Interconnection of PV systems in diesel powered electrical microgrids in the tropics

Ronald Stephan
r.stephan@q-cells-com

RIO 12 – World Climate & Energy Event
Granada, Nicaragua
January 18th, 2012

Overview

- Microgrids
- PV Systems in the tropics
- Irradiance Ramps
- Energy storage
- Measures for grid stability
- Case study for the Island of Fernando de Noronha, PE, Brazil

Microgrids

- A microgrid is a localized grouping of electricity generation, energy storage, and loads that operates disconnected from a centralized grid.
- The main generation component that dominates the traditional microgrid parameters is a primary genset.
- Often is the goal to operate the gensets close to the rated power while keeping idling capacity for any load jumps on the grid.
- The power usually gets distributed on the medium voltage level if the peak load on the grid exceeds one megawatt.
- Grid management ensures the supply to the load profile.

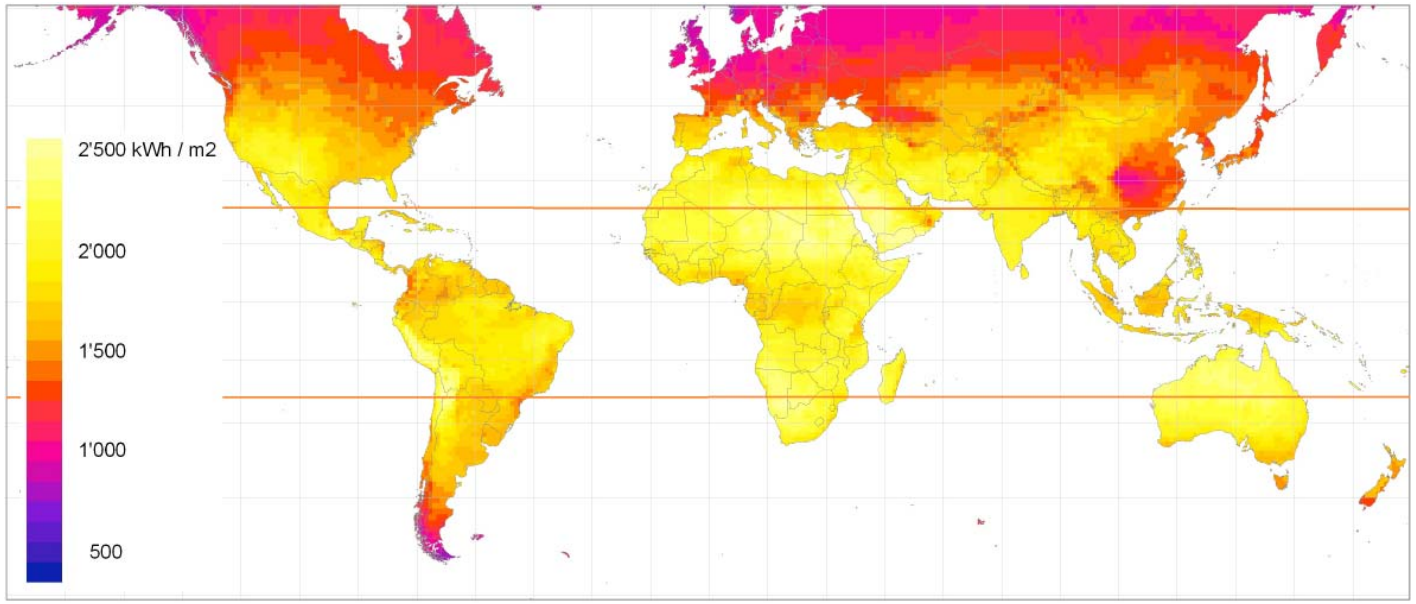
- Gensets are an assembly consisting of a diesel/heavy oil engine coupled with a synchronous generator
- Gensets are designed for standby/emergency power, continuous or prime power applications
- Limited power range for operation
- Frequency drop on overload / Frequency rise on underload
- The grid management for additional power sources has to be selective to the diesel engine control of the prime genset
- Rising fuel cost have lead to an substantial increase in energy production cost.

