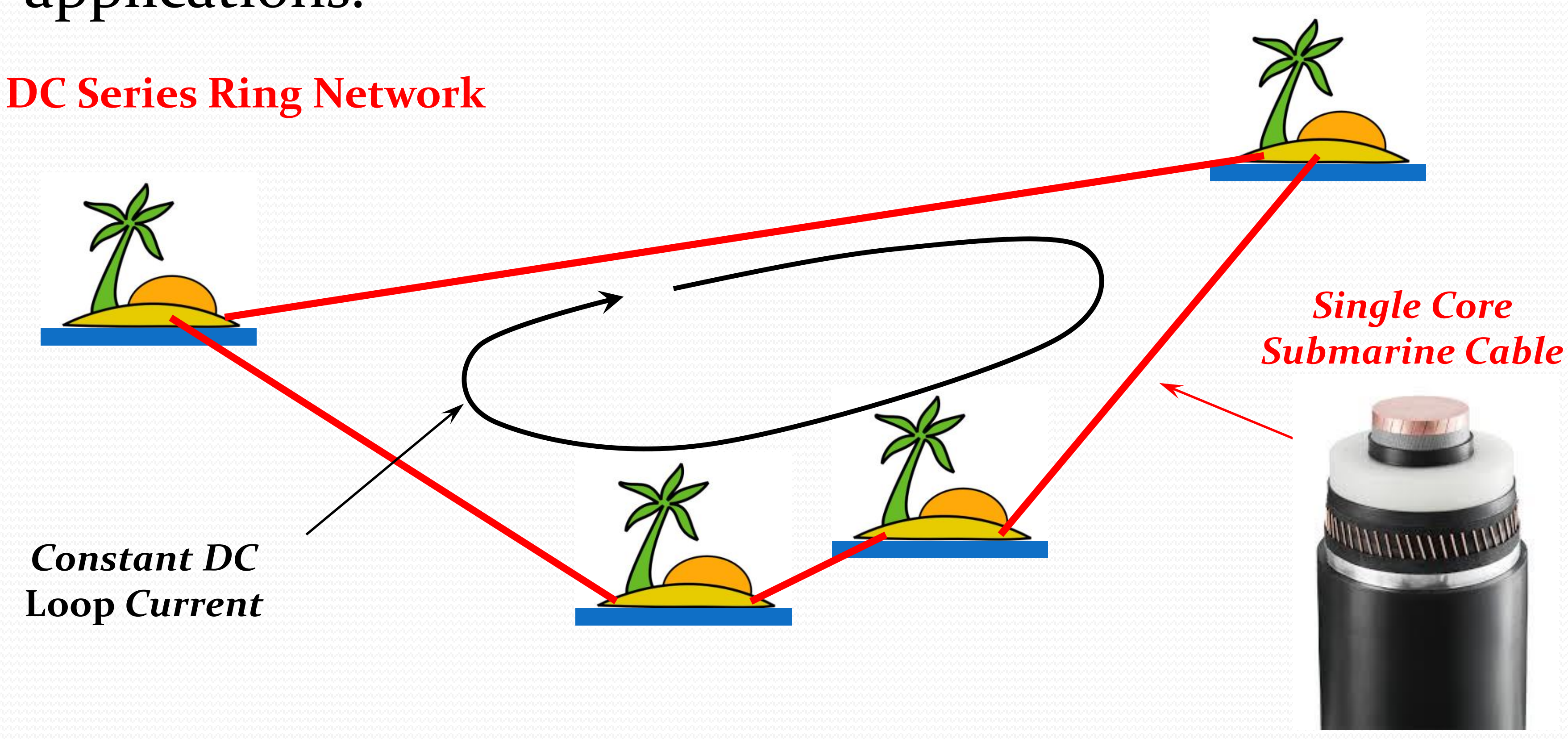
# Case Study:
# Low Cost Inter-Island DC Power Transmission for Chuuk State

