Electrical Design Of Off-Grid System

Energy Auditing

Hire an Energy Auditor

Use LED, BEE 5* appliances

Get sign-off from client on Load Profile

Design Step

“Divide and Rule Policy”

“Worst Case Design”

Basics

Power	Watts	W	**$P = V \times I$**
Energy	Watt-Hour	Wh	**$E = P \times Time$**

Daily Energy Consumption

Appliance	Watts (W)	No.s	Total Watts (W x No.)	No.of hours	Energy (Wh)
Fan	80	3	240	8	1920
Tubelight	60	3	180	8	1440
			Total wattage = 420W		**Total Energy = 3360 Wh**

Inverter Design

Inverters are rated in
Output Power (VA) and Input DC voltage

Total wattage of Load = 420W

Assume 2% cable loss between any two components (98% eff)

Inverter output power **= 420W / 98% = 429W**

System Voltage: 12V, 24V or 48V?

	12V	24V	48V
Max Load	<300W	<1.5kW	<10kW
Current	<10A	<40A	<80A
Appliances	Lights	TV, AC, Fridge	special industrial or agricultural use

Single Phase or Three Phase Inverter?

	Single	Three
Power	<5kW	>5kW
Cost	Cheaper	Costlier

But, always Inverter and Market will Determine System Voltage

In the market, check the standard value of inverter available with 429W rated power and determine the input voltage.

The available inverter will decide the system voltage.

If available inverter for our power rating can take only ‘X’ volts as input voltage, then the system should be designed for ‘X’ volts

For this example, consider the Meanwell 500W, 48V True Sinewave inverter that is available in the market.

So system DC voltage = 48V

Inverter Design – Other calculations

Daily Energy of AC Load = 3360 Wh

Consider Inverter efficiency as 93%

Inverter Output Energy after 2% cable loss = 3360Wh / 98% = 3429Wh

Inverter Input energy = 3429Wh / 93% = 3687Wh

Battery Design

Specification for Battery is given in terms of

Capacity (Ah) and Output Voltage

Input Energy of Inverter = 3687 Wh

Consider 2% DC cable loss between Battery and Inverter

Battery Output Energy = 3687Wh / 98% = 3762Wh

Ah capacity = Energy / System voltage = 3762Wh / 48V = 79 Ah

Battery Design

Consider Depth of Discharge (DoD) as 50%

Actual capacity = Ah capacity / DoD = 79 / 50% = 158 Ah

Consider Days of Autonomy (DoA) as 2 days

Final capacity = Actual capacity x DoA = 158 x 2 = 316 Ah

Battery requirement and Market Availability

In the market, a battery of 316Ah will not be available.

The available battery size is 120Ah, 12V

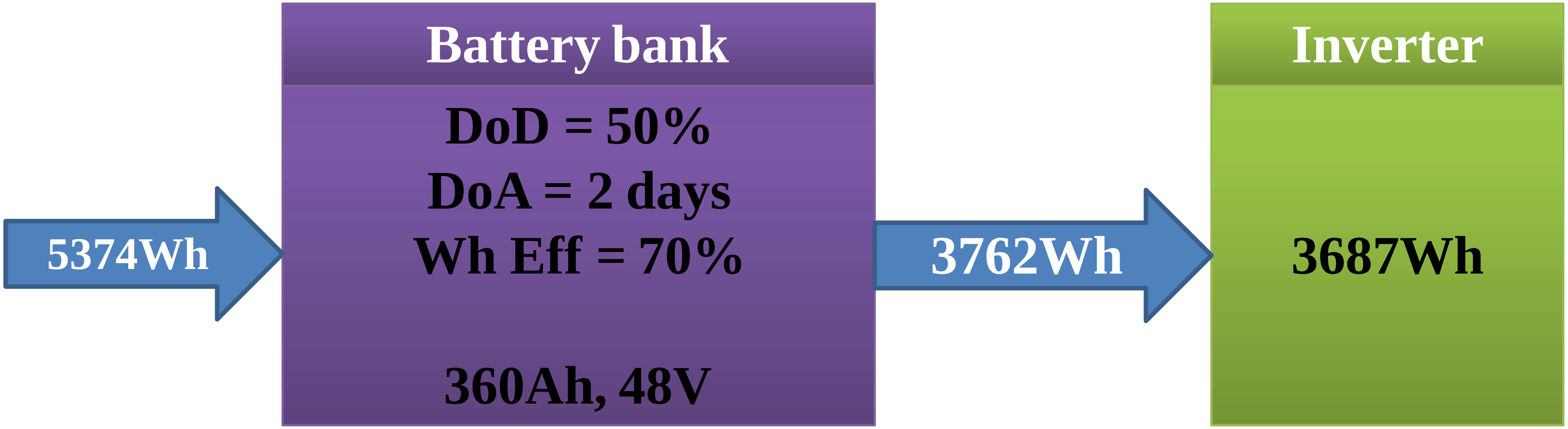
Connect 4 of these batteries in series to get 48V