PV Systems in the tropics

Environmental considerations in the tropics for PV system design

- high temperature
- high humidity
- good solar energy resource
- limited seasonal effects

[Meteotest]



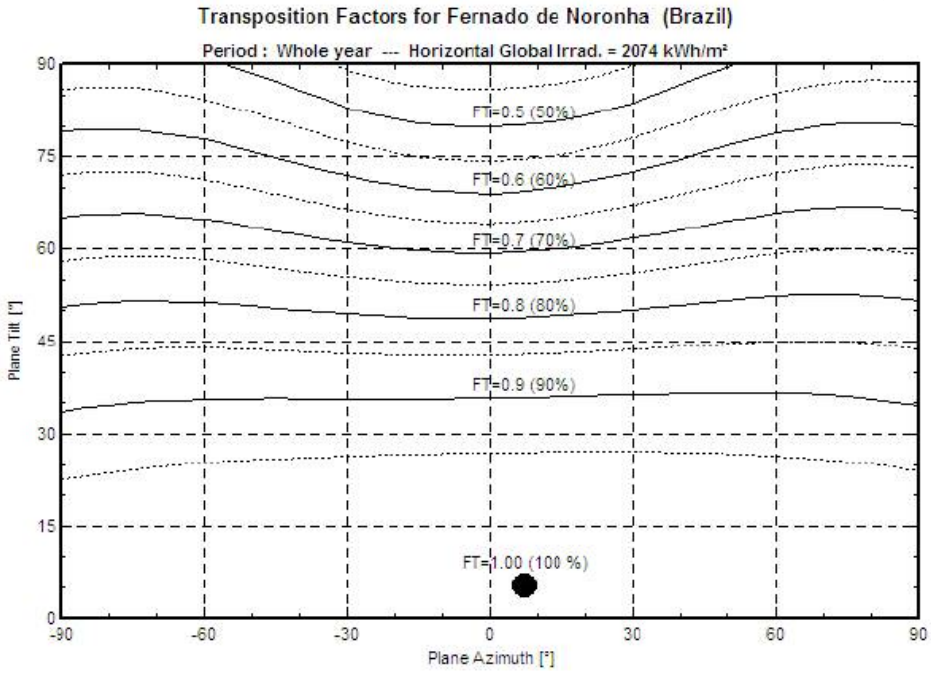
The high temperatures in the tropics lead to higher cell temperature in the operation the system.

Modules are likely to commonly operate on a lower voltages than rated at Standard Test Conditions

Module	Cell technology	P_{max} @ T_{cell}(50°C)
Solon Blue 220	poly-crystalline Si	- 11.00 %
Sunpower SPR-220	mono-crystalline Si	- 9.50 %
Würth Solar GeneCIS	CIS	-7.25 %
First Solar FS-280	Cd-Te	-6.25 %
Unisolar PVL-124	amorphous Si – triple Junction	-5.25%
EPV Ino 40	Amorphous Si - Tandem	-4.75%

- The isolation close to the equator is year around high.
- The orientation on a micro grid should consider the daily and the seasonable load profile.
- The self cleaning effect of the PV arrays often weighs out energy loss due to a slightly higher inclination.

[PVSyst]



Considerations for interconnection PV Systems into micro grids

- To limit voltage limitations on longer feeders find an interconnection point for large systems relatively close to the central genset to avoid additional transformer investments
- If possible decentralize the PV arrays to limit irradiance.
- To minimize energy storage needs renewable energy forecasts via satellite data or measured weather data and the identification of less critical loads can be very effective.
- Energy efficiency measures and incentives for peak shaving , etc. lead to effective results