Author: Craig Harrison
Managing Director, I S Systems Pty Limited

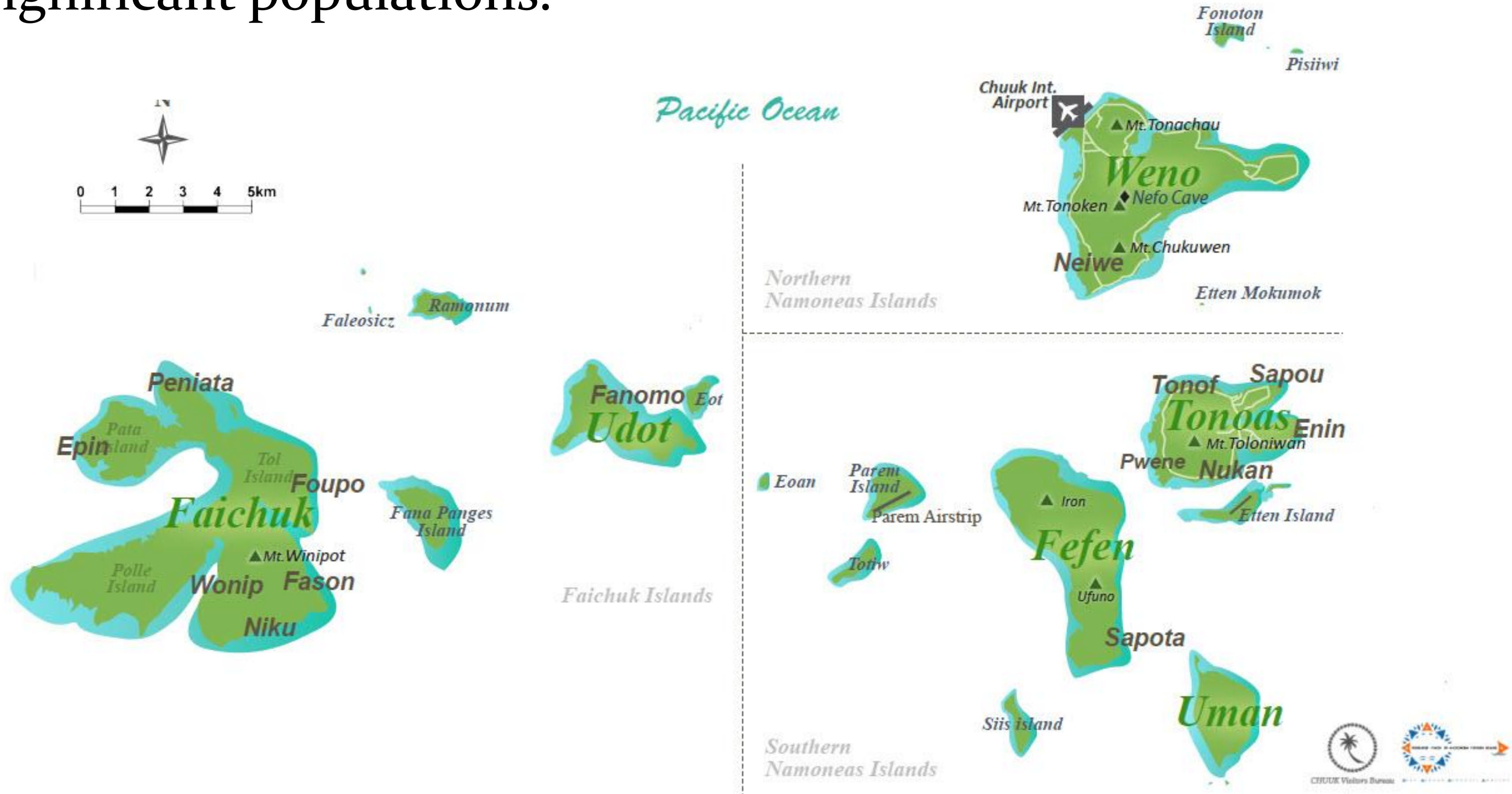
# Background

- Self initiated case study to demonstrate the practicality of a DC Series connected, constant current, single core subsea transmission architecture for certain applications.



# Background

Chuuk Lagoon was chosen for the study as only one island is currently electrified and there are several nearby islands with significant populations.



