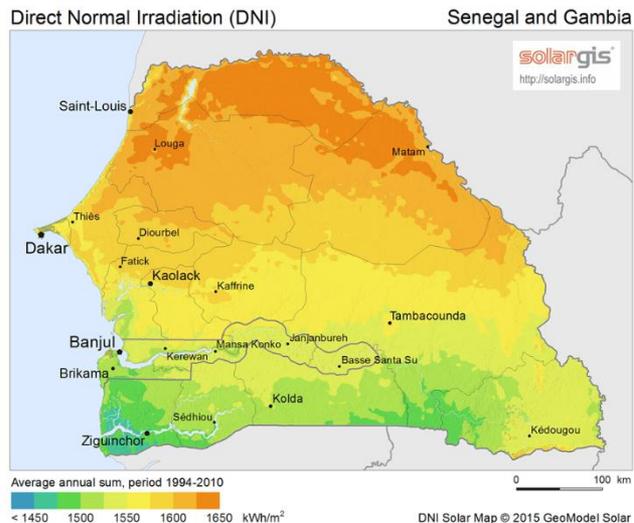




APOLLO SOLAR

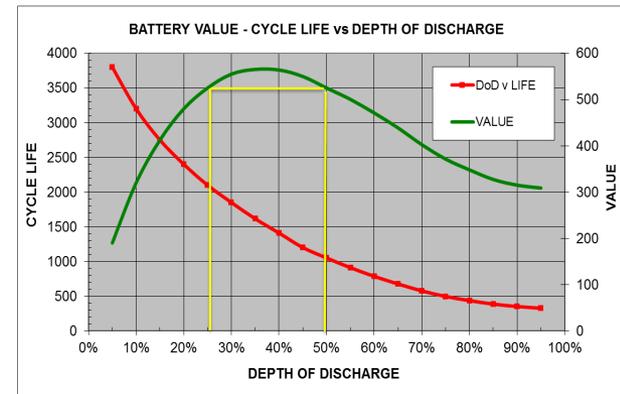
Initiation à la conception des systèmes - Systèmes d'énergie pour sites isolés Telecom



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Fournir de l'Energie en site isolé – Page 1

Le cout de l'énergie en site isolé a bien change dans la dernière décennie.

- **Energie continue et fiable** – Chaque site télécom doit etre alimenté en continu 24h/24; 7j/7. Une coupure induit des couts importants.
- **Zone électrifiée** – Si le réseau est disponible et fiable, on s'y raccorde simplement.
- **Zone non Electrifiée** – (Les réseaux telecom plus rapides que les réseaux électriques).
- **STEP 1 – Installer des GEP** – Plus de 640 000 sites sont en GE. Bonne solution ais cout élevé donc à réduire.
- **STEP 2 – Ajouter des batteries à Cyclier** – Le fonctionnement des GE peut etre optimisé et leur cout d'explotation réduit. Mais le cyclage frequent des batteries réduit leur durée de vie et le cout de remplacement devient trop cher.
- **STEP 3 – Ajouter du solaire** – La baisse des prix des panneaux permet de faire un appoint solaire dans la journée. Mais le cout d'exploitation du GE reste.
- **The NEXT STEP – PUR SOLAIRE**

Fournir de l'énergie en site isolé – Page 2

Le cout de l'énergie en site isolé a bien change dans la dernière décennie

- **The NEXT STEP – PUR SOLAIRE** – Il est maintenant prouvé que la solution pure solaire est la plus fiable et la moins chère en site isolé télécom.
- **Des milliers de sites télécom fonctionnent au solaire sans coupure** – C'est la preuve de la fiabilité.
- **Un champ solaire coute souvent moins cher qu'un GE** - Un GE continue est remplacé tous les deux à 3 ans alors que le champ PV produit endant 25 ans et n'a pas besoin de carburant.
- **Pourquoi le solaire est fiable?** 0 de mouvement – 0 carburant – faible maintenance
- **Pourquoi le solaire est rentable maintenant?** Baisse du cout des modules. Forte irradiation dans les pays à faible couverture électrique (Afrique)
- **C'est quoi un système pur solaire Apollo Solar?** Un Champ PV; Un parc batteries et un coffret de regulation qui gère charge, décharge, utilisation, enregistrement et envoie des données de monitoring par internet.
- **C'est quoi un système Hybride Solaire/GE Apollo Solar?** C'est un site ou le solaire n'est pas suffisant auquel on ajoute un GE d'appoint géré par le régulateur.

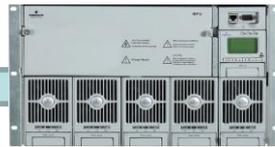
Avant: 1

STEP 1
Pas de réseau électrique on
installe des GE

2 GE en continu.



**Redresseurst
48V DC**



BTS 48V DC / 2kW.

Avant: 2

Step 2 - Rajout de batteries pour réduire le temps de fonctionnement des GE

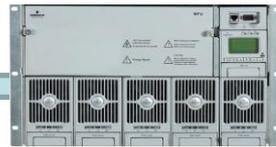


T

Batteries DCB

Avant: 3

Step 3 Rajout d'un appoint solaire



Régulateurs
simples



MAINTENANT

Step 1 TOUT SOLAIRE



Coffret de régulation



The Tower BTS needs 48V DC at typically 2kW.



Step 2 – If the space limits the PV Array, add a small (8kW) DC Generator for back up to fill in the difference.



Deep Cycle Batteries provide continuous DC power.

The losses in the battery are not critical because the Solar energy is essentially free.