No.of battery strings in parallel = Total Ah capacity / Available capacity = 316/120 = 2.6 ~ 3 strings of batteries

All these 12 batteries are connected in series-parallel combination to increase the overall capacity

To[illegible] capacity = 120Ah x 3 = 360Ah

Battery Design



Considering battery bank Wh efficiency to be 70%, the input energy to the battery bank is:

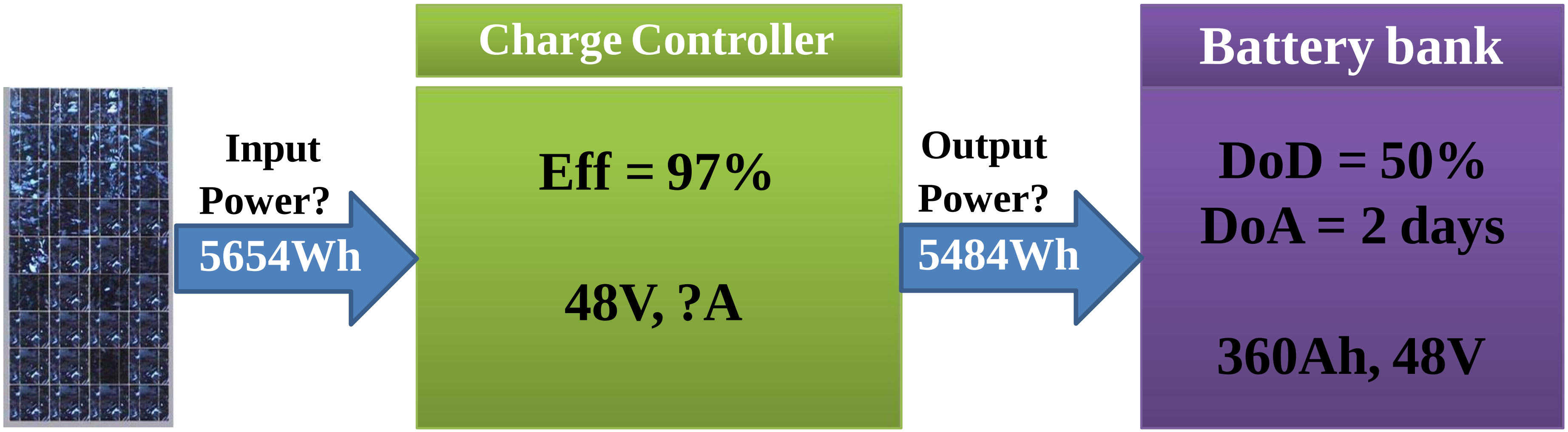
Input energy = Output energy / Efficiency
= 3762Wh / 70%
= 5374Wh

Charge Controller Design

Consider cable loss of 2% between Charge Controller and Battery (98% eff)

Output Energy of CC = 5374Wh / 98% = 5484Wh

Charge Controller Design



Considering CC efficiency to be 97%, the input energy to the controller is:

Input energy = Output energy / Efficiency
= 5484Wh / 97%
= 5654Wh

Solar PV Array Design

Input Energy of Charge Controller = 5654 Wh (Output energy of Array)

Consider 2% cable loss between Panel and CC (98% eff)

Output energy of array = 5654**Wh / 98% = 5770Wh**

Solar PV Array Design

Specification for Panel is given in terms of

Output Power (Wp) and Output Voltage (Vmpp)

Output energy of Array = 5770 Wh

Find peak sun hours for the location (say, 5 hrs/day for Delhi)