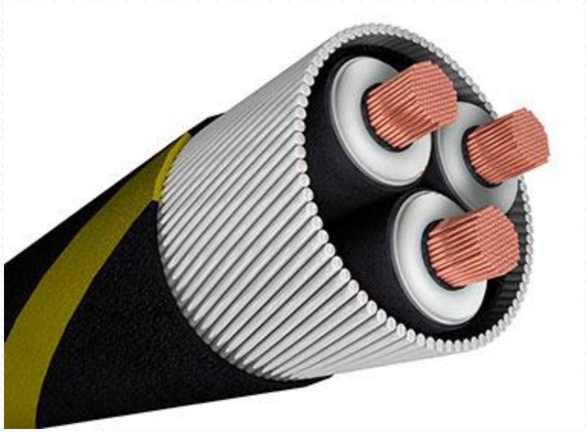
# Advantages

- Utilises existing power station capacity and infrastructure on Weno Island. Many benefits:
  1) higher power station efficiencies,
  2) simplified fuel logistics (delivery & storage).
  3) reduced maintenance & skilled personnel requirements.
  4) reduced land footprint on outer islands.
- Significantly cheaper option for reaching the other islands in the lagoon.

# AC or DC Transmission?

HV AC approach. 3-core HV submarine cable

→3-Core. Expensive.

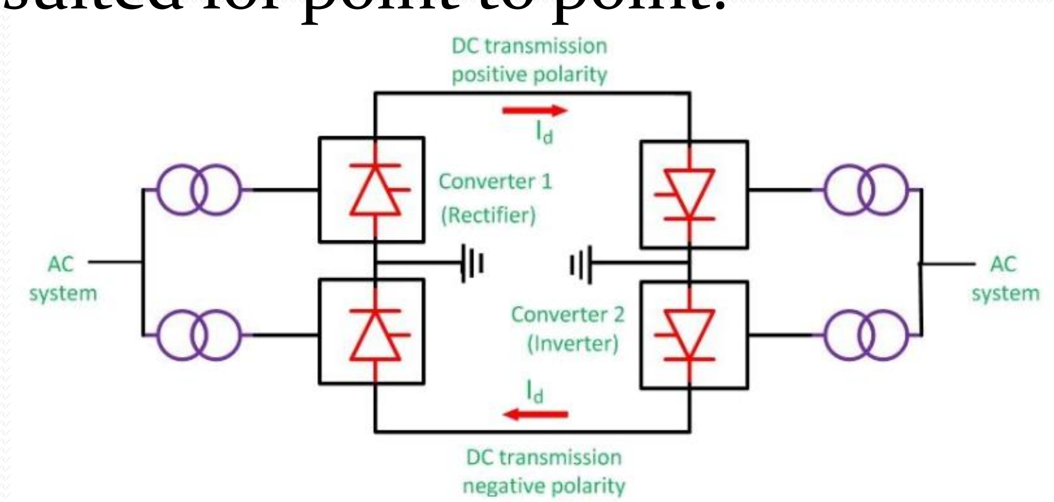


→Potential reactive power & voltage regulation issues.

# Traditional DC

Constant Voltage HV DC:

→Better suited for point to point.




→ Expensive protection equipment.

→ 2-Core for bipolar.

# Single Core DC Series Loop

Economic savings are substantial compared to 2-core or 3-core.

→ Cable price is reduced.

→ Laying costs are reduced:

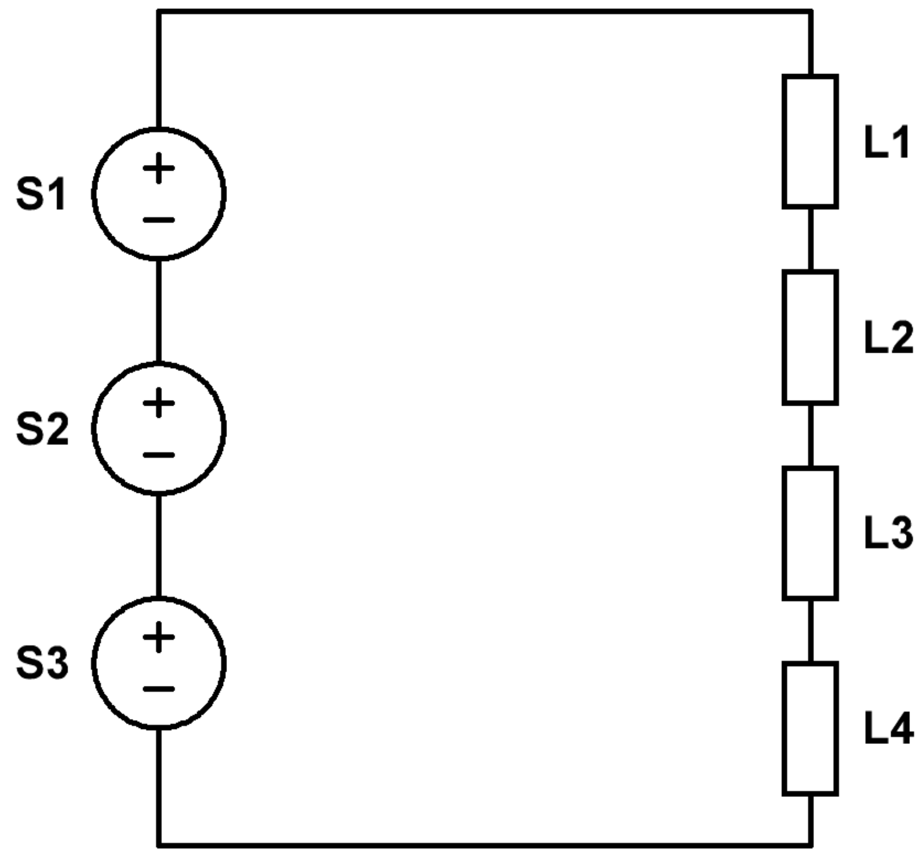
- Lighter cable.
- Longer lengths per drum = fewer splices.
- Cheaper splices- only 1-core.

# The Basic DC Series Ring

1.

Standard schematic layout.

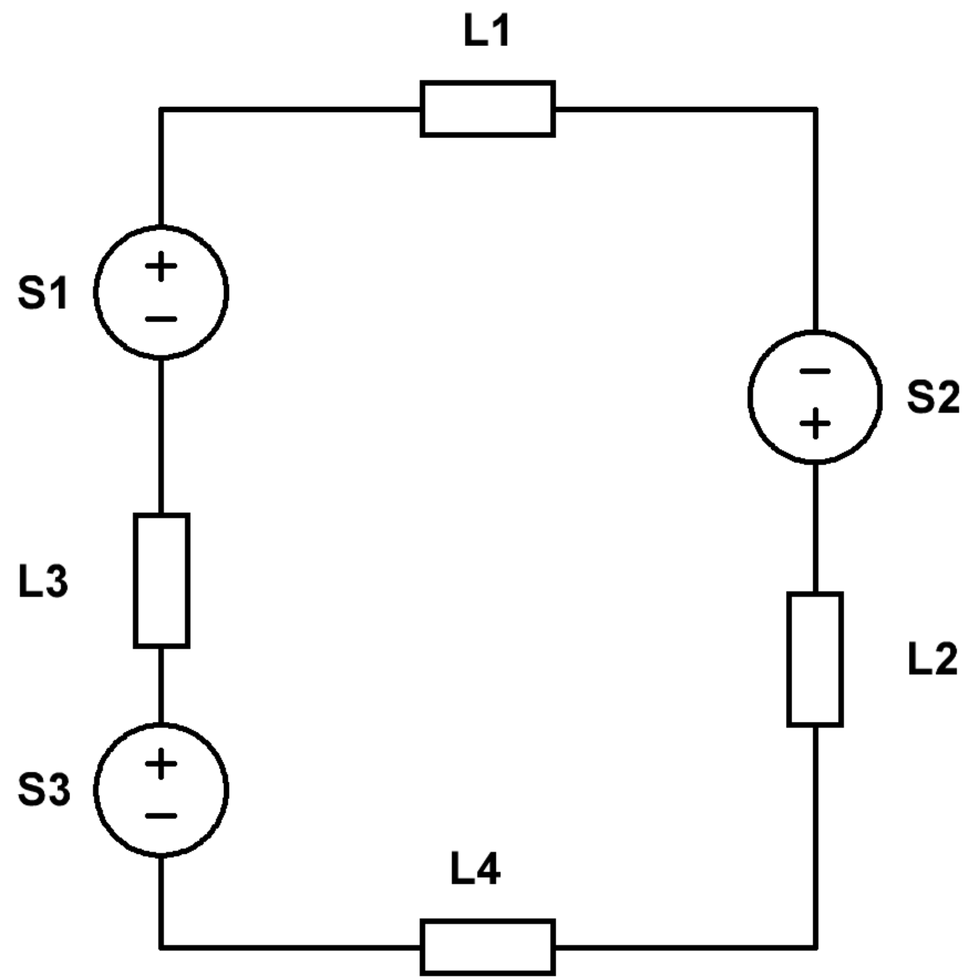
Clearly 1-core only.