Summary of System Design - Irradiation

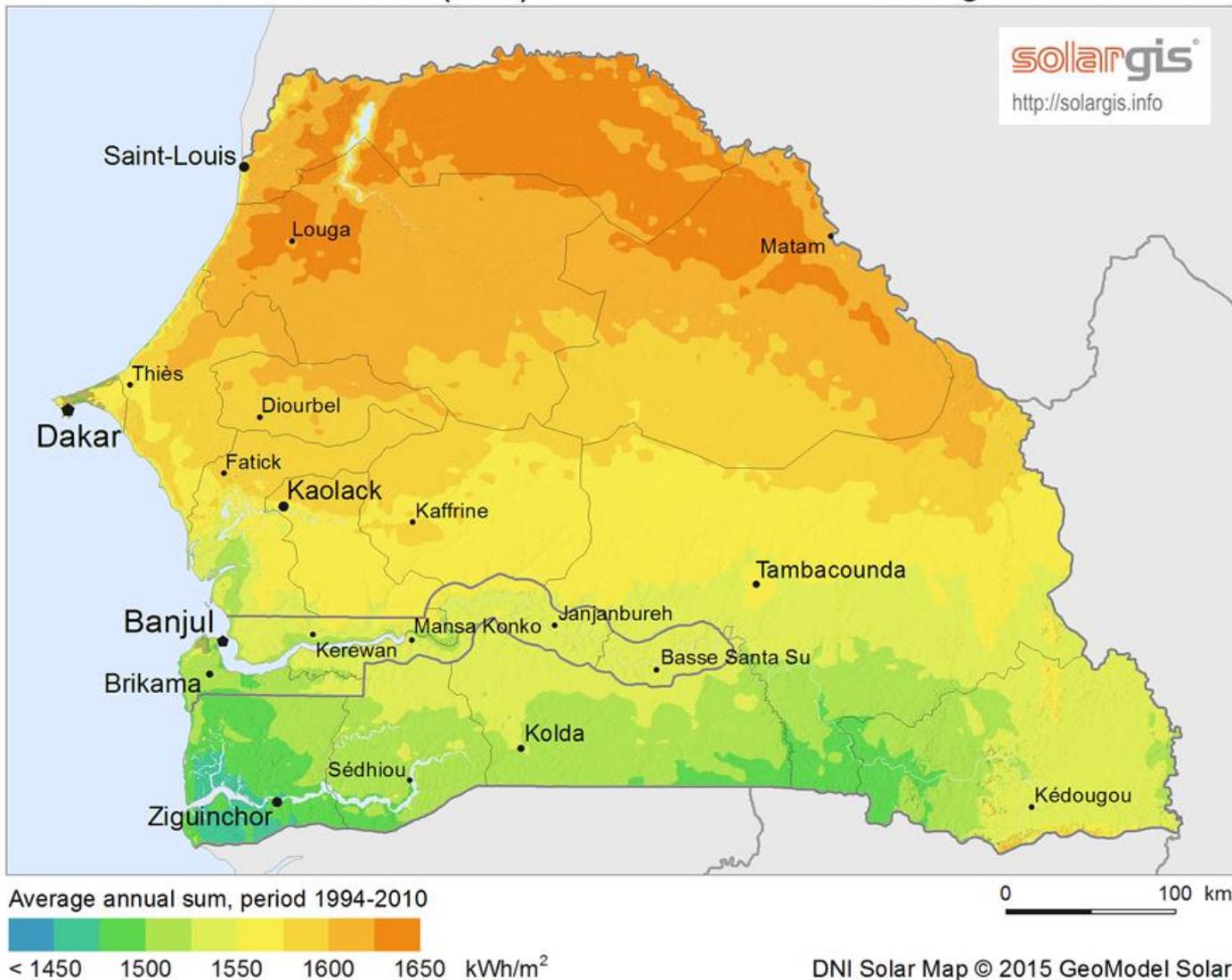
The Map at the right is shown in Annual averages. We use the energy per day which is simply the annual average divided by 365.

So Louga will have $1650/365$ or 4.52 kWh/m²/day average.

For Pure Solar systems, we must use the Minimum instead of the Average. Tables are available showing the min every month.

Direct Normal Irradiation (DNI)

Senegal and Gambia



Summary of System Design

Pure Solar Systems – No diesel generator or grid

1. The BTS is a constant Load supplied by the Battery 24/7.
2. The Battery must be recharged early the next day.
3. The PV Array is sized to provide all the energy to recharge the battery in one day while also powering the load.
4. Rule of thumb: PV Array to Load Ratio (ALR) of about 10:1. So a 1kW load will require about 10kW of PV Array. 9:1 ALR is also used.
5. Clouds will limit the Solar on some days, so the battery is oversized. Providing 3 days of Autonomy allows the system to run for 3 days with zero solar without damaging the batteries. Some locations require more autonomy.
6. Rule of thumb: The battery in kWh (at C100) will be about 130 times larger than the load in kW. So a site with 2kW Load will need a 260kWh battery. That is 5,000 Amp-Hours using 52 charging volts.

Pure Solar Examples

The actual sizing calculations done by Solene shown at the right show the results from calculations for 29 sites in West Africa.

The average ALR is 9.65 to 1.

The average Battery to Load ratio is 129 to 1.

We have found that these factors make reliable Pure Solar sites and are typical of the 900 sites using Apollo Solar equipment in Africa over the past 4 years.

If the average Insolation is low, the ALR must be increased. If the climate has monsoon storms with many days of darkness, the battery size must be increased.

