

# Successful Off-Grid Living, An example

You can have your cake and eat it too!

By Donald E. Turner



For many Americans off grid living congers up thoughts of reading by candle light, sitting in the cold and extreme sacrifice. Actually, there is little to support these misconceptions. This presentation describes an off-grid system currently supplying power for a fully functional, comfortable home. Although a system to power a modest home isn't cheap, it well within the reach of anyone who can afford a new SUV. And, unlike a new SUV, your system won't depreciate to zero in ten years. It will have paid back your investment in utility savings.

# Appliances and Toys -- no sacrifice!

- Dishwasher, microwave oven, refrigerator, freezer, zone air condx, toaster, coffee maker, washer, dryer (gas fired), well pump, large screen TV, and music system.
- Studio A, FT-1000D and Legal limit HB amp.
- Studio B, RCA BTA 250M and 304TL HB xmtr

# Amateur Radio Toys



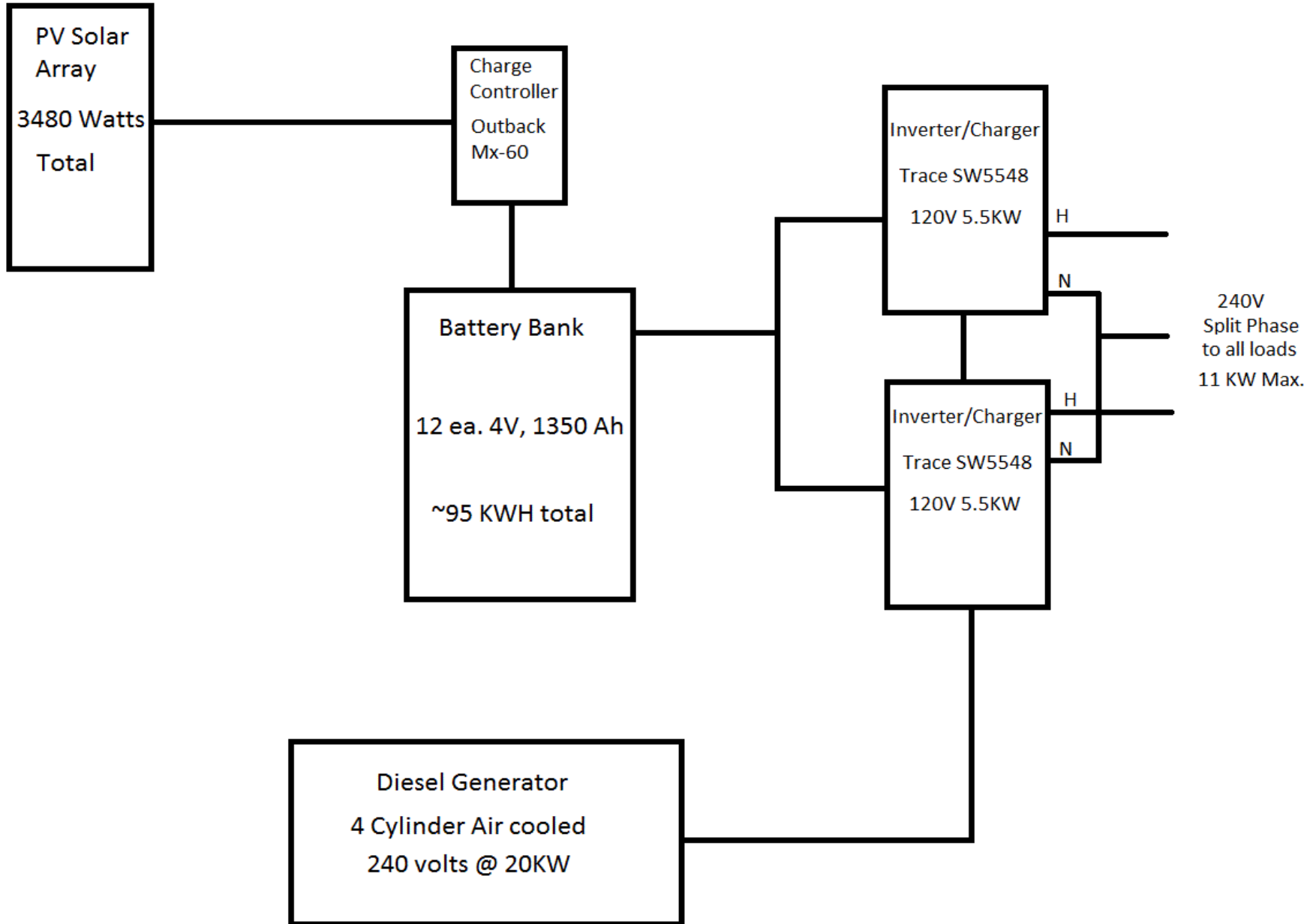
# More Amateur Radio Toys



# What to cover today

- Off grid system description and components
- Performance, limitations and changes I'd make
- Real world system design, small or large
  - The *right* way to approach design
  - Actual PV panel performance versus ratings
  - Battery types, ratings and proper care
  - Smart charge controllers
  - Smart, really smart inverter/chargers

