Bruno Gaiddon

TRAINING ON RENEWABLE ENERGY MINI-GRIDS

Session 4 : PV system and storage predesign

ISA/Government of Tonga/PCREEE/INES

16 November 2021

Introduction

Training on Renewable Energy Mini-Grids

Day 1

- Session 1: Grid and mini-grid fundamentals
- Session 2: Why Solar PV Mini-grid is a promising alternative for conventional power generation in Tonga
- Session 3: How to select components that suit the Tonga/Pacific Islands context ?

Day 2

- Session 4: PV system and storage predesign
- Session 5: Commissioning on the ground
- Session 6: Optimizing maintenance

Content of session 4

- Load profile of the island
- Predesign 1 : stand-alone based architecture
- Land use assessment
- Location of the PV system and connection to the mini-grid
- Predesign 2 : hybridization of grids

Load profile of the island

Foreword

- A precise knowledge of the load profile of the island is vital for a reliable sizing !

- If no monitoring system is in place, consider the installation of low cost and non-intrusive devices available on the market !

Fludia
Smart Energy Components

Load profile of the island

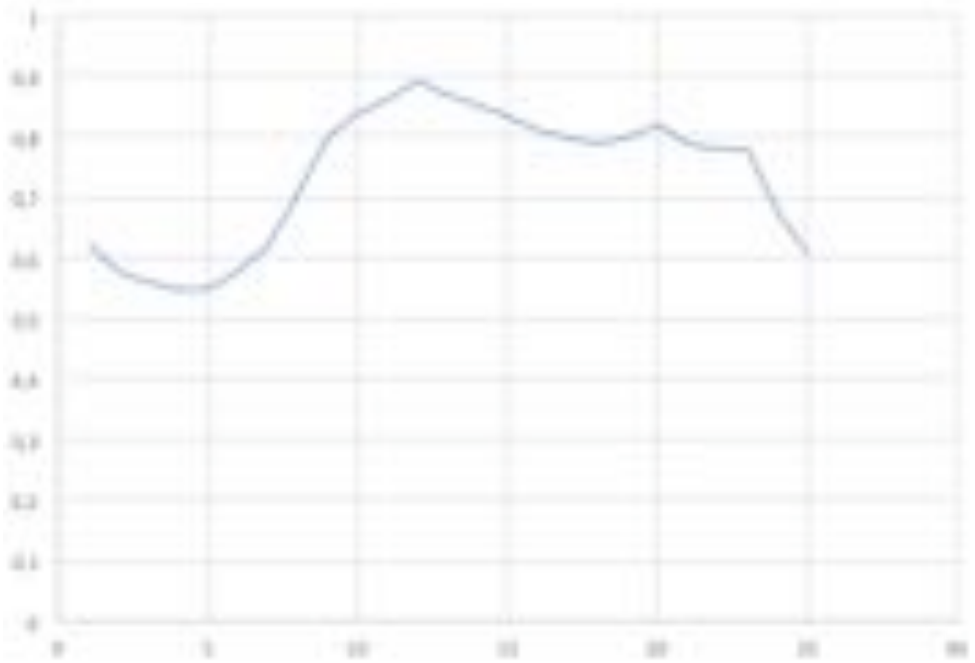
Necessary data

- Yearly power consumption
- Maximum power consumed
- Daily load profile
- Seasonal variation
- Yearly load curve
- Future evolutions
- …

Load profile of the island

Daily load profile (La Réunion)

Daily load profile – P_{norm}
(La Réunion – July)



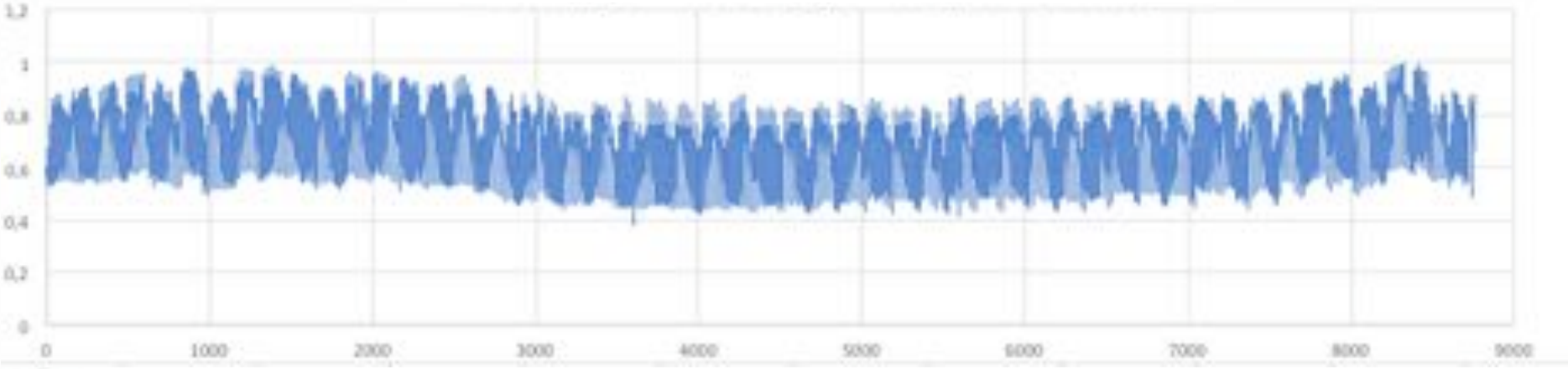
www.hespul.org

(source : EDF SEI)

Load profile of the island

Yearly load curve (La Réunion)

Yearly load curve – P_{norm} (La Réunion)



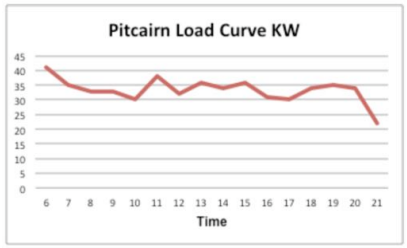
(source : EDF SEI)

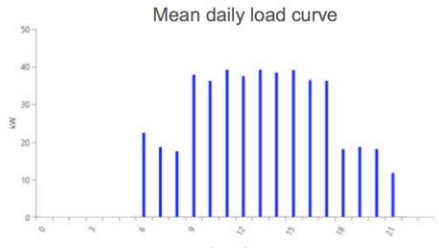
- Set of 8760 data (time step of 1 hour)
- Maximum power consumed, seasonal variation, …

Load profile of the island

Necessary data for Adamstown (Pitcairn)

- Yearly consumption : 150.000 kWh/year
- Maximum power consumed : 40 kW
- Daily load profile :



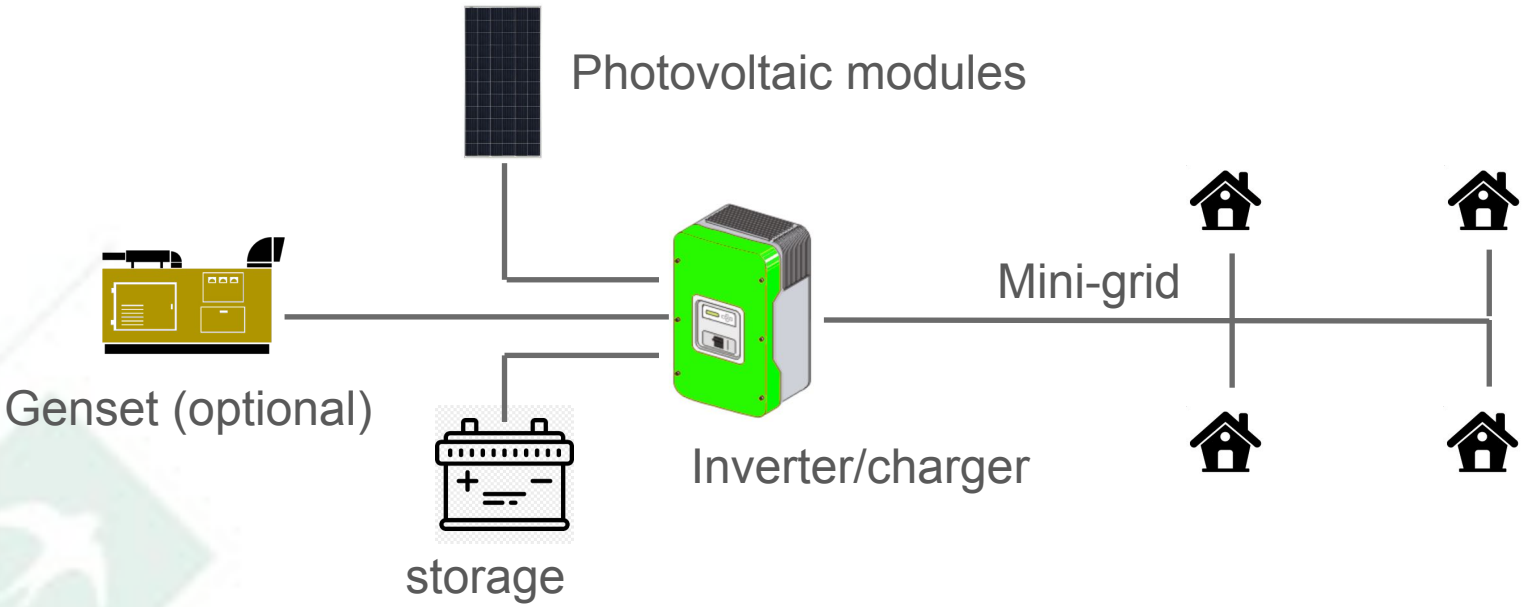


- Seasonal variation : -
- Yearly load curve : -
- Future evolution : → 193.800 kWh/year (24 hours service)

Mini-grids ?

Stand-alone based architecture

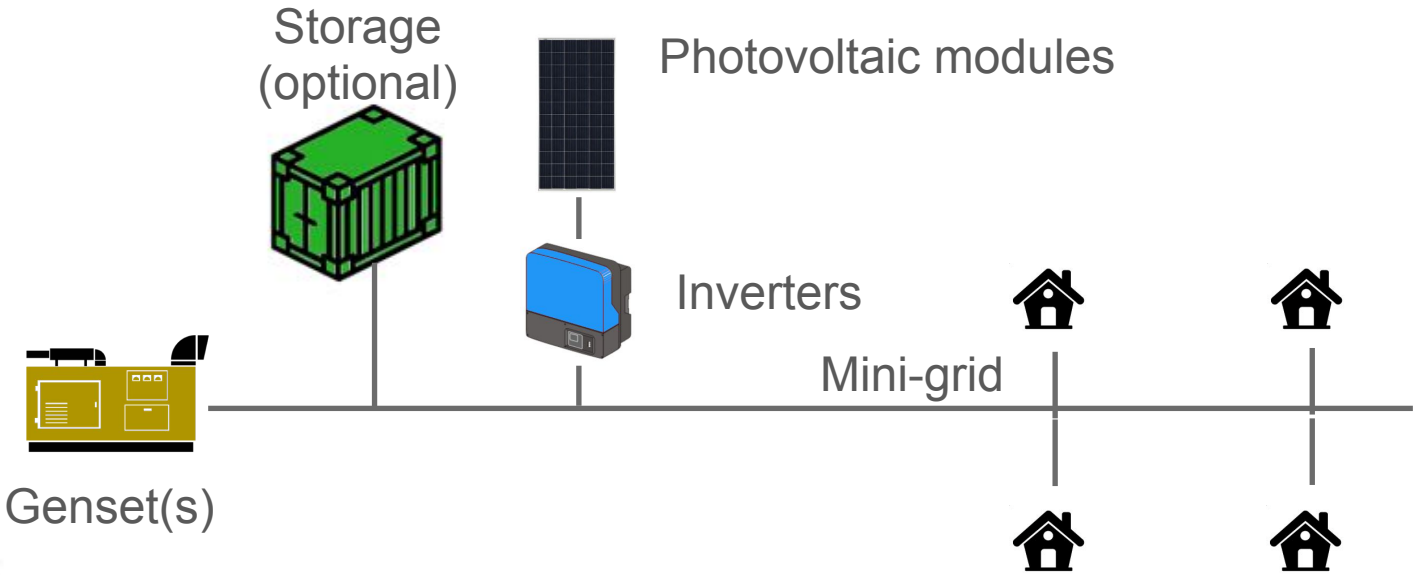
- One inverter/charger connected to the PV modules, the storage (lead-acid) and a back-up genset (optional)



Mini-grids ?

Hybridization of grids

- PV system connected to a diesel genset powered micro-grid with an inverter/charger dedicated to Li-ion storage (optional)



Predesign 1 : stand-alone based architecture

Pre-design steps

- Step 1 : assessment of the yearly and daily consumption
- Step 2 : solar generator sizing
- Step 3 : battery sizing

Predesign 1 : stand-alone based architecture

Step 1: yearly and daily consumption

- For a predesign, two figures are necessary :
  - the yearly power consumption : E_{year} in kWh/year
  - the mean daily power consumption : E_{day} in kWh/day

Predesign 1 : stand-alone based architecture

Step 2: solar generator sizing

- Yearly power consumption : E_{year} in kWh/year
- Peak power of the solar generator : P_{peak} in kWp
- Specific yield of the PV system : Y_{PV} in kWh/kWp

$$E_{year} = P_{peak} \times Y_{PV}$$

$$P_{peak} = E_{year} / Y_{PV}$$

Predesign 1 : stand-alone based architecture

Step 2: solar generator sizing for Adamstown (Pitcairn)

- Estimated yearly power consumption : 193.800 kWh/year
- Specific yield of the PV system

  Y_{PV} = 1.603 kWh/kWp in Adamstown
- **Peak power of the solar generator**

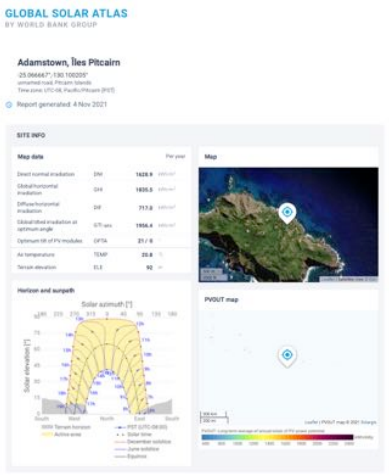
  P_{peak} = 193.800 / 1.603 = **121 kWp**

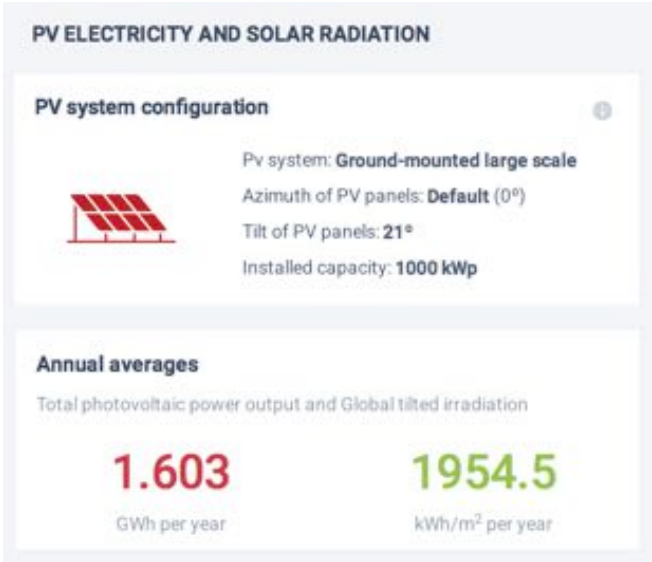
Predesign 1 : stand-alone based architecture

Step 2: solar generator sizing for Adamstown (Pitcairn)

- Specific yield of the PV system in Adamstown

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP





Y_{PV} = 1.603 kWh/kWp in Adamstown

Predesign 1 : stand-alone based architecture

Step 3: battery sizing

- Mean daily power consumption : E_{day} in kWh/day
- Number of days of autonomy : Autonomy in days
- Battery capacity : E_{bat} in kWh

$$E_{bat} = E_{day} \times \text{Autonomy}$$

Predesign 1 : stand-alone based architecture

Step 3: battery sizing for Adamstown (Pitcairn)

- Estimated yearly power consumption : 193.800 kWh/year
- Mean daily power consumption

  E_{day} = 193.800/365 = **531** kWh/day

- Number of days of autonomy : **3** days

- **Battery capacity**

  E_{bat} = 531 x 3 = **1.593 kWh**

Predesign 1 : stand-alone based architecture

Conclusion

	Predesign method	Request for proposal
Peak power of the solar generator	121 kWp	134 kWp
Battery capacity	1593 kWh	1594 kWh

- The request for proposal assumes a power degradation of the PV modules which leads to a slightly larger solar generator !

Land use assessment

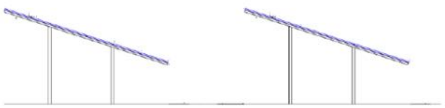
Power ←→ Surface

PV module

200 Wp → 1 m2

1 MWp → 5.000 m2
→ 0,5 hectare

PV system



1 MWp → 10.000 m2
→ 1 hectare

Land use assessment

Power – Surface conversion for Adamstown (Pitcairn)

- Peak power of the solar generator : 121 – 134 kWp
- Minimum surface of the area : 1.200 – 1.350 m2
- Request for proposal : "*The area of the proposed site is 1,500 square meters, approximately 30 x 50 meters in dimension, facing north with an average slope of 23 degrees.*"

Land use assessment

Location of the solar system

- **Ideal situation :** surroundings of the present power station offers enough space for the solar system

- **Other situation :** solar system must be installed elsewhere on the island

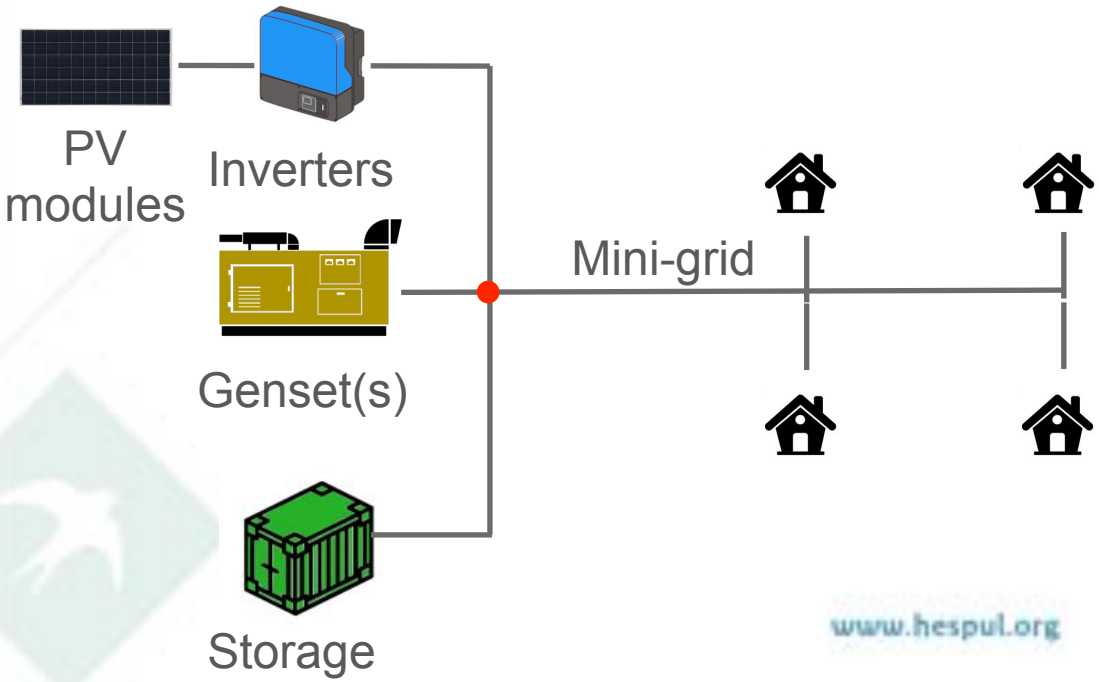
Land use assessment

Location of the solar system for Adamstown (Pitcairn)

Connection to the grid

At the former power station

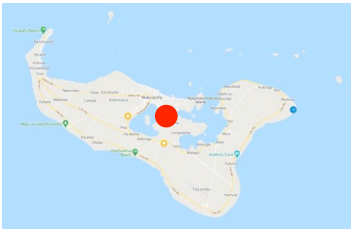
- Little impact on the existing grid
- Requires the right area at the right place



Connection to the grid

At the former power station for Tongatapu (Tonga)

- Popua power station of Tonga Power
- 8 gensets – 12,7 MW
- Maama Mai Solar Farm (1.32MW)

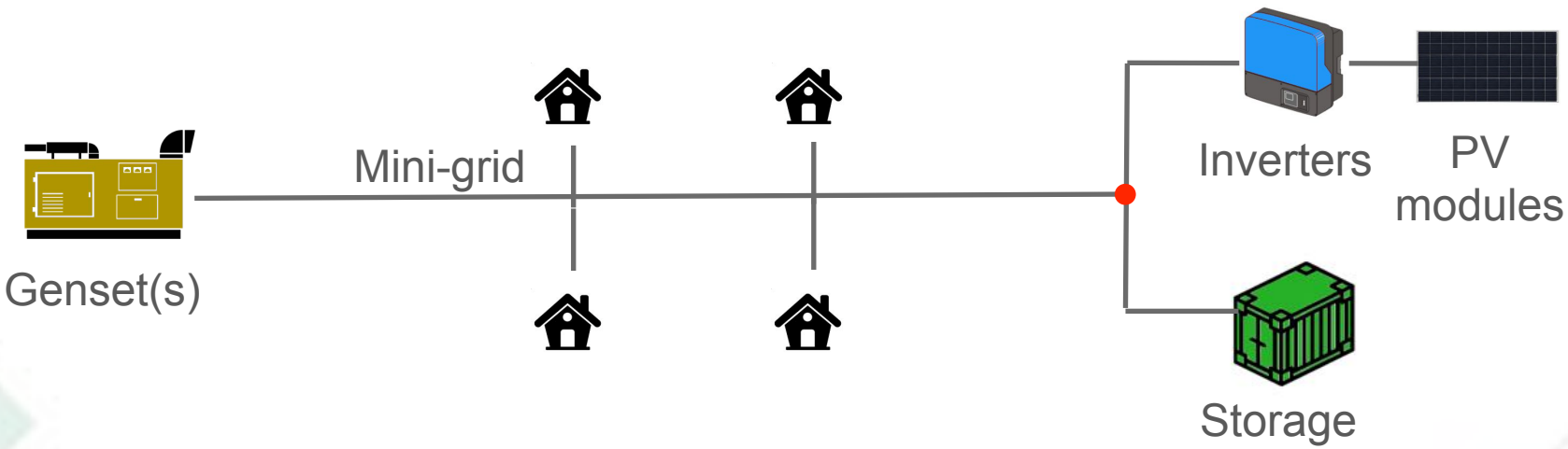


www.hespul.org (source : Tonga Power LTD)

Connection to the grid

At another point of the grid

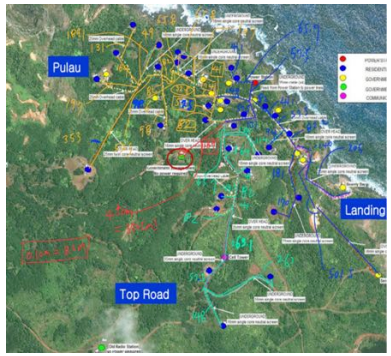
- Possibility to choose the best location
- **Strong impact on the existing grid !**

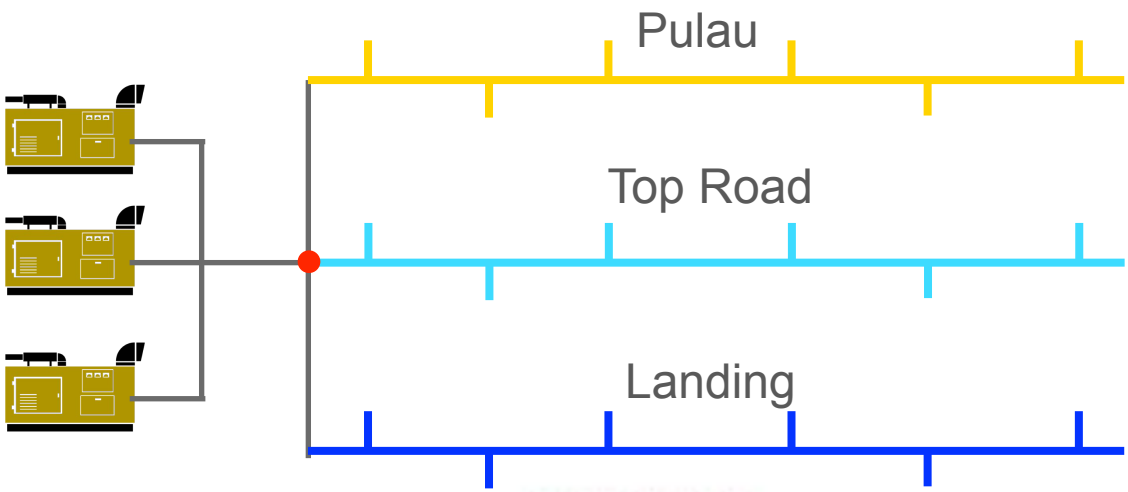


Connection to the grid

At another point of the grid for Adamstown (Pitcairn)

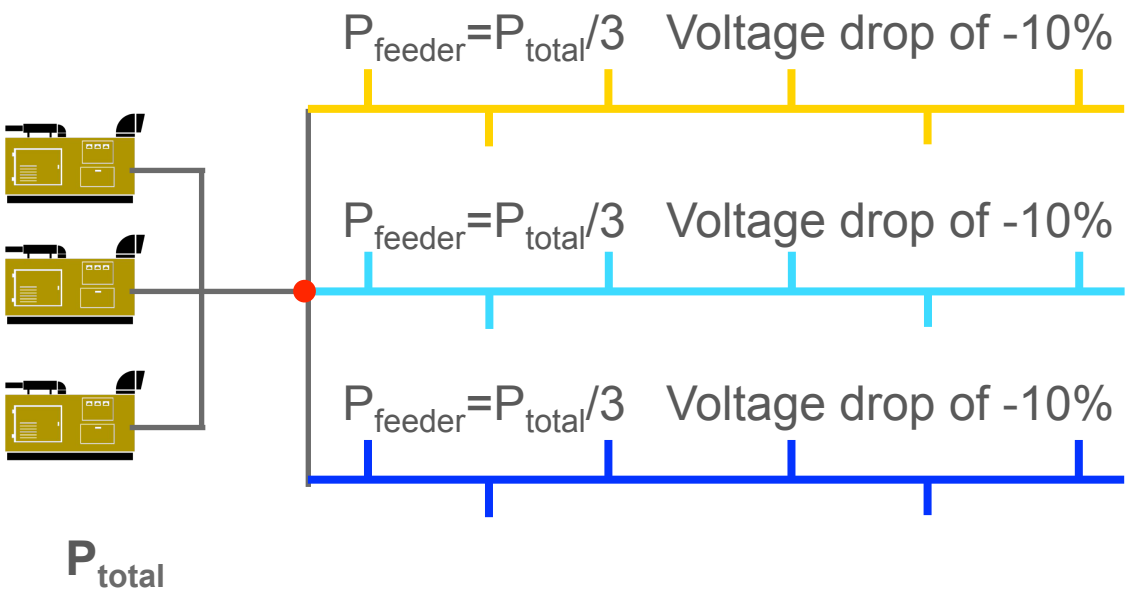
- 3 feeders
  - Pulau (North West)
  - Top Road (South West)
  - Landing (South East)





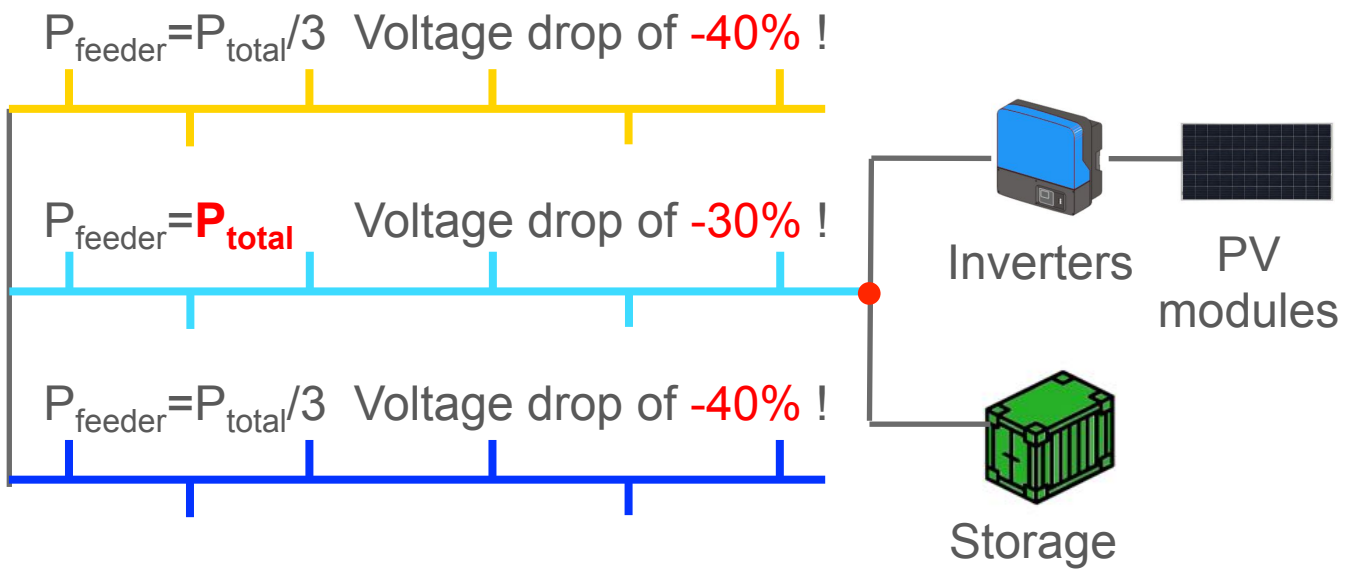
Connection to the grid

At another point of the grid for Adamstown (Pitcairn)



Connection to the grid

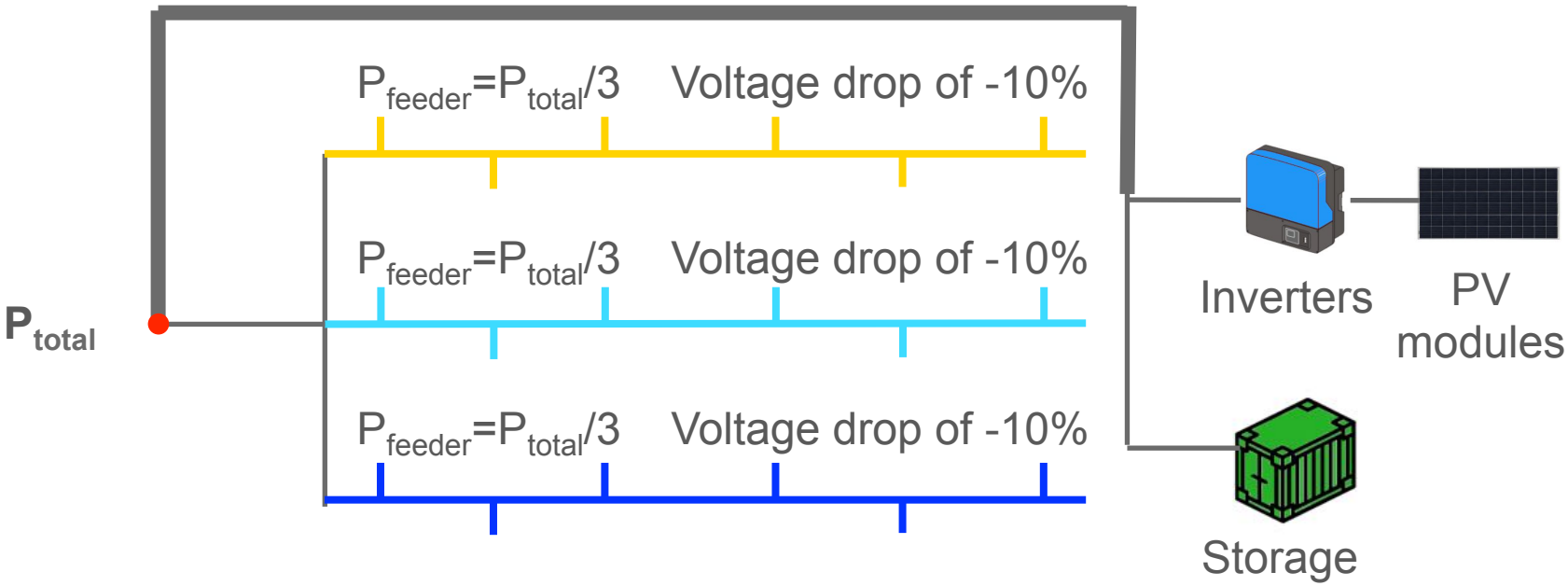
At another point of the grid for Adamstown (Pitcairn)



- Problem 1 : feeder may not be sized to accept P_{total} !
- Problem 2 : unacceptable voltage drops may occur at the end of each feeder !

Connection to the grid

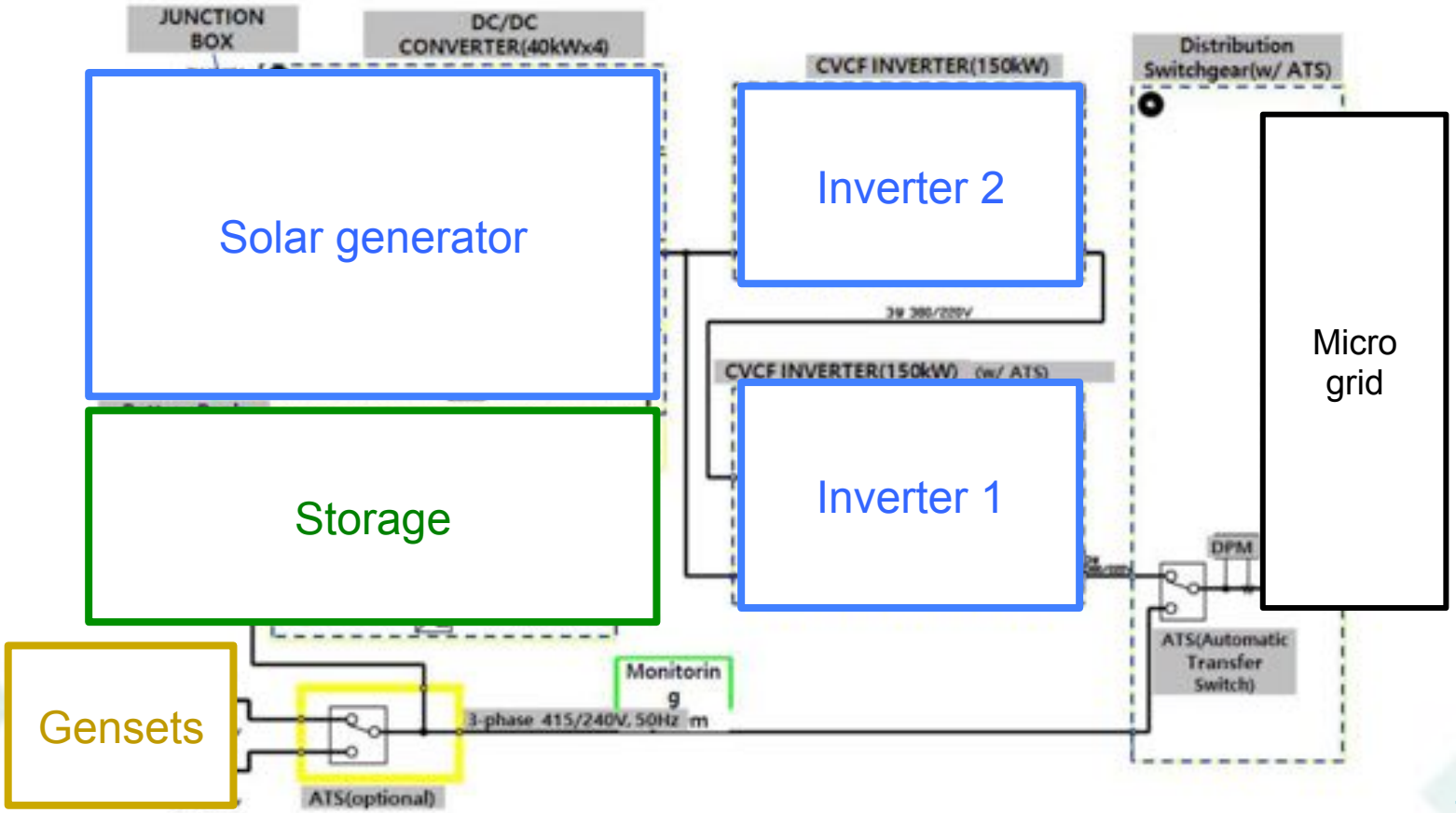
At the former power station for Adamstown (Pitcairn)



- Solution : design a dedicated cable from the PV system to the former power station !

Preesign 1 : stand-alone based architecture

Single line drawing for Adamstown (Pitcairn)



Predesign 2 : hybridization of grids

Data of the case-study

- Virtual island
- 100 km2 with 8.000 inhabitants (ex: Wallis-et-Futuna)
- Power consumption : 44 GWh/year
- Peak power : 9 MW
- Installed production capacity : 13 MW
- 9 diesel gensets – 2 power stations

CAT C32 – 1250kVA/1000kW – 252l/MWh

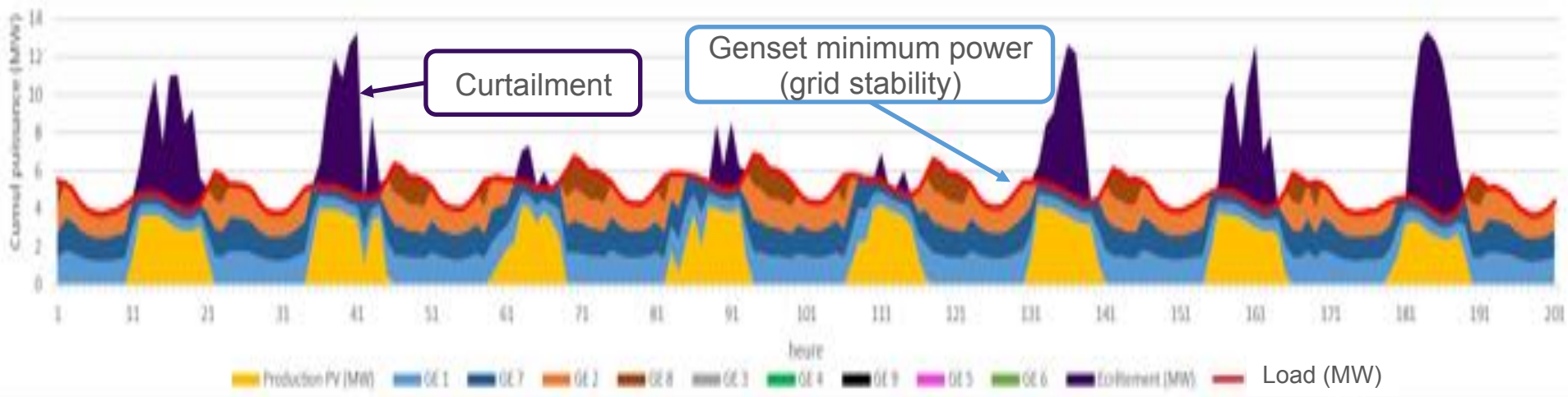
→ Local utility wants to reduce the use of diesel and increase the use of solar

Predesign 2 : hybridization of grids

Predesign with Excel

- **Yearly load curve**
- 15 MWp PV system (PV only, no storage)
- With curtailment

Sample of the load curve (8 days)

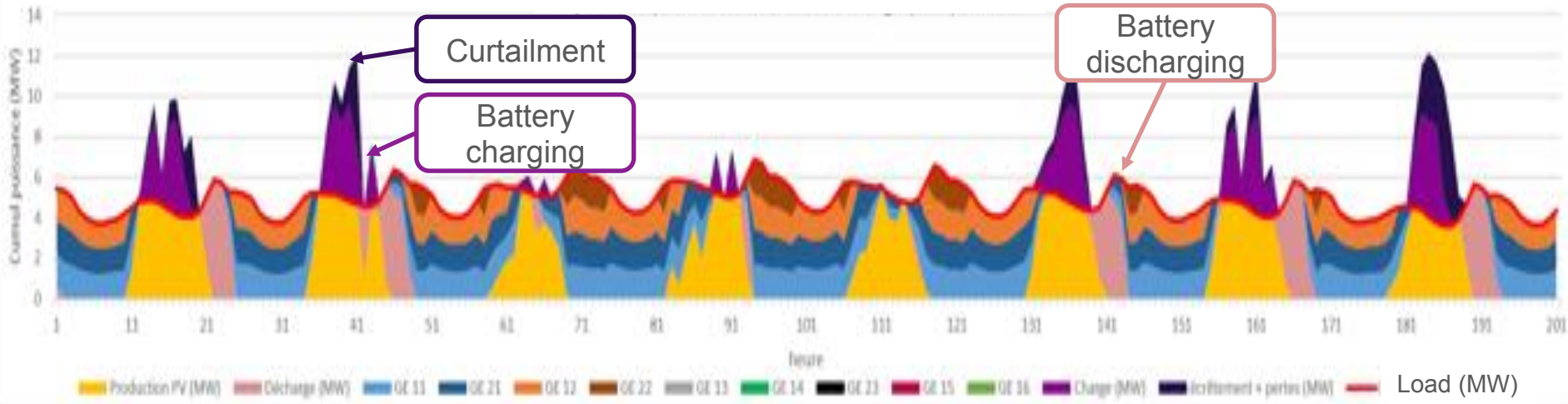


Predesign 2 : hybridization of grids

Predesign with Excel

- Yearly load curve
- 15 MWp PV system
- **6MW/20MWh storage**

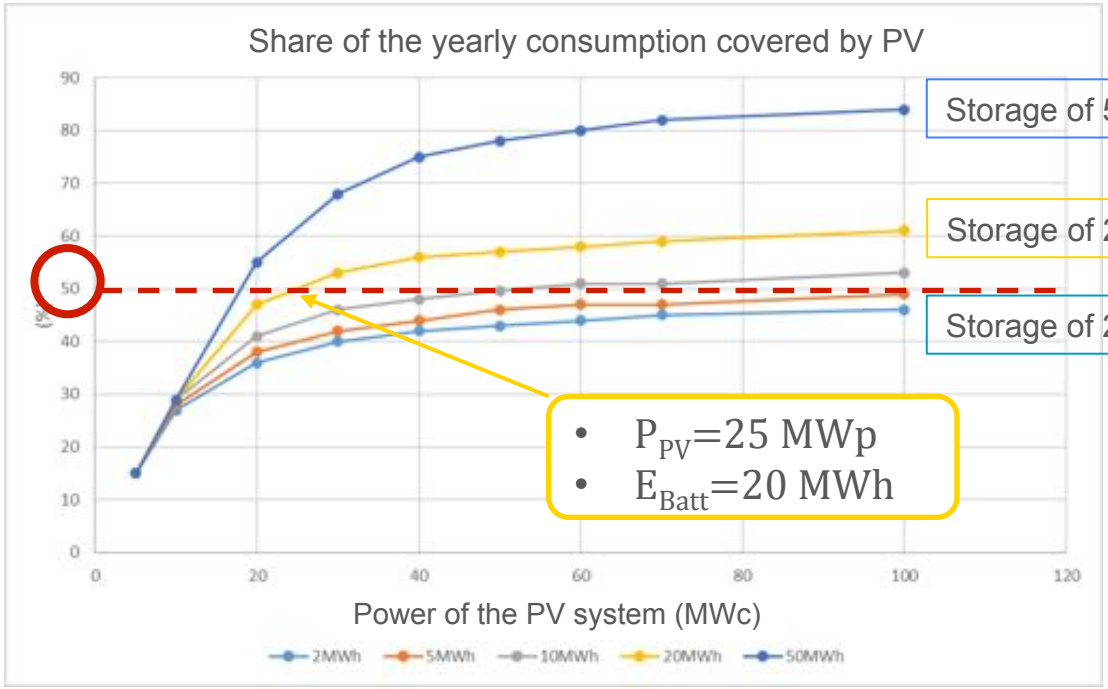
Sample of the load curve (8 days)



Predesign 2 : hybridization of grids

Predesign with Excel

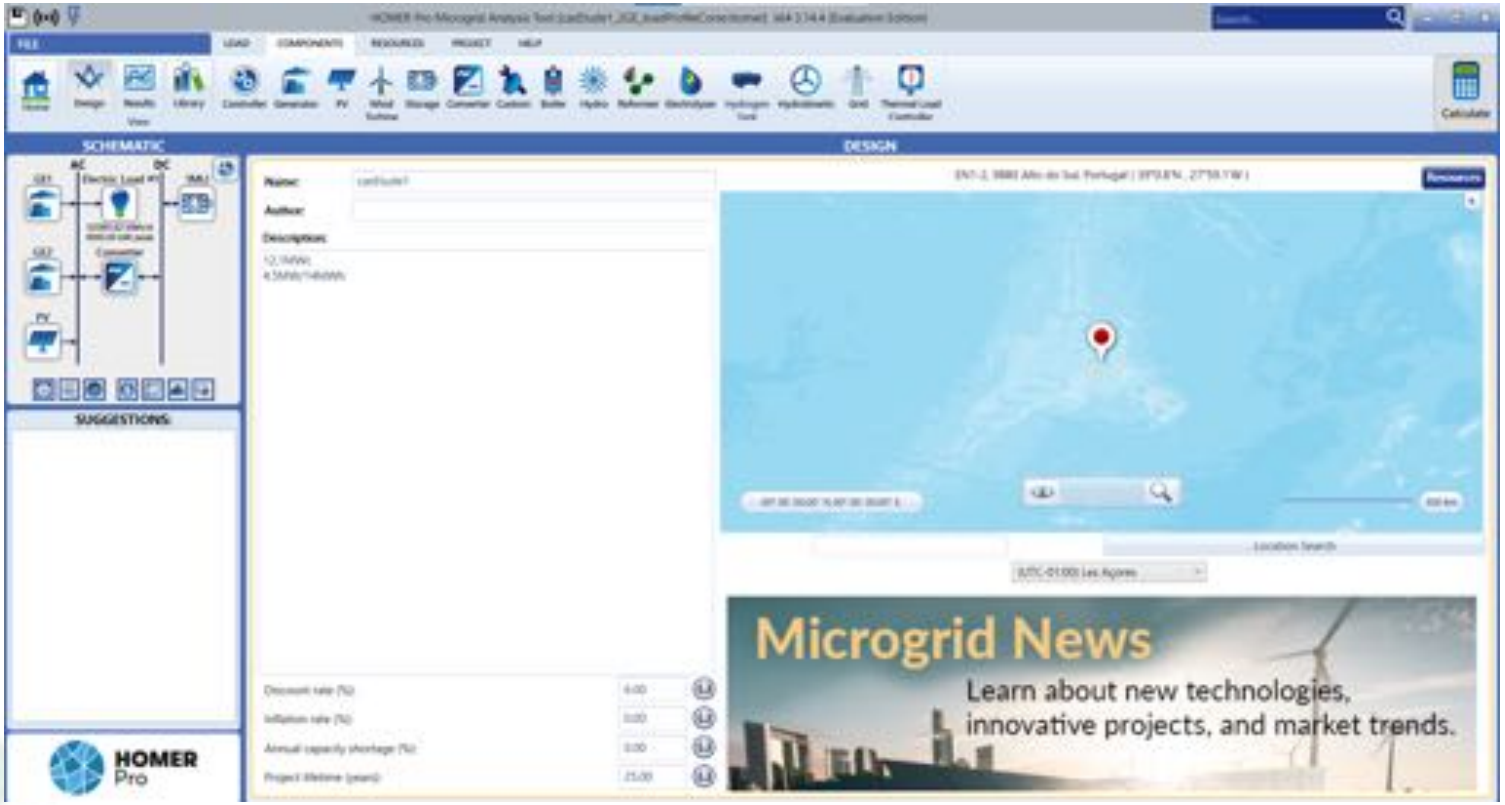
- Example of PV and storage sizing to cover a share of the yearly consumption



- **Difficult to reach 100% of the consumption covered by PV !**

Predesign 2 : hybridization of grids

Predesign with HOMER PRO®



Predesign 2 : hybridization of grids

Predesign with HOMER PRO®

Reference system: 9 gensets
Actualized net value (25years) **: $160M**
Mitigation of CO2 emissions : 38.340t

Predesign 1 :
« Most profitable PV system »

PV system: 11MWp
Battery: 1,5MW/2MWh

Share of the consumption covered by PV (%)	27,31
Share of the consumption covered by battery (%)	0,78
Share of the consumption covered by genests (%)	71,91
Diesel-off mode duration in hours	900
Amount of CO2 mitigation in tons	10 916
Actualized net value (25years) in M$	**140,6**
Return on inversement in years	9,5

Predesign 2 :
« Largest profitable PV system »

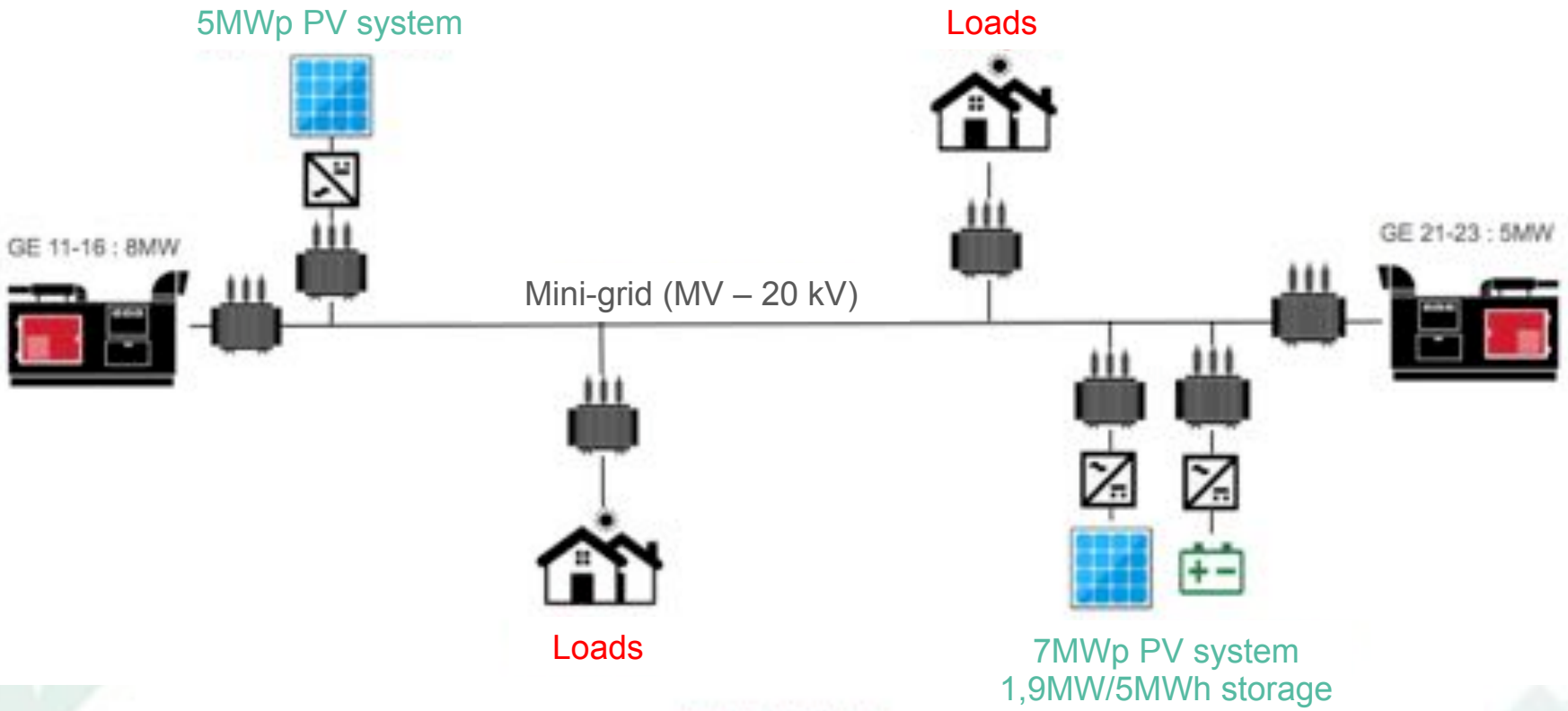
PV system: 16,7MWc
Battery: 10MW/23MWh

Share of the consumption covered by PV (%)	**32,56**
Share of the consumption covered by battery (%)	**10,39**
Share of the consumption covered by genests (%)	57,05
Diesel-off mode duration in hours	2434
Amount of CO2 mitigation in tons	16 607
Actualized net value (25years) in M$	155,3
Return on inversement in years	21,9

Predesign 2 : hybridization of grids

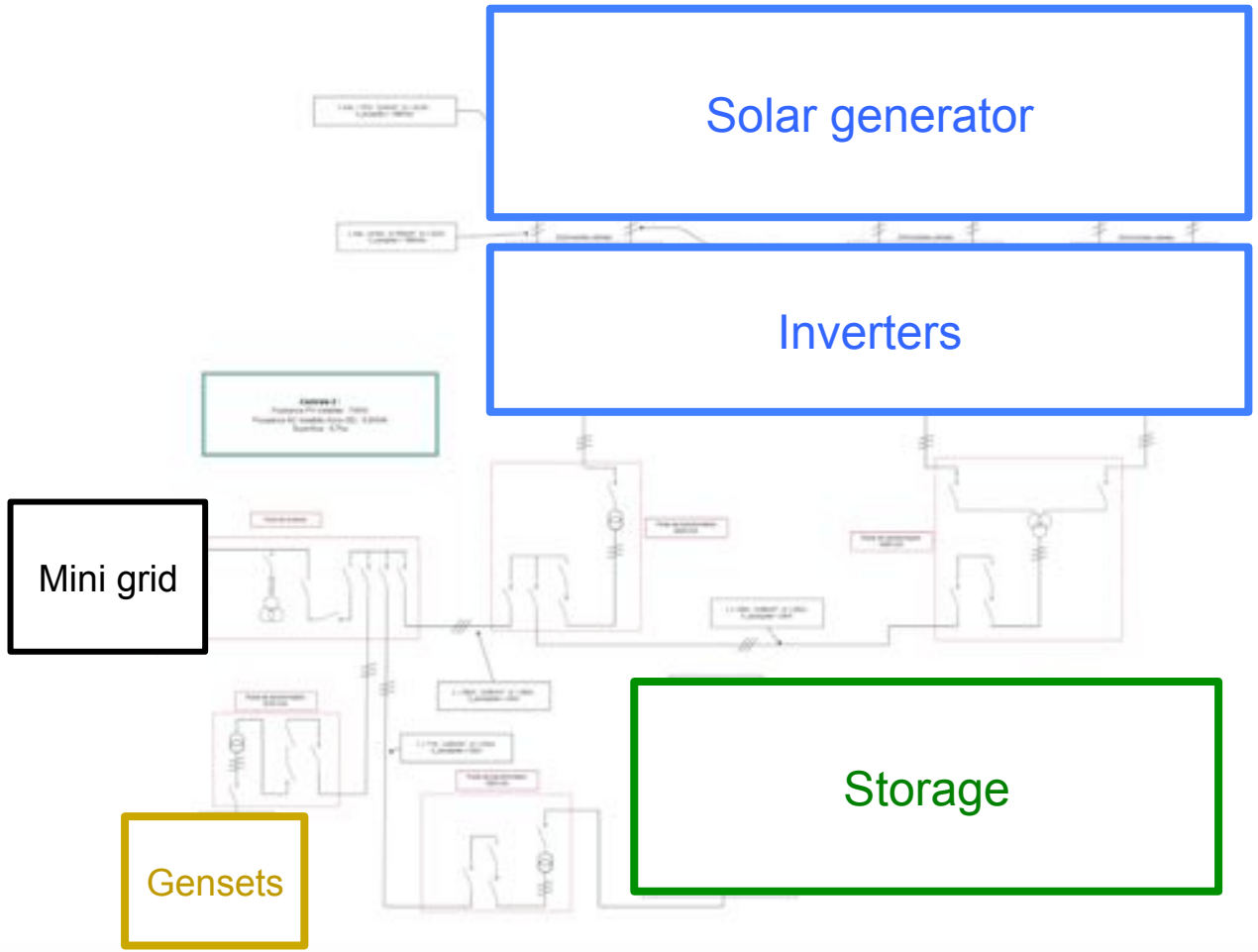
Predesign with HOMER PRO®

- 5+7 MWp PV systems + 1,9MW/5MWh storage



Predesign 2 : Hybridization of grids

Single line drawing



Conclusion

Tokelau Energy project – project review

- IT Power (Australia) report commissioned by the by the New Zealand Ministry of Foreign Affairs and Trade – September 2013

4 Recommendations

4.1 Recommendation #1 – Create a utility

"Tokelau Power"

It is critical that all levels of government in Tokelau understand and agree to the concept that the entity with the liability for the operations of the generation asset must also have the ability to set and collect the tariff.

The three key areas to be developed are: Ownership, Responsibility and Authority;

- Allow or deny, and set the requirements for, any new loads (beyond simple domestic growth)
- Allow or deny and set the standards for any new generation on the grid

MERCI

pour votre attention

www.hespul.org

@hespul

@HespulAsso

HESPUL

Your contact
Bruno Gaiddon
PV and grid expert
bruno.gaiddon@hespul.org