SITE REFERENCE NAME	LOAD IN WATTS	ACTUAL PV ARRAY IN WATTS(p)	ARRAY TO LOAD RATIO	ACTUAL BATTERY CAPACITY Ah @ C100	BATTERY CAPACITY IN kWh	BATTERY TO LOAD RATIO
SUSANA	1163	11,340	9.75	3210	164	141
ONDAME	2316	22,680	9.79	5460	278	120
VARELA	1129	11,340	10.04	2730	139	123
PITCHE	1901	17,955	9.45	4560	233	122
CÓ	1100	10,395	9.45	4110	210	191
BINAR	2606	25,515	9.79	6510	332	127
BAFATA 2	2304	22,680	9.84	5460	278	121
PRABIS	2345	22,680	9.67	5460	278	119
GABU EMBALO CUNDA	2519	24,570	9.75	6510	332	132
DEMBA CALI ORANGE	1518	15,120	9.96	3660	187	123
CATEL ORANGE	1546	15,120	9.78	3660	187	121
BAMBADINCA PRACA	2387	22,680	9.50	6510	332	139
CONTUBOEL	2243	21,735	9.69	5460	278	124
GALOMARO	1639	16,065	9.80	4110	210	128
XITOLE	1699	16,065	9.46	4110	210	123
CUTIA	1550	15,120	9.65	4110	210	135
SALTINHO	1551	16,065	9.39	4110	210	135
CUTIA (2)	1567	15,120	9.65	4110	210	134
SALTINHO (2)	1710	16,065	9.39	4110	210	123
PONTA GARDETE	1824	17,955	9.84	4560	233	128
ZONA 7	2665	25,515	9.57	6510	332	125
GABU 2017	2665	25,515	9.57	6510	332	125
BAFATA 2017	2665	25,515	9.57	6510	332	125
BUBA PRACA	3507	34,020	9.70	8700	444	127
CUNTUM2	2665	25,515	9.57	6510	332	125
CANCHUNGO 2017	2665	25,515	9.57	6510	332	125
QUELELE	2665	25,515	9.57	6510	332	125
ANTULA 3	2665	25,515	9.57	6510	332	125
BISSORA SECTOR 2017	1300	12,285	9.45	3210	164	126
	LOAD	PV WATTS	ALR	Bat Ah	Bat kWh	Bat:Load
AVERAGES:	2072	20,041	9.65	5172	264	129