# System Block Diagram





## Roof Mounted Solar Array

- 16 ea. 120 Watt Kyocera
- 8 ea. 130 Watt Kyocera
- 8 ea. 65 Watt Solarex
- Total 3480 rated Watts



# Charge Controller

- Outback MX-60 microprocessor based smart DC to DC converter
- 60 Volts @ 70 amps maximum
- Remote monitoring via the “Mate”
- Is an (M)aximum (P)ower (P)oint (T)racking controller, truly Magic!





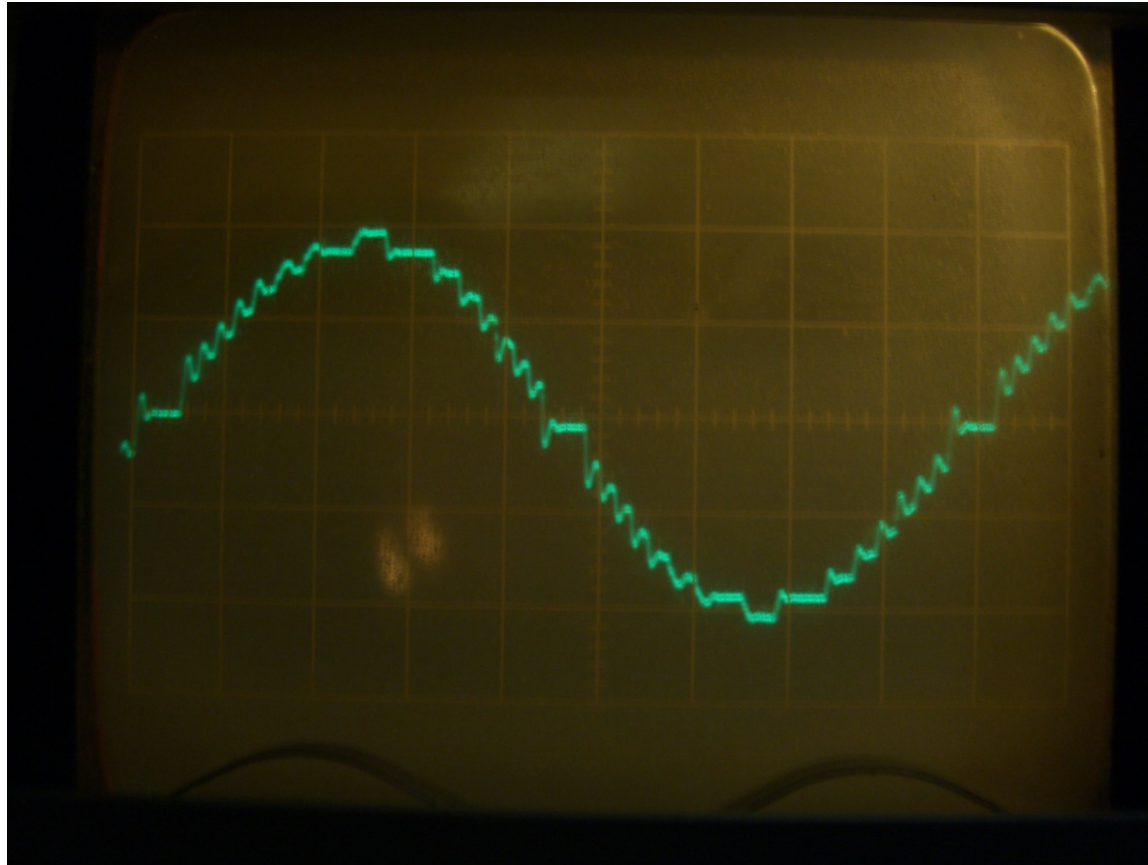
## Battery Bank

- Series connected 12 ea. Rolls Surette 4KS-25PS, 48 volts
- 4 Volts ea. Rated at 1900 amp hours @ 100 hour rate
- Weight, 315 lbs each
- Total storage, 95 Kilowatt hours
- About 10 day supply for home



# Inverter/Chargers

- 2ea. Trace SW-5548 inverter/charger
- Rated at 5500 watts continuous output
- Configured for “split phase” 240 volts output



## Inverter/Charger AC output

- Filament xmfr output
- Tektronics 454 @2 mS/cm w/X10 probe



## 20KW Diesel Generator

- Truly a generator only a mother would love
- 4 cylinder air cooled
- Runs about two hours to replace charge from a day of system use

# System Performance

- Solar (PV) output 13 KWH or more per day, 4200 watts peak output (sucker hole)
- Actual residence usage is 8 KWH per day (average over two years)
- 2 hours generator run time = one day usage
- Battery bank capacity, 10 day supply!
- Inverter capacity ample, will start a 6 HP compressor!