Output power of array = Output energy of array / Peak sun hours

- **= 5770Wh / 5h = 1154W**

Module Derate Factors

PV module nameplate DC rating (5% Loss) - *Avoidable*

Mismatch in PV Modules (2% loss) - *Avoidable*

Panel Soiling (5% loss) - *Avoidable*

Shading (2.5% loss) - *Avoidable*

Module Aging (1% per year, 10% eff loss after 10 years)

Temperature correction based on temp coeff. rated power of module (-0.45% / ^{o}C)

Applying Module Derate Factors

Derate Factor	Loss%
PV module nameplate	5%
Panel Soiling	5%
Shading	2.5%
Mismatch in PV Modules	2%
Power Temp Coeff = STC temp diff x module power coeff = (80 – 25) x 0.45%	24.75%
Total	**39.25%**

$$T_{Cell} = T_{Air} + \frac{NOCT - 20}{80} S$$

Let's say the module temp reaches 80°C in Delhi.

After applying above factors, Module power = 1154W / 60.75% = 1900W

After applying Aging factor, Module power = 1900W / 90% = 2111W

Solar PV Array Design

- Consider that only Solarworld 275W modules are available in market at Vmpp = 31V and Impp = 8.94A
- No. of modules = 2111 / 275 = 7.7 ~ 8 modules
- **So total Array peak watts = 8 x 275 = 2200Wp**

Solar PV Array Design

Charge Controller

Output Power = 2200Wp

Eff = 97%

48V, ?A

Module rating is 275Wp at 31Vmpp

8 modules to be connected in series-parallel combination based on i/p operating voltage of CC

Solar PV Array Design

We’ll get back to PV Array design after selecting the Charge Controller

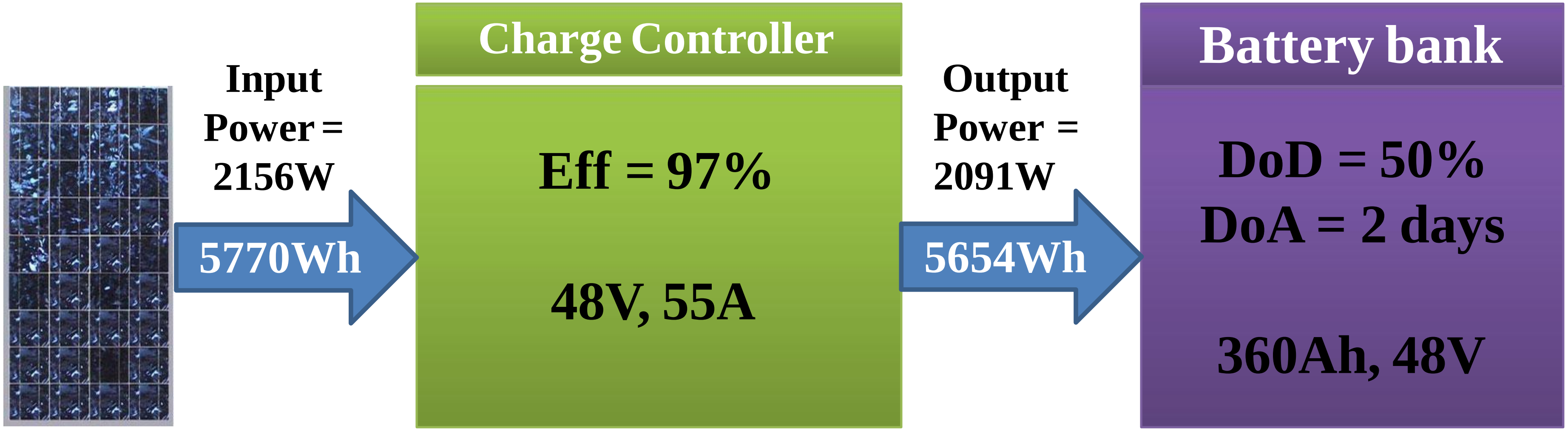
Coming Back to Charge Controller Design…

Input power at CC = Output power of PV array x Cable Eff%
= 2200 x 98%
= 2156W

Output power of CC = 2156 x 97%
= 2091W

Output current of CC = 2091W / 48V
= 44A

As a precaution, increase the rated current by 25% to account for solar panel producing more power than normal. So the charge controller rating will be 48V, 55A