# The Basic DC Series Ring

2.

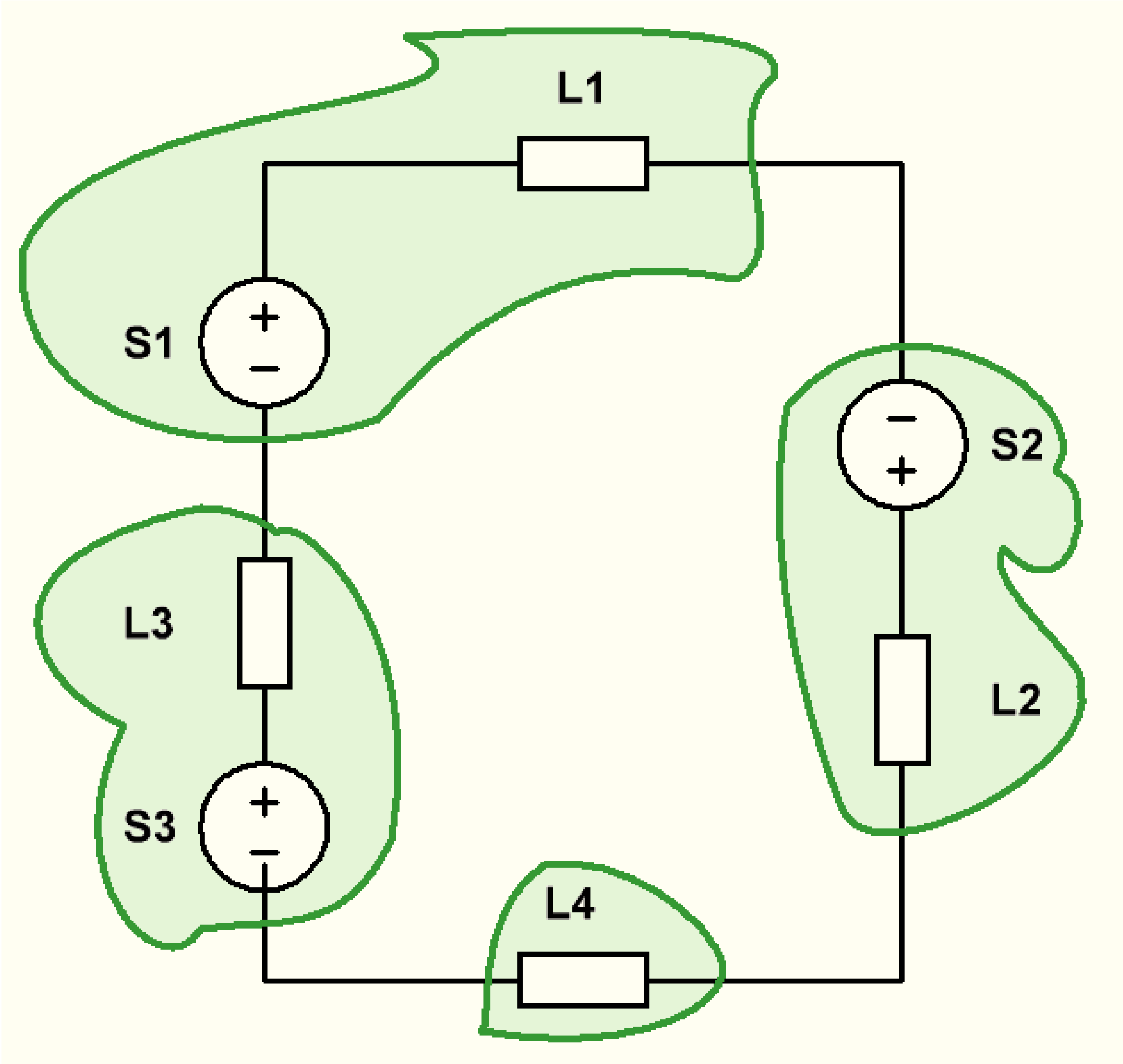
Randomly ordered.