# Limitations and Recommendations

- Avoid central air conditioning and heat, use zone air and pellet stove
- Avoid electric cook top, oven and dryer, use LPG
- For small system designs use an LPG refrig
- Use CFL' s for lighting, minimize incandescents
- Use energy saving appliances

# System changes I'd make

- Increase PV array to provide two day recharge, ~ 16 KWH = less generator run time
- A replacement battery bank can be half the current size, 5 days autonomy instead of 10 (*autonomy = days without charge*)
- All house and shop wiring should be shielded for less radiated noise

# System Design Procedure

- Determine daily load to be supplied in kilowatt hours (*kilowatt hours = watts X time/1000*)
- Size Battery bank to supply that load for 5 days of autonomy
- Size PV array to supply a one day supply (minimum) two days preferable
- Size inverter/charger for maximum continuous load



# An actual daily load example

<u>Item</u>	<u>Power use</u>	<u>Daily use</u>	<u>Power used</u>
TV, Living Rm.	110 W	4 hrs./ day	440 w hrs
TV, bedroom	65 W	1 hrs./day	65 w hrs
TV, bedroom	54 W	2 hrs./day	108 w hrs
DirecTV box	55 W	24 hrs/ day	1320 w hrs
Computer	72 W	2 hrs/ day	144 w hrs
Washer	480 W	1 hr/ day	480 w hrs
Dryer	300 W	1 hr/day	300 w hrs
Stereo	100 W	1 hr/day	100 w hrs
Microwave	1000 W	.5 hr/day	500 w hrs
Oven (glow)	300 W	.5hr/day	150 w hrs.
Vacuum cleaner	1400 W	1 hr/day	1400 w hrs
Well pump	1000 W	.5 hr/day	500 w hrs
Lights (6 CFL' s)	120 W	5 hrs/day	600 w hrs
Sub Total			6.1kw hrs.
20% growth	1220 W		1.22 kw hrs
<b>Total</b>			<b>7.32 kw hrs</b>

# Photovoltaic (PV) panel output

*it varies with everything!*

- ✓ Aiming, azimuth (direction) and elevation (tilt)
- ✓ Temperature (lower temperature = more output)
- ✓ Irradiance, sun ray strength (cloudy/smoggy = less, clear/high elevation = more)
- ✓ Advertised ratings (STC) are wishful thinking (not appropriate for design)
- ✓ “Sucker hole” conditions = output > STC rating

# Typical solar panel specification

## Kyocera KD-140 SX

### (S)tandard (T)est (C)onditions

- Usually the “advertised” power output
- Irradiance = 1KW per M<sup>2</sup>
- 25 C cell temperature
- AM 1.5 spectrum
- Power output 140 watts

### (N)ormal (O)perating (C)ell (T)emp

- Usable for design
- Irradiance = 800 watts per M<sup>2</sup>
- 20 C ambient, 45 C cell temperature
- Power output 101 watts
- Bottomline, your power output will be ~**75%** of STC

# Flooded Lead Acid Batteries

- Old technology, dates back to 1890' s
- Basically alloy lead plates with and water/ sulfuric acid mix to about 25%
- Packaged from one cell (2V.) to six cells (12V.)
- Cousin types include gel cell and AGM
- Flooded deep cycle are best for off grid, will take allot of abuse!
- Need to be routinely watered, equalized and specific gravity (SG) recorded – **warranty!**