Solar PV Array Design

Since Charge Controller operating voltage starts from 100V, and

Vmpp of Panel = 31V

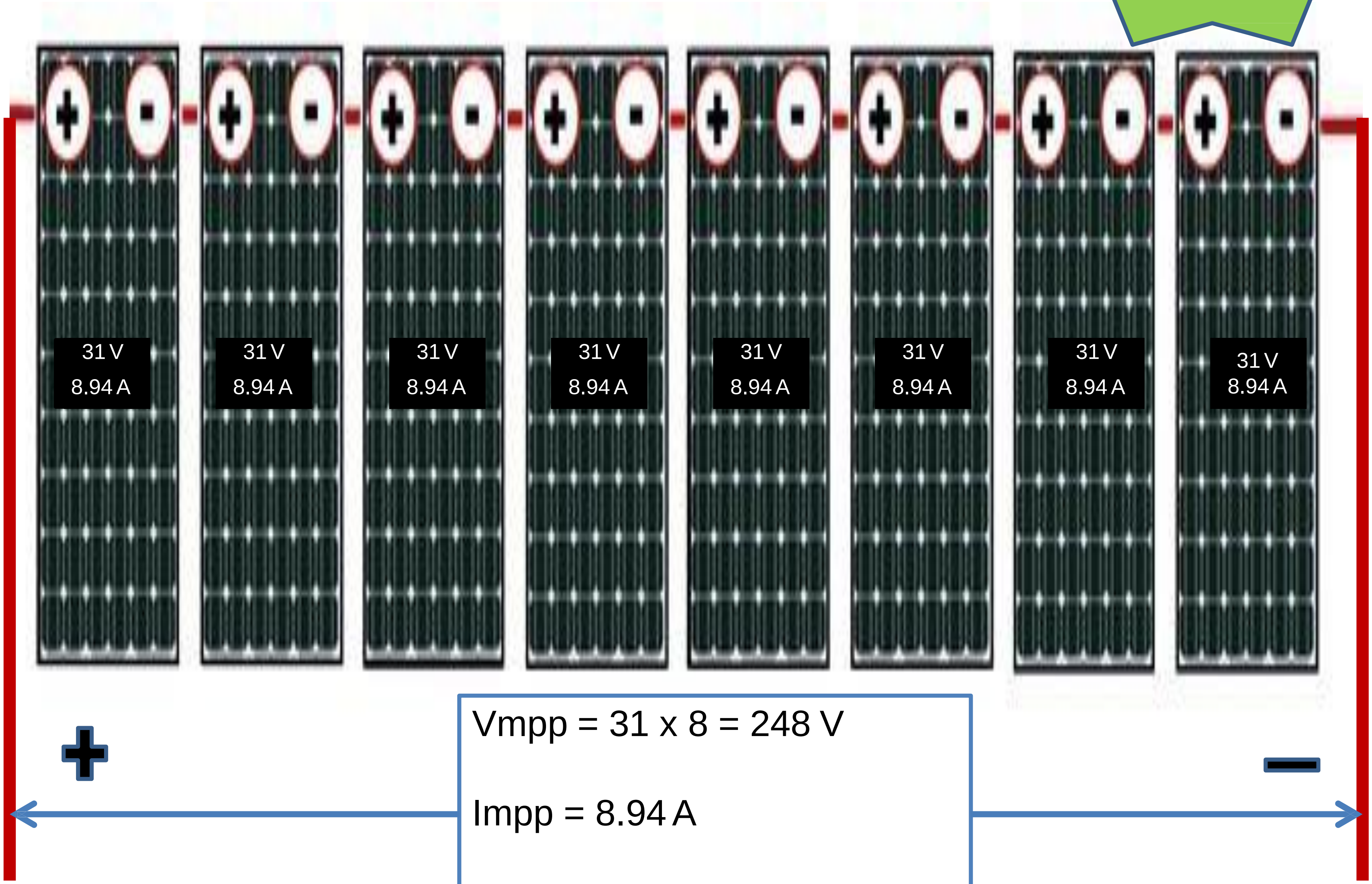
We need at least 100/31 = 3.2 ~ 4 panels connected in series

There are 8 panels in total

So 8/4 = 2 strings can be connected

Solar PV Array Design

Good



Vmpp = 31 x 8 = 248 V

Impp = 8.94 A

Pmpp = 248 x 8.94 = 2217 W

Overall design

Prepare Line Diagram