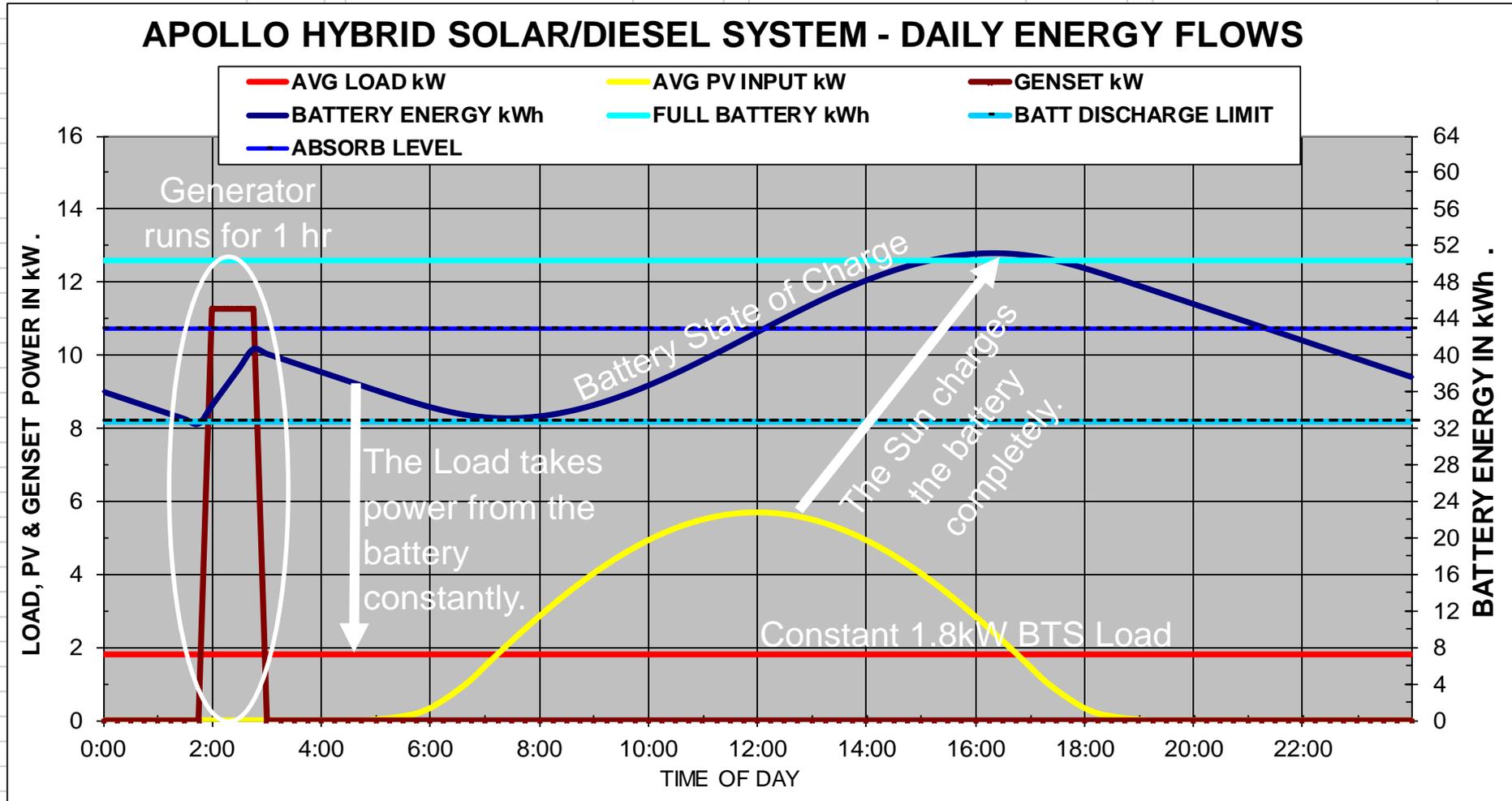
Summary of System Design

Solar / DG Hybrid Systems –Add backup generator

1. The difference from the Pure Solar system is that the 3 days of autonomy can be reduced to 1 day or less.
2. Cutting the size of the Battery by a factor of 3 cuts the cost greatly.
3. This reduces the initial Capital Expense (CAPEX), with an increase of the Operating Cost (OPEX) which is the diesel fuel and all other generator maintenance costs.
4. The optimum balance of PV Array and Battery size to Generator Run Time and Fuel Consumption is an important set of calculations.
5. The Apollo equipment works with the entire spectrum from Pure Solar to total DG.
6. Many sites have a limited amount of land and that becomes the limit on the size of the PV Array.
7. Some customers will request that the sites be 70% Solar and only 30% Diesel. We use a software simulator to achieve these targets.

How the Apollo Hybrid Solar/DG System works

This chart shows when the battery is charged. The BTS load is always on.