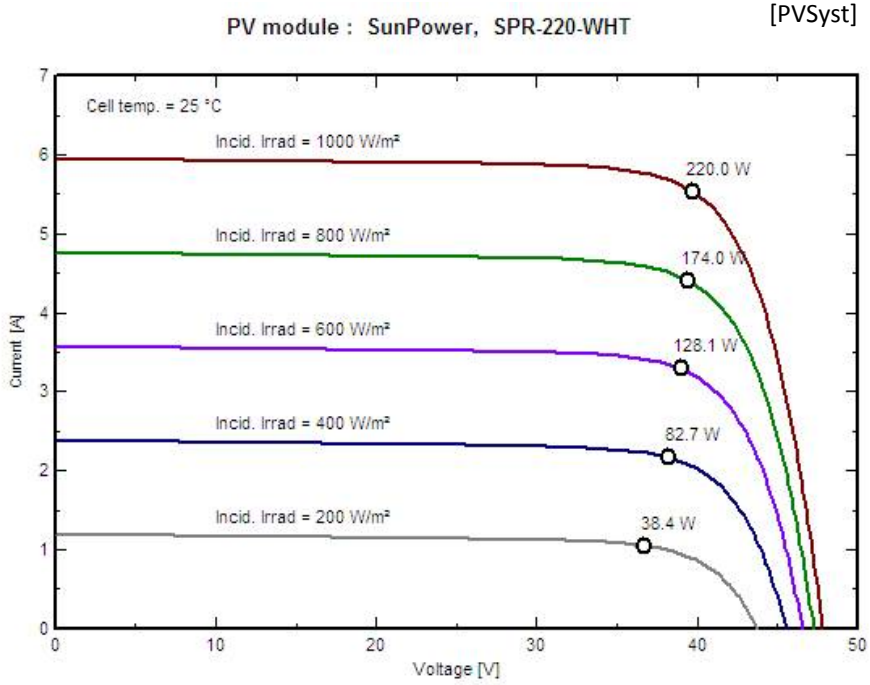
Irradiance ramps

In a PV generator the power output is almost linear to the irradiation.

Irradiance ramps are the Irradiance change divided by the respective time.

In few minutes irradiance jumps of 800W/m² are possible.

[PVSyst]



Irradiance ramps

The Irradiance ramps are mainly influenced by:

- Irradiance
- Cloud speed
- Irradiance pass-thru of the cloud
- Cloud break effects

Research at Sandia National Laboratory showed that 99.7 % of the investigated ramps had a ramp speed of less than 100 W/m² s on a single pyranometer. The fastest ramp was around 500 W/m² s.

Load ramps on the grid are just as influential.

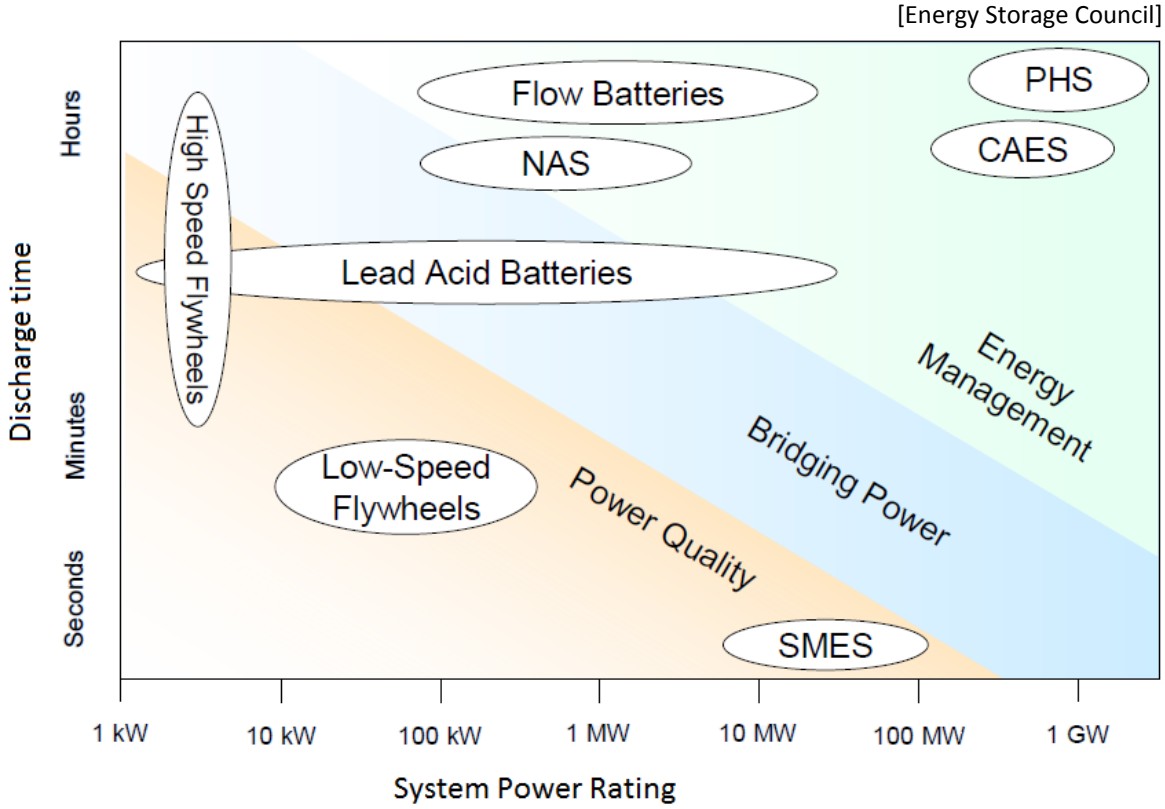
The combination of load and supply ramps can destabilize the grid heavily.