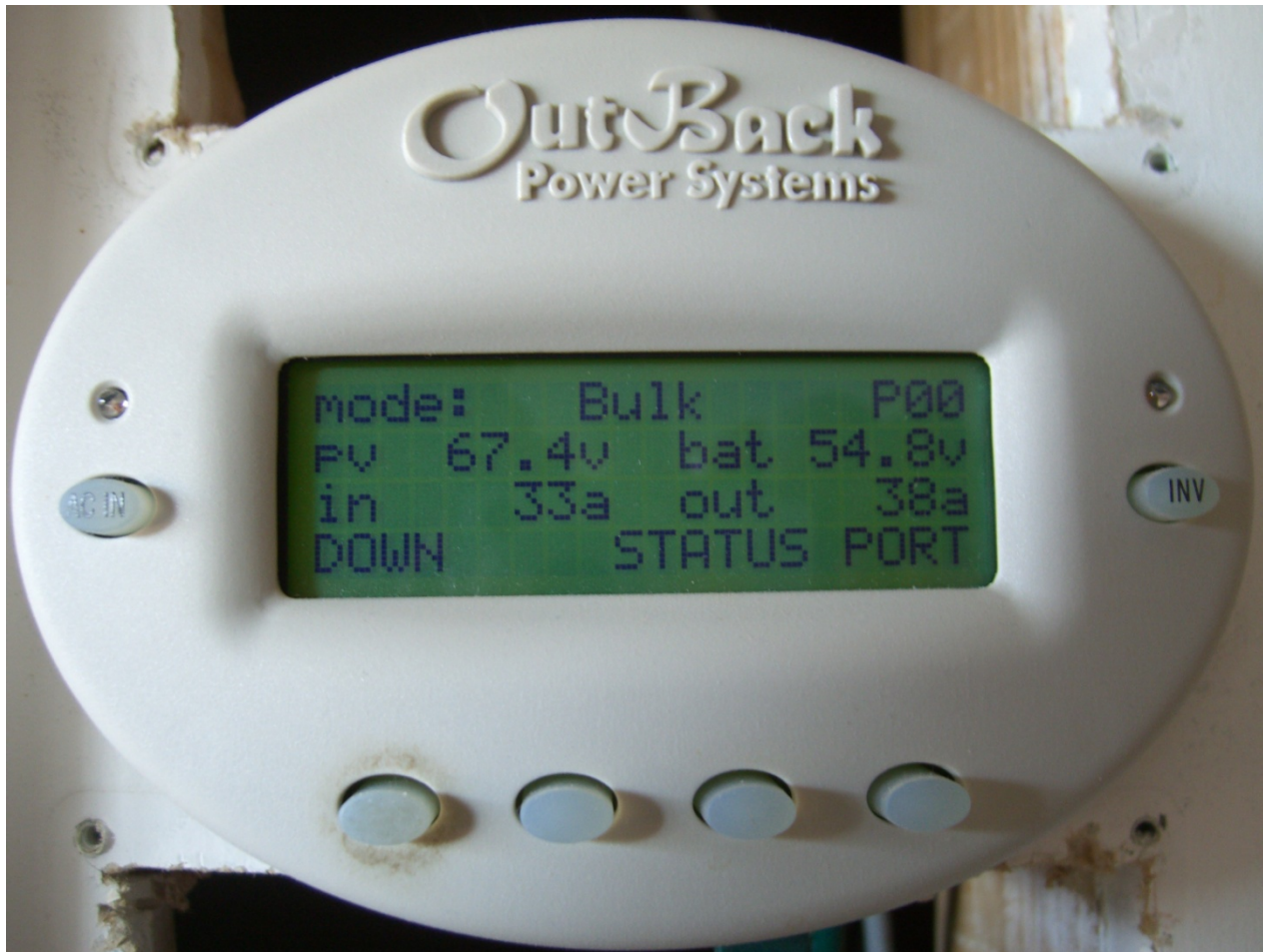
# Flooded Lead Acid Batteries cont.

- Rated in amphotours (Ah) over a 20 hour period (industry std) from fully charged (SG=1.265) until dead (SG= 1.100)
- Deep cycle type also rated for 100 hour discharge, much closer to off-grid use
- Common sizes range from 225 AH (golf cart 6V.) to 2430 AH (2V.) and larger
- Stored power in KWH=#cells X 2volts X Ah rating/1000

# Smart Charge Controllers

- Provides microprocessor control of voltage and current to charge battery bank
- Have many settings, control modes and comm
- Provide charge control in three stages:
  - **Bulk**, maximum charge current until voltage rises to the absorb voltage
  - **Absorb**, voltage held constant as current decreases thru a set time or to a set current
  - **Float**, voltage held constant to maintain full charge

# Charge Control Remote Out Back “Mate”



# Smart Inverter/Chargers

- Convert battery voltage to regulated 60 Hz 120/240 VAC @ many KW capability
- Low distortion, THD 3 – 5% but **NOT** noise free
- Provides three stage battery charging when generator or utility is available
- Moves from AC input to inverter seamlessly, **no dropout.**
- Makes the system a uninterruptable power supply -- UPS



# We Live in a remote location

## Vic' s (K61C) Big Kitty