Simulation of Hybrid Solar/DG System

APOLLO SOLAR - HYBRID DG SIMULATOR - REV 33 - Copyright 2015

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CONFIDENTIAL

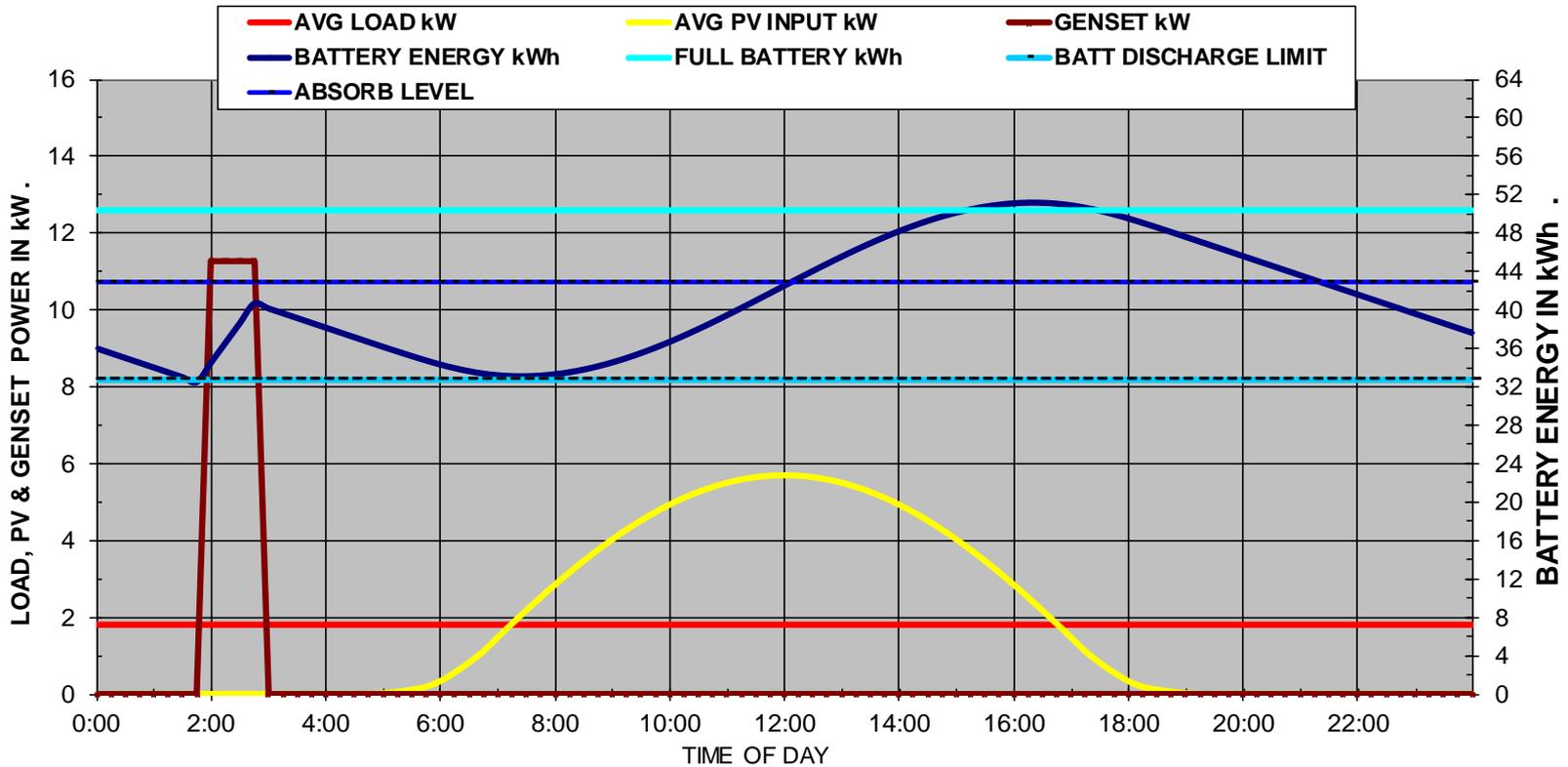
1.8 kW

MODEL: **B**

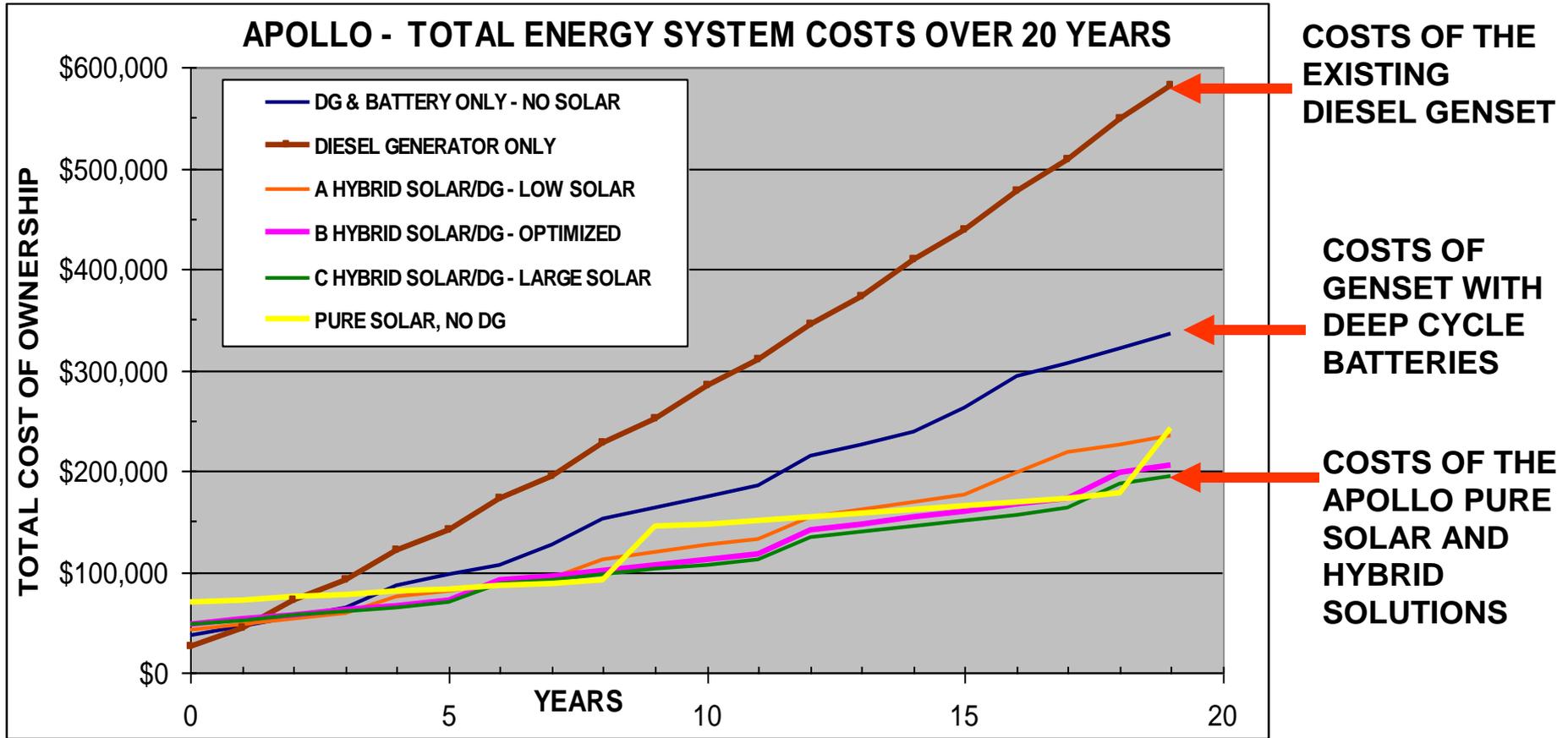
AGM Lead Acid Battery

INDIA		CELLATECH		BATTERY RESULTS		GENSET RESULTS	
GIVENS		SOLAR ARRAY RESULTS		BATTERY RESULTS		GENSET RESULTS	
TOWER LOAD IN kW	1.8	PV ARRAY IN kW	7.8	MAX ALLOWABLE DoD	35%	GENSET RUN TIME IN hr	1.00
ANNUAL AVG INSOLUTION	5.56	SQ METERS FOR PV ARRAY	45.3	CAPACITY in Ah at C10	1050	RUN TIME AS % OF DAY	4.2%
GENSET SIZE IN kW	12.0	NUM OF T80HV CHG CTRLRS	2	CAPACITY REQUIRED IN kWh	30	FUEL USAGE IN LITERS/DAY	4.06
GENSET RUN POINT	100%	PEAK PV CHARGE AMPS	60.3	MAX BATT CHARGE AMPS	336	FUEL USAGE IN LITERS/MO	124
DG BATT CHARGE AMPS	182	PV ENERGY in kWh/DAY	43.8	DEEP DISCHARGES / YEAR	730	TOTAL DG ENERGY kWh/DAY	12.0
ENERGY REQ IN kWh/DAY	56.5	% OF ENERGY FROM SOLAR	77.6%	BATTERY LIFE IN YEARS	2.7	% OF ENERGY FROM DG	21.2%

