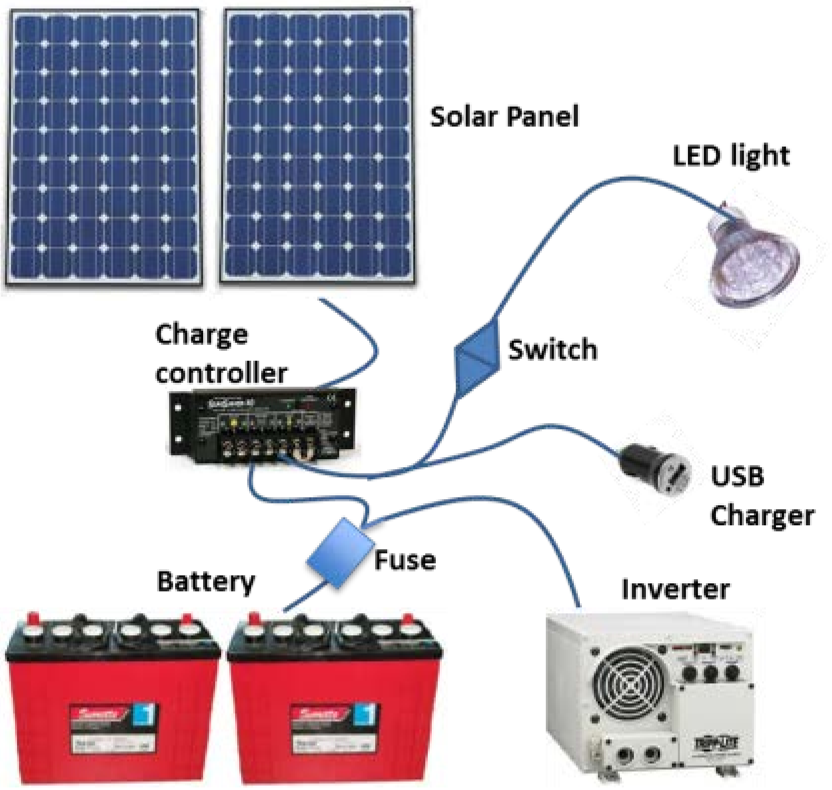
Solar Hut Small System



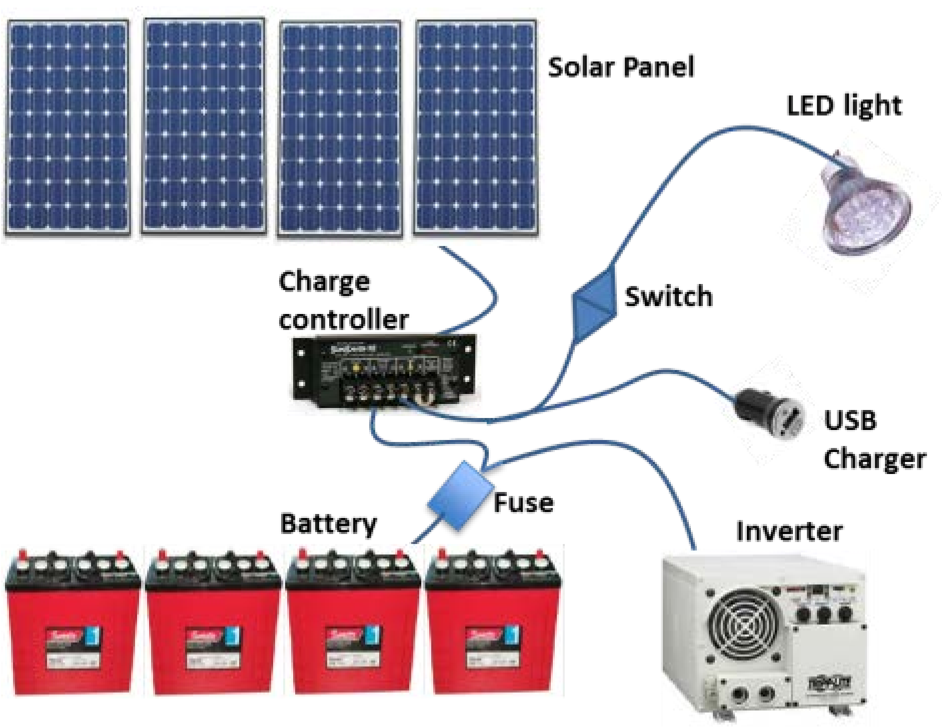
Solar Hut large System



Solar House Small System

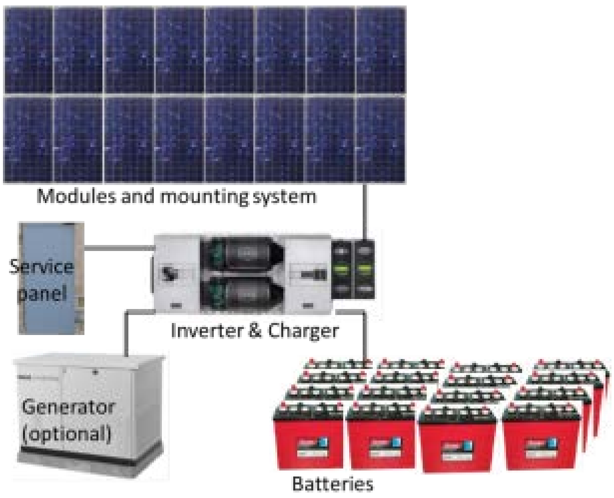


Solar House Large System

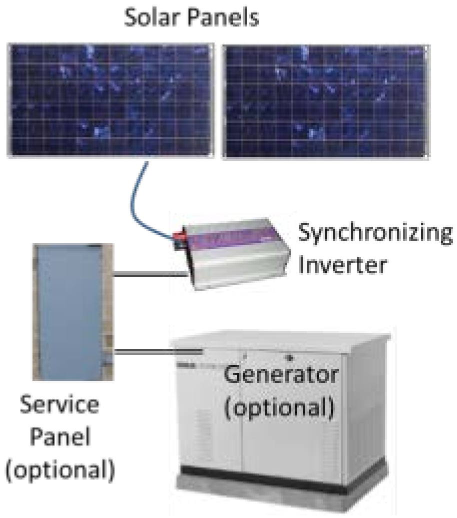


Advanced Systems Systems

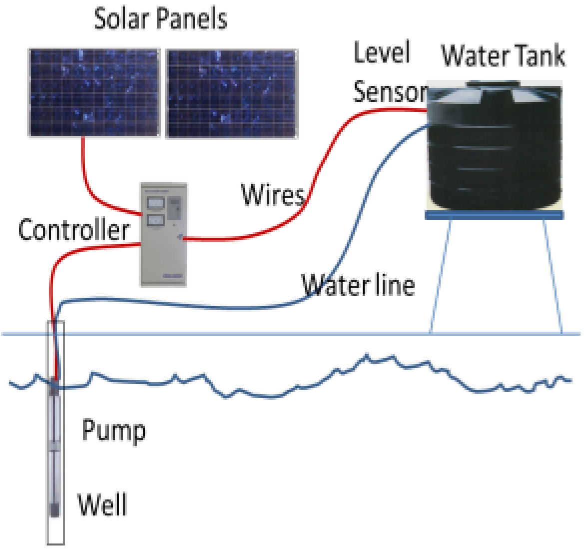
Solar Mansion and Compound System



Solar Generator Fuel Saver



Solar Water Well



Solar Irrigation Pump