Energy storage

- In order to maintain a constant balance between energy supply and demand a is spinning reserve for fluctuations on both sides is needed. Usually this is archived by operation the generators below their power ration.
- Additional traditional gensets require about two minutes to synchronize and supply full power to the grid.
- For a high renewable energy penetration in the micro grid additional energy storage is required.
- This allows to shut down gensets while full renewable energy output.

A number of energy storage technology have proven in the energy sector for different applications.

[Energy Storage Council]



Energy storage

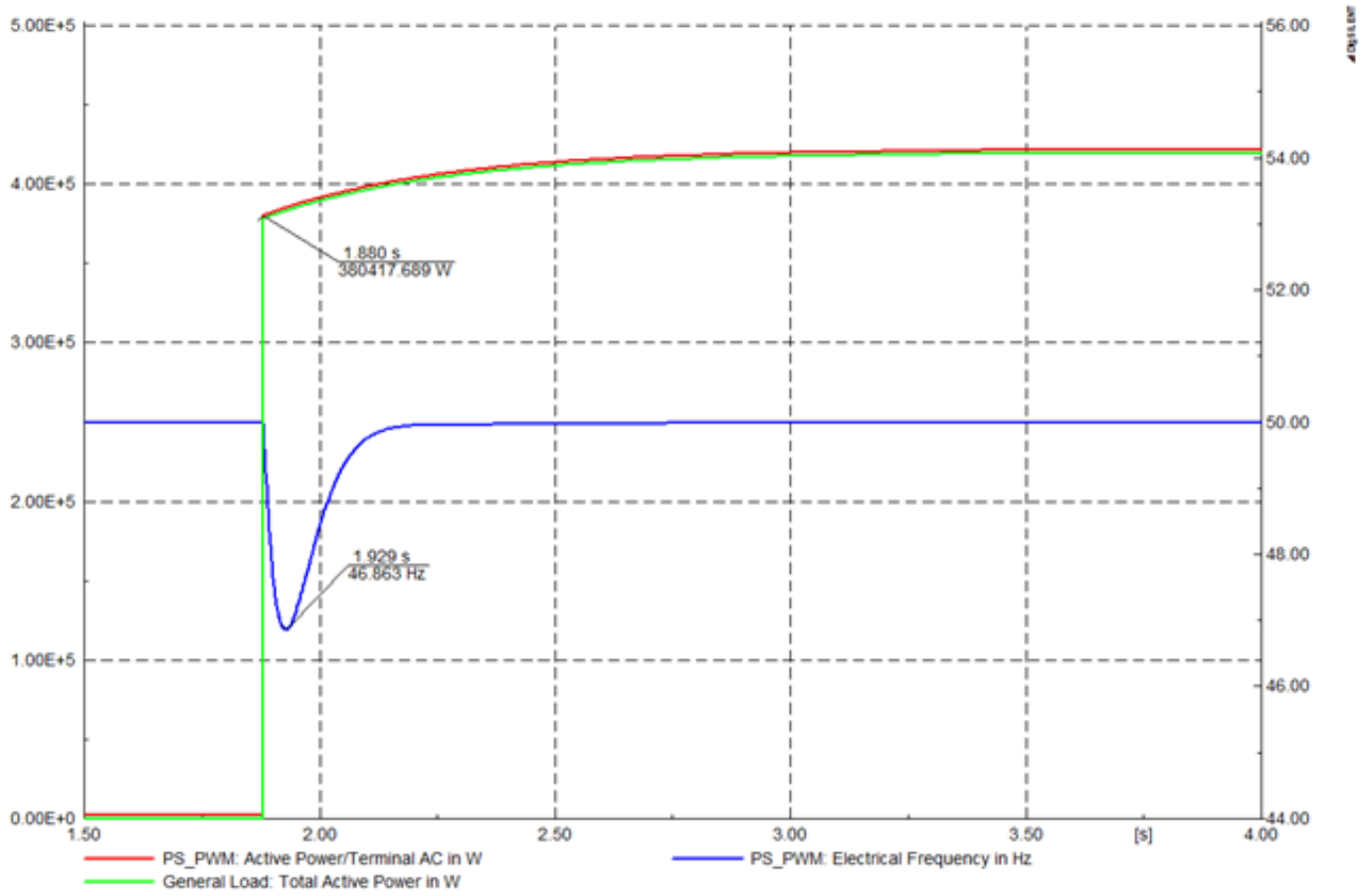
Flywheels and lead acid battery banks are for the required power and time range the best suitable option.