APOLLO HYBRID SOLAR/DIESEL SYSTEM - DAILY ENERGY FLOWS



Total Cost of Ownership

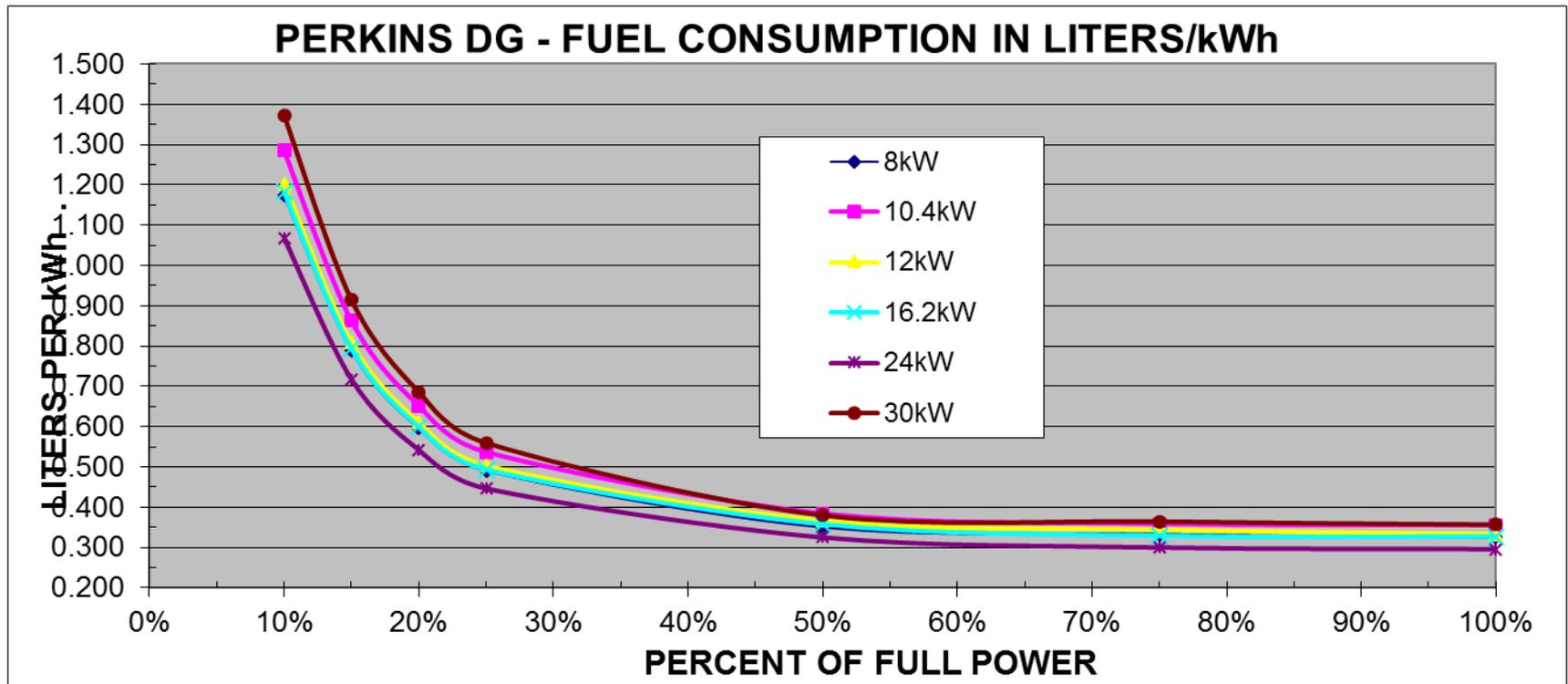


The TCO chart shows a real 1kW load system. The costs for each system depend on local parameters including the cost of diesel fuel and the solar irradiance available.

The Efficiency Curve of Diesel Generators

With Solar added, we run the generator at 3 to 4 times better efficiency than DG only.

- A typical site using diesel generators has 2 generators that are 12kW to 24kW each.
- The avg tower load is 2kW, so the generators are running at 8% to 17% of full power.
- From the chart below, we see that the fuel consumption at 10% of full power is about 1.2 Liters per kWh.
- We add solar and batteries and run the Generator at 100% full power so the fuel consumption is only 0.3 Liters per kWh – a full 4 times improvement.

