

How to reduce the cost of supplying power to an off-grid BTS

(and simultaneously increase up time)

1. Conventional solution

Off-grid BTS supplied by 1 or 2 generators, each rated at 7,5 kVA

1.1. Load and fuel consumption

	Duration (hr)	Load (W)	Energy (kWh)	Generator load (%)	Fuel (l/hr)	Duration (hr)	l/day
Day							
BTS + MW	12	1000	12.0				
Aircon	12	836	10.0				
			1836	22.0	24%	1	12
Night							
BTS + MW	12	700					
			700	8.4	9%	0.9	12
Total per day				30.4			22.8

1.2. Capital and operational expenses (1 generator 7,5 kVA)

Capex

Generator 7,5 kVA 3 phase **\$6,500.00**

Opex + equipment replacement cost:

Generator replacement every 2 years, cost per year \$3,250.00
(replacement after 18.000 running hours)

Fuel consumption, liters per day 22.8
Cost of 1 liter of diesel (including delivery) \$1.00
Cost per day \$22.80
Cost per year \$8,322.00

Periodic maintenance (24/24 operation)
Every 250 hr: oil change (3 liter) \$15.00
oil filter \$10.00
travel and work \$100.00
Cost per year (site visit every 10 days, 32x per year) \$4,500.00

Every 500 hr: fuel filter and other maintenance \$25.00
Cost per year \$450.00

Opex per year \$16,522.00

1.3. Capital and operational expenses (2 generators 7,5 kVA)

For reasons of reliability, often 2 generators are installed.

Capex roughly doubles in comparison with 1.2.

Opex is similar to 1.2.

2. Hybrid solution consisting of one 7,5 kVA generator and a 3 phase Phoenix MultiPlus inverter/charger system + battery

In this configuration the running hours of the generator can be reduced by a factor 2 or more.

Typically the generator would supply the load and recharge the battery during day time, and the inverter/charger would take over during the night, when the aircon is off.

In order not to over stress the battery, the calculation below is based on a generator run time of 8 hr per day.

During the night the load is 700 Watt and will be supplied by the inverter/charger.

In addition, the inverter/charger will also supply the load during 4 hours of day time.

In case of a 24 V battery, the discharge current would be:

$I_{dn} = 700/20 = 35$ A during night time (12 hr), and

$I_{dd} = 1836/20 = 91$ A during day time (4 hr)

A rather low discharge voltage (20 V) has been taken in order to take into account efficiency losses in the inverter/charger and cabling.

Total discharge: $C_d = 12 \times I_{dn} + 4 \times I_{dd} = 420 + 364 = 784$ Ah

During the day the generator will supply the load and recharge the battery.

The average recharge current during the 8 hours available will be:

$C_d / 8 = 98$ A

And the average power required by the inverter/charger:

$P_m = 98 \times 28 = 2744$ W

A rather high average recharge voltage has been chosen in order to take into account efficiency losses of the battery, cabling and inverter/charger.

Battery capacity needed: 1600 Ah

(the reserve capacity will also allow for approx. 8 hours MTTR in case of generator failure)

Battery type: we recommend flooded tubular plate lead acid for the best price/performance

(this the battery used in electric vehicles such as fork lift trucks)

2.1. Load and fuel consumption

	Duration (hr)	Load (W)	Energy (kWh)	Generator load (%)	Fuel (l/hr)	Duration (hr)	l/day
Day							
BTS + MW	8	1000	8.0				
Airco	8	836	6.7				
Inverter/charger	8	2744	22.0				
			4580	36.6	61%	1.6	8
Night: generator off							
Total per day			36.6				12.8

The amazing result is that although the total energy consumption has increased from 30,4 to 36,6 kWh, fuel consumption has decreased from 22,8 to 12,8 liter.

The increased energy consumption is due to efficiency losses in the battery, cabling and inverter/charger.

The dramatically improved fuel efficiency is due to better fuel efficiency of the generator at higher load.