Flywheel	Battery
Charging periode of seconds	Charging periode of hours
Charging state can be presily measured	Charging state can only eastimated
Charging cycles are almost irrelevant to lifespan	Charging cycles are shorting lifespan
No degradation of capacity	Degradation of capacity by charging cycles and environmental impact
High investment costs	Low investment costs
Low maintance costs	High maintance and replacement cost
High standy losses	Low standby losses

A combination of both often a technically and financially sound solution.

Power response by a 400kVA flywheel

[Powercorp.]

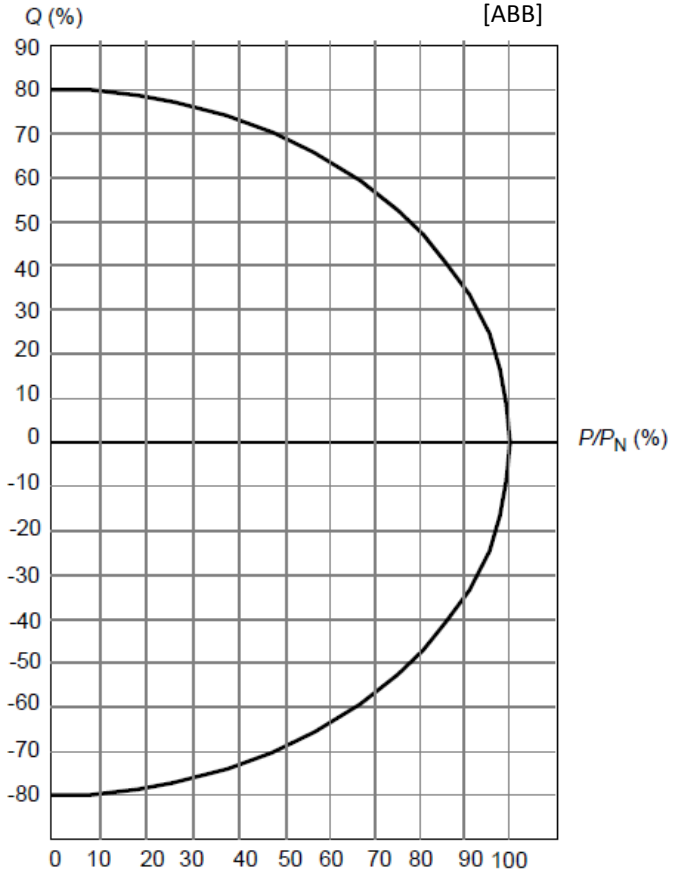


Energy storage

Measures for grid stability

Reactive power supply

- If the PV system fails to provide reactive power to the micro grid the complete reactive power would need to be provided by the genset.
- If the PV system has a relevant size this leads to an instability of the synchronous generator.
- A dynamic power factor input requirement is very useful. That allows stable operations of the generators and the minimization of the voltage fluctuations.
- Many inverters have an operating range between about 0.8 over-excited and 0.8 under-excited.

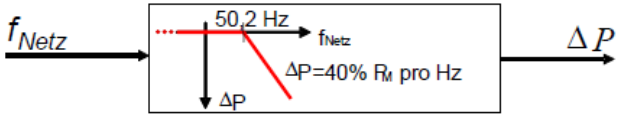


Q *Reactive power in percentage of nominal active power*
P/P$_N$ *Relative active power*

Power reduction at grid frequency increase

- An increase in frequency is usually cased by a power oversupply to the grid.
- A power reduction by grid frequency increase supports a stabilization of the grid.
- The diesel gensets units are usually equipped with speed control selectively involved in the power control.