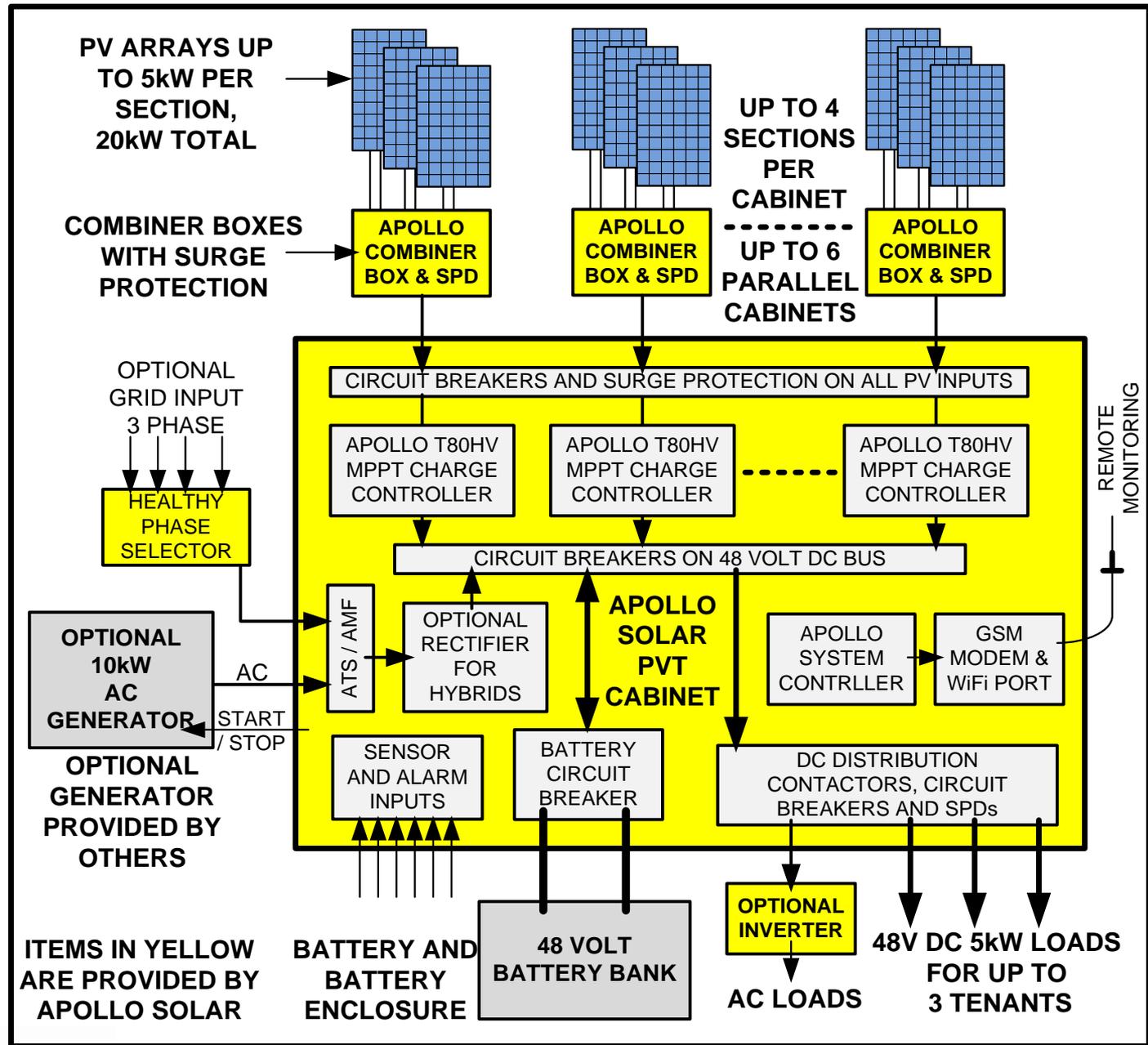


Apollo Solar Hybrid Power System Block Diagram

The Apollo system provides all the elements to provide reliable energy for the tower.

Options allow our system to provide all possible features cost effectively.

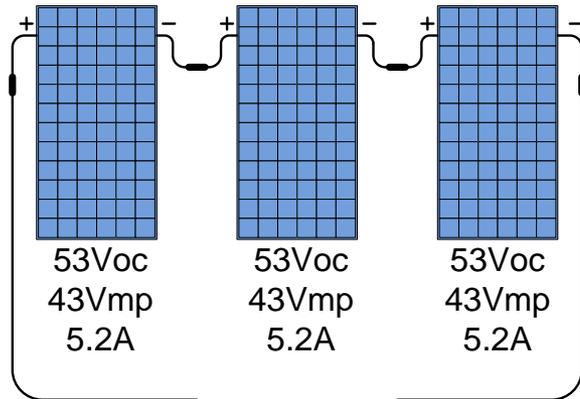
The input can be Solar, Generator, or Utility Grid.



Designing the PV Array

WIRING PV MODULES FOR THE BEST VOLTAGE

Using Sanyo HIT 225 watt modules



3 Modules in Series is 675 watts
159 volts open circuit,
129 volts at maximum power,
with 5.2 Amps at maximum power.

A run of 60 meters using 6mm² (200 ft
of No 10) wire will have about 0.2
ohms of resistance which is 5.4 watts
or 0.8% loss of power.

With the same modules wired in
parallel with the same wire will have
48.7 watts or 7.2% loss of power.