2.2. Capital and operational expenses, hybrid solution

Capex:

Generator 7,5 kVA 3 phase	\$6,500.00	
Tubular plate battery 24V/1600Ah (including automatic watering system)	\$3,500.00	
3x Phoenix MultiPlus 24/1600/40	\$2,424.00	(see note 1)
VE.Net control and monitoring	\$500.00	(see note 2)
Total	\$12,924.00	

Opex + equipment replacement cost:

Generator replacement every 6 years, cost per year (replacement after 18.000 running hours, 8 hours per day)	\$1,083.33	
Battery replacement every 4 years, cost per year	\$875.00	(see note 3)
Multi replacement every 8 years, cost per year	\$303.00	
VE.Net replacement every 8 years, cost per year	\$62.50	

Fuel consumption, liters per day	12.8	
Cost of 1 liter of diesel (including delivery)	\$1.00	
Cost per day	\$12.80	
Cost per year		\$4,672.00

Periodic generator maintenance (8/24 operation)		
Every 250 hr: oil change (3 liter)	\$15.00	
oil filter	\$10.00	
travel and work	\$100.00	
Cost per year (site visit every month, 12x per year)		\$1,500.00

Every 500 hr: fuel filter and other maintenance	\$25.00	
Cost per year		\$150.00

Opex per year		\$8,645.83
10% capex cost over additional investment	\$6,424.00	\$642.40
Total		\$9,288.23

Yearly cost advantage of hybrid solution	\$7,233.77
Total cost has been reduced by more than 40%!	

3. Additional advantages of the hybrid system

3.1. Increased reliability compared to the 1 generator solution

In case of generator failure the system will operate on battery for at least 8 hours (800 Ah battery reserve capacity, discharge current 91 A)

3.2. Longer generator engine life due to higher load

When operating at low load, the engine will suffer bore glazing, reducing service life. Replacement intervals therefore may even exceed 6 years in case of the hybrid solution.

3.3. Less pollution

Due to lower fuel consumption and better combustion.

3.4. Possibility to add solar or wind power

The battery is already there!

3.5. Improved control and monitoring with VE.Net

VE.Net enables remote control and monitoring of the inverter/chargers and the generator

4. DC solution

Supplying the BTS directly with the DC from the battery.

The inverter/chargers would be replaced by battery chargers.

This would eliminate the capex for 3x Multi 24/1600/40 (\$2.240,00)

They would be replaced by 2x Skylla 24/80 (\$1.846,00)

The cost reduction is not impressive.

The DC supply voltage would range from 20 V (battery discharged) to 34 V (absorption charge)

If the BTS needs a better stabilized voltage, the additional cost of a DC-DC converter would result in the DC solution being more expensive than the hybrid solution.

Alternatively, a 48 V battery could be used, if the DC voltage required for the BTS is 48 V.

Notes

1. Phoenix MultiPlus 24/1600/40

Three units are needed, to create a 3 phase AC supply

Continuous AC output at 25°C: 3 x 1600 = 4800 VA

Continuous AC output at 45°C: 3300 VA

Peak output: 9600 VA

AC transfer switch included in the Multi's

When the generator is running, the Multi's will automatically reduce battery charge current if needed to prevent an overload of the generator during periods of peak demand by the BTS.

2. VE.Net

Needed for timing (8/24 operation of the generator) and monitoring of battery state of charge.

VE.Net can also be used to monitor and control both the Victron equipment and the generator from a central control room.

3. Battery

The tubular plate lead-acid battery offers the best price performance (that is why it is the standard battery for forklifts)

Cycle life

Battery manufacturers claim 1500 - 2000 charge/discharge cycles of 80%, in forklift applications.

This is equivalent to 2400 - 3200 cycles of 50%, which is well in excess of 4 years (4 x 365 = 1460 cycles) service life as assumed under 2.2.

Cycle life is not much affected by temperature.

Float life

Float life is reduced by 50% for every 10°C temperature increase.

Manufacturers claim 10 to 20 years float life for flooded tubular plate batteries, at 20°C ambient temperature.

This would reduce to 5 - 10 years at 30°C ambient and 3,5 - 7 years at 35°C (average temperature)

Service life

End of life is reached when either the max # of cycles is reached, or when the end of float life is reached, whichever comes first.

Battery manufacturers experience and guarantee conditions (and possibly local field experience with electric forklifts) is needed to obtain reasonable certainty that 4 years service life is realistic.

4. Fuel consumption of generator: see table