[Transmission Code 2007]



$$\Delta P = 20\, P_M \frac{50{,}2\ Hz - f_{Netz}}{50\ Hz} \quad \text{bei } 50{,}2\ Hz \leq f_{Netz} \leq 51{,}5\ Hz$$

P_M Momentane verfügbare Leistung

ΔP Leistungsreduktion

f_{Netz} Netzfrequenz

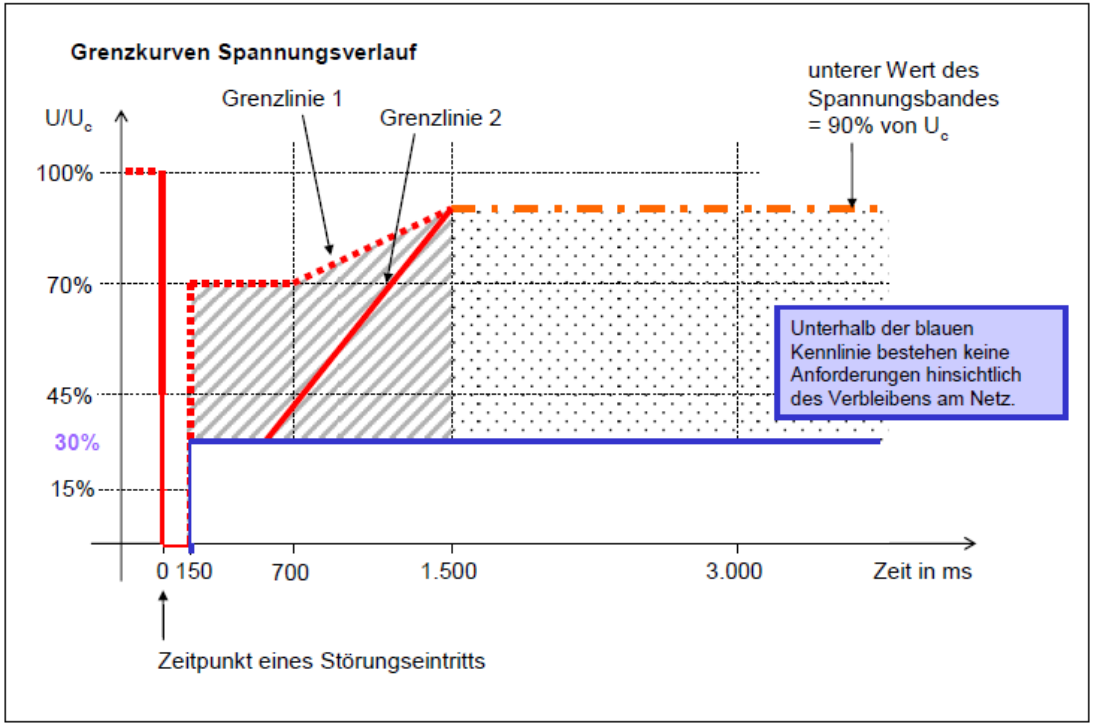
Im Bereich 47,5 Hz $\leq f_{Netz} \leq$ 50,2 Hz keine Einschränkung

Bei $f_{Netz} \leq$ 47,5 Hz und $f_{Netz} \geq$ 51,5 Hz Trennung vom Netz

Fault Ride Through

- In the case of minor network errors or short severe voltage drops a shut off of large generation capacity not wanted to avoid avalanche-like shut offs in the system.

[Transmission Code 2007]