PV Module Wiring

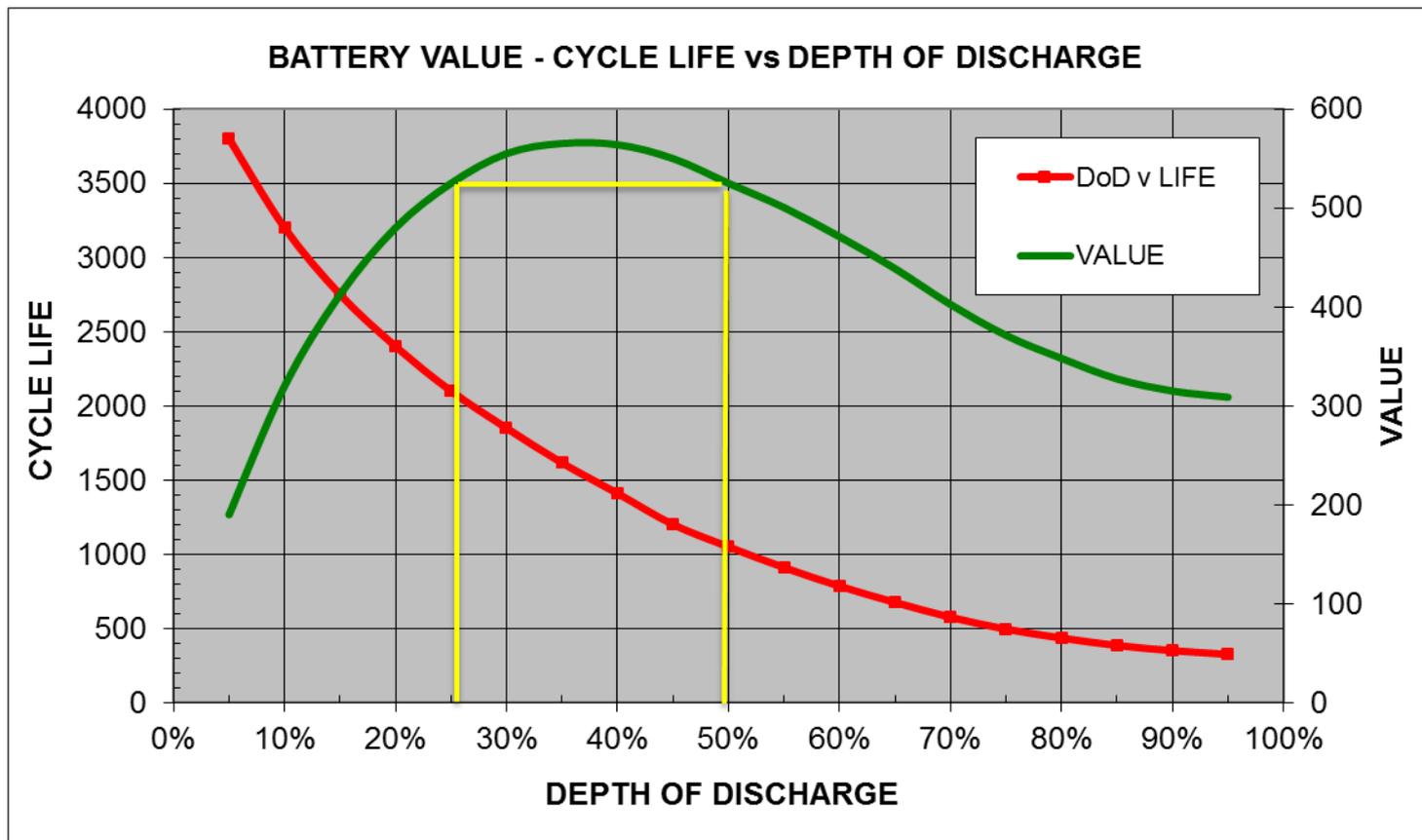
1. The rule of thumb is to use the highest voltage that the Charge Controller can take. Keeping the current low reduces the losses in the long runs of wire.
2. The Open Circuit Voltage of the modules at the coldest temperature the PV array will ever see is always the limiting factor.
3. The Apollo Solar T80HV requires at least 16% greater voltage from the PV array than the maximum voltage needed to charge the battery.
4. Typically this means that 3 PV modules will be wired in series in each string.

These are Battery Based Systems

- **COST** – The battery can often be 50% of the cost of the energy system. Proper sizing and selection of the battery type makes a big difference in the cost of your energy.
- **CAPACITY** – The price of the battery is based on its rated capacity. The Apollo Solar Charge Controllers make sure 100% of the rated capacity is used effectively. We measure the battery voltage at the battery terminals continuously for accurate charging. When the battery needs equalization, we provide that automatically.
- **LIFETIME** – If the battery is not charged properly, the lifetime will be reduced. The Apollo Solar Charge Controllers optimize the battery life. The voltage and temperature are monitored accurately and charging voltages are adjusted automatically.
- **SIZING** – We use a separate enclosure for the batteries so the size of battery bank can be optimized for each site.
- **EXPERIENCE AND FEEDBACK** – Apollo monitors the sites that are installed using our electronics. We have the feedback of the performance over years on hundreds of sites so we can be certain with battery or PV array sizing to optimize cost and performance.
- **CELL CHEMISTRY** – The Apollo Solar T80HV is designed to charge all available battery types including: AGM, GEL and Flooded Lead-Acid, Ni-Cad, Nickel-Iron and Lithium Ion including LiFePO4. As Lithium Ion batteries become more cost effective, we are ready to use them.

Battery Depth of Discharge for Optimum Value

1. A battery will provide more Charge-Discharge Cycles if the DoD is lower.
2. However, at <25% DoD, the size of the battery must be increased such that the initial cost can outweigh the advantage of longer cycle life.
3. At >50% DoD, the cycle life becomes shorter and the value is lost.



Batteries in Separate Enclosure

By providing a separate enclosure for the batteries, Apollo systems can be optimized for the conditions at each site.

Insolation, ambient temperature, size of PV array, cost of diesel fuel and size of the DG figure in the optimization of battery size.



Battery Facts

Over-sizing the Battery Never Hurts



1. The battery must be the Deep Cycle type, no exceptions.
2. Flooded, AGM and GEL all have pros and cons. If the end user is not going to maintain the water in the cells, then AGM or GEL will be a better choice.
3. The size of battery in Amp-Hours must include:
Maximum Depth of Discharge 25% to 50%.
Several days of running loads without charging.
Safety margin of 20% to cover aging and cold temperature
1. Wiring battery cells in series up to 48 volts is normal.
2. Wiring batteries in parallel should be limited to 3 strings.
3. It is good practice to use series strings of large 2 volt cells.
4. The weight must be considered in transporting the battery.