# The Basic DC Series Ring

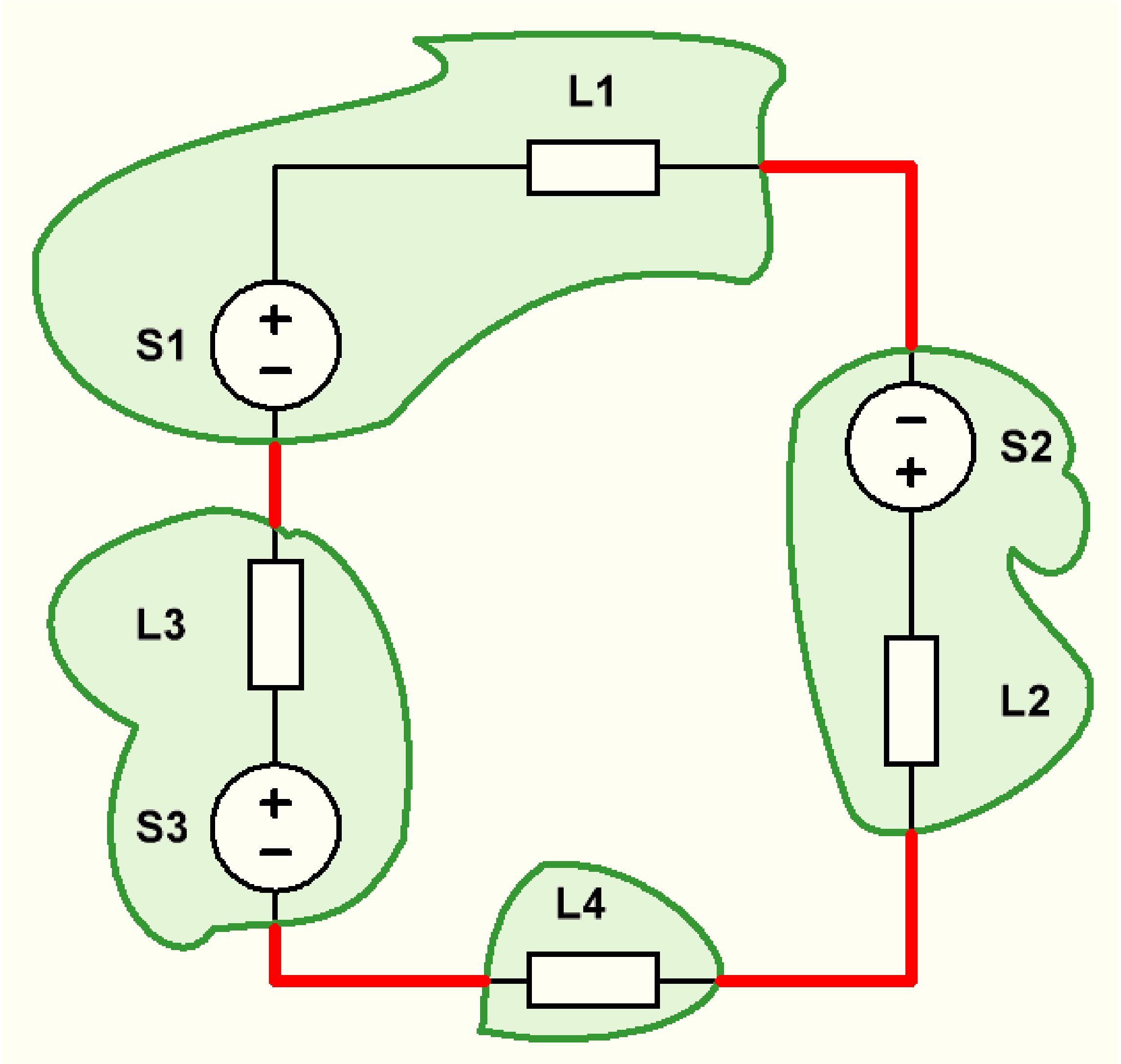
3.

Grouped by island.



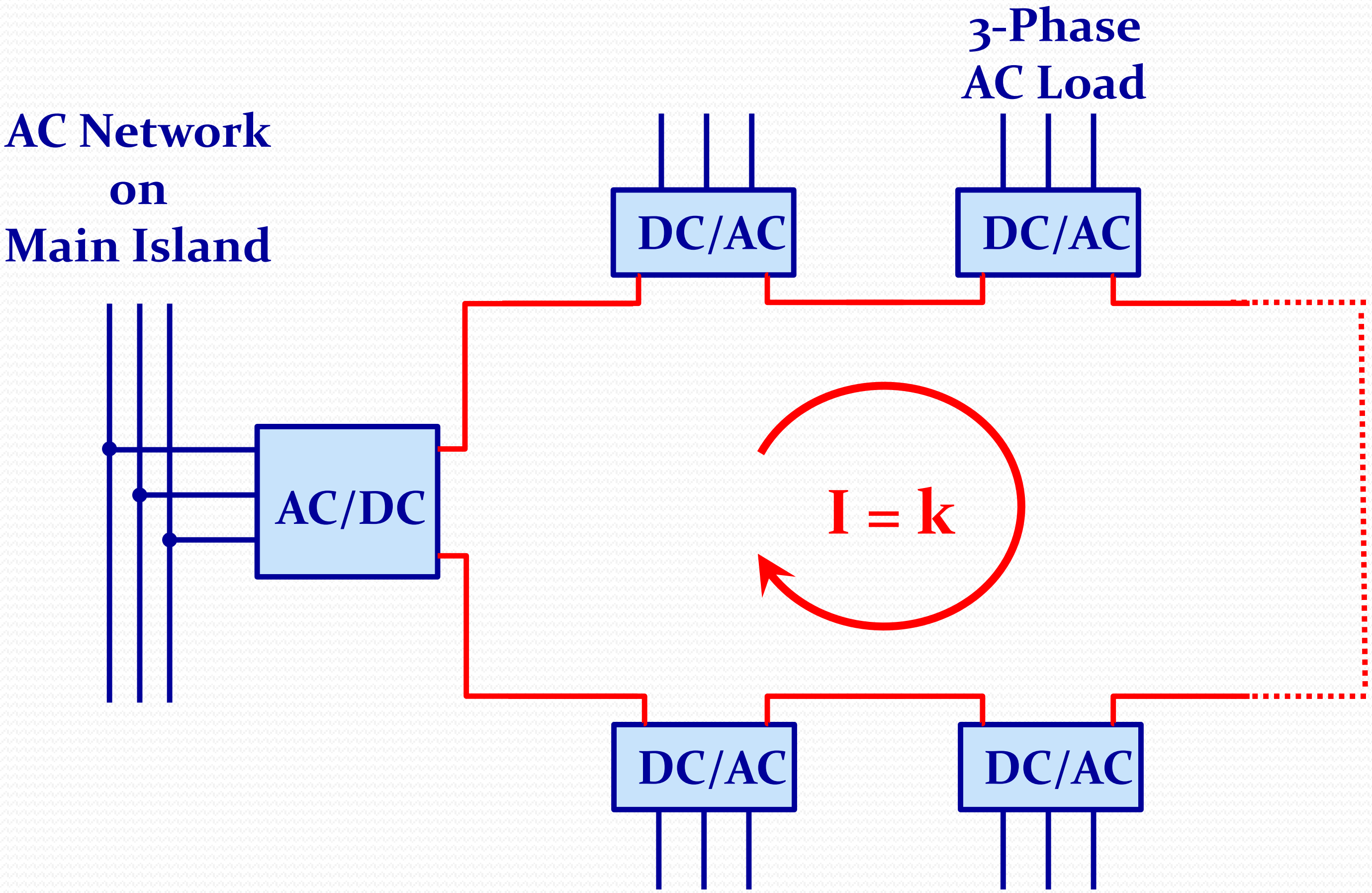
# The Basic DC Series Ring

4. Highlighting the 1-core submarine cable.