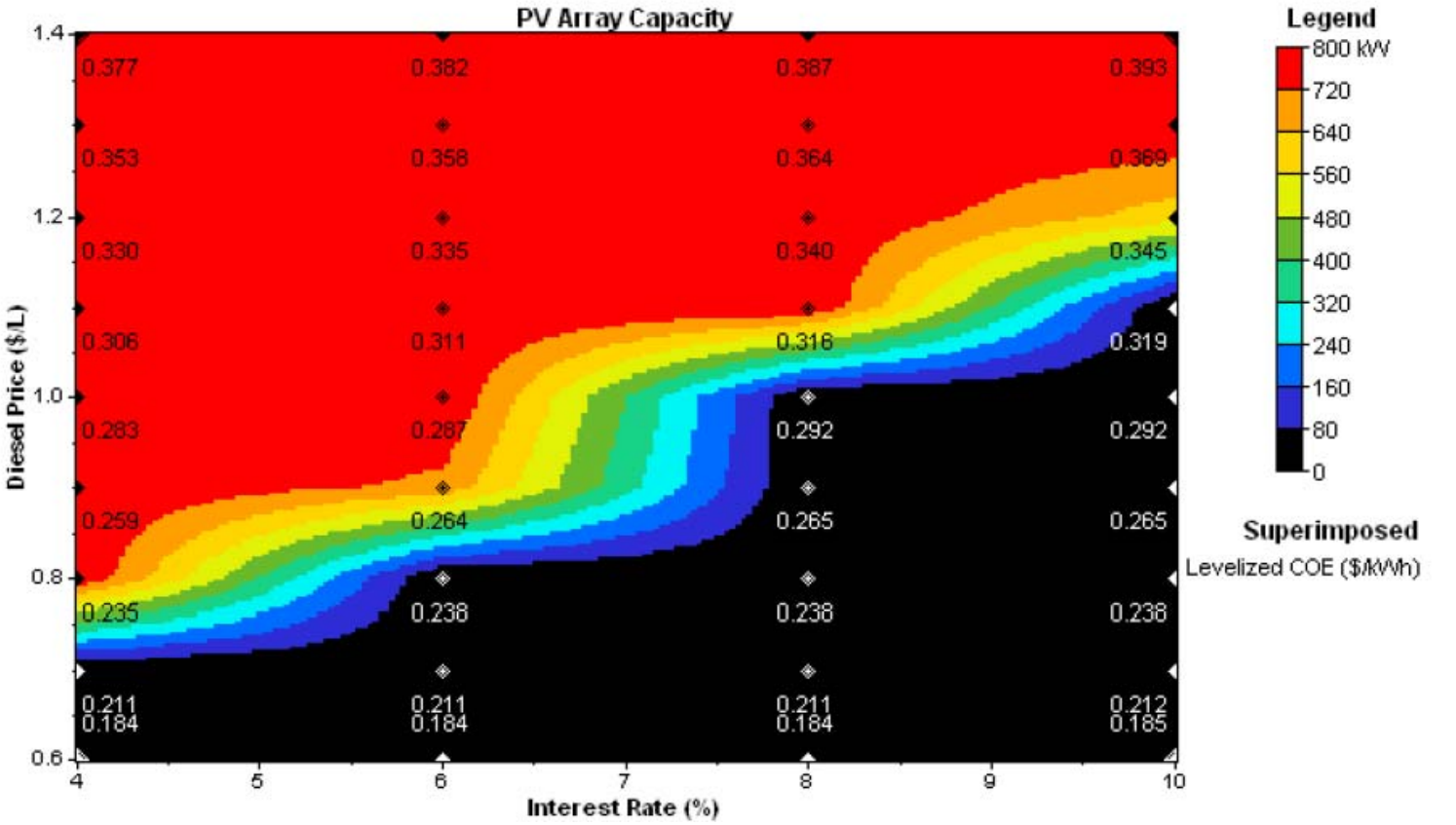
Case study for the Island of Fernando de Noronha, PE, Brazil

[Wikipedia]

- Latitude 3° 51’ S
- Isolation about 2 000 kWh/a
- Peak load around 2 MW, average load around 1,1 MW
- 5 gensets (2x 910 kW prime, 2x 600kW back up, 1x maintains)
- Continuous minimal power of 40%
- Wind turbine 225 kW (asynchronous)
- PV system sizes investigated (100 kW, 400 kW, 800 kW)

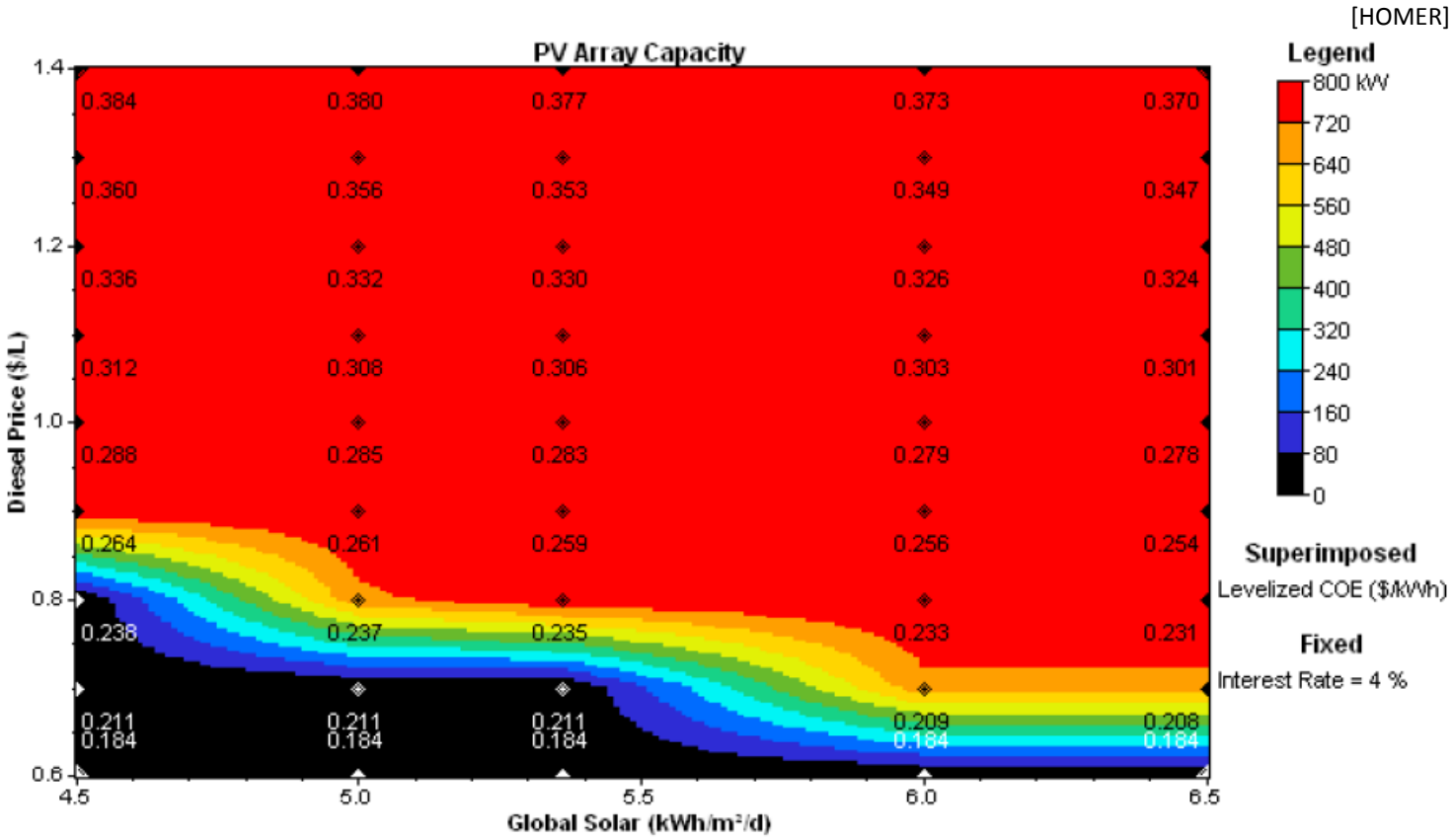
Energy rates shown in dependence of fuel prizing and interest rate

[HOMER]



Case study for the island of Fernando de Noronha, PE, Brazil

Energy rates shown in dependence of fuel prizing and isolation at 4 % interest rate



Case study for the island of Fernando de Noronha, PE, Brazil

Results of the case study

- Small PV systems (up to about 10% of the peak load) often do not need additional energy storage to be connected to a microgrid.
- Medium PV systems (up to 40% of the peak load) require some additional attention to grid stability. To avoid larger PV power limitation energy storage is needed.
- Larger PV systems require energy storage and is likely to experience power limitations in partly cloudy conditions.
- Diesel price development and interest expectations on the needed investment are the main financial aspects.
- PV Systems are technically and financially a very attractive option for a long term (10y+) interconnection to a microgrid.

Gracias por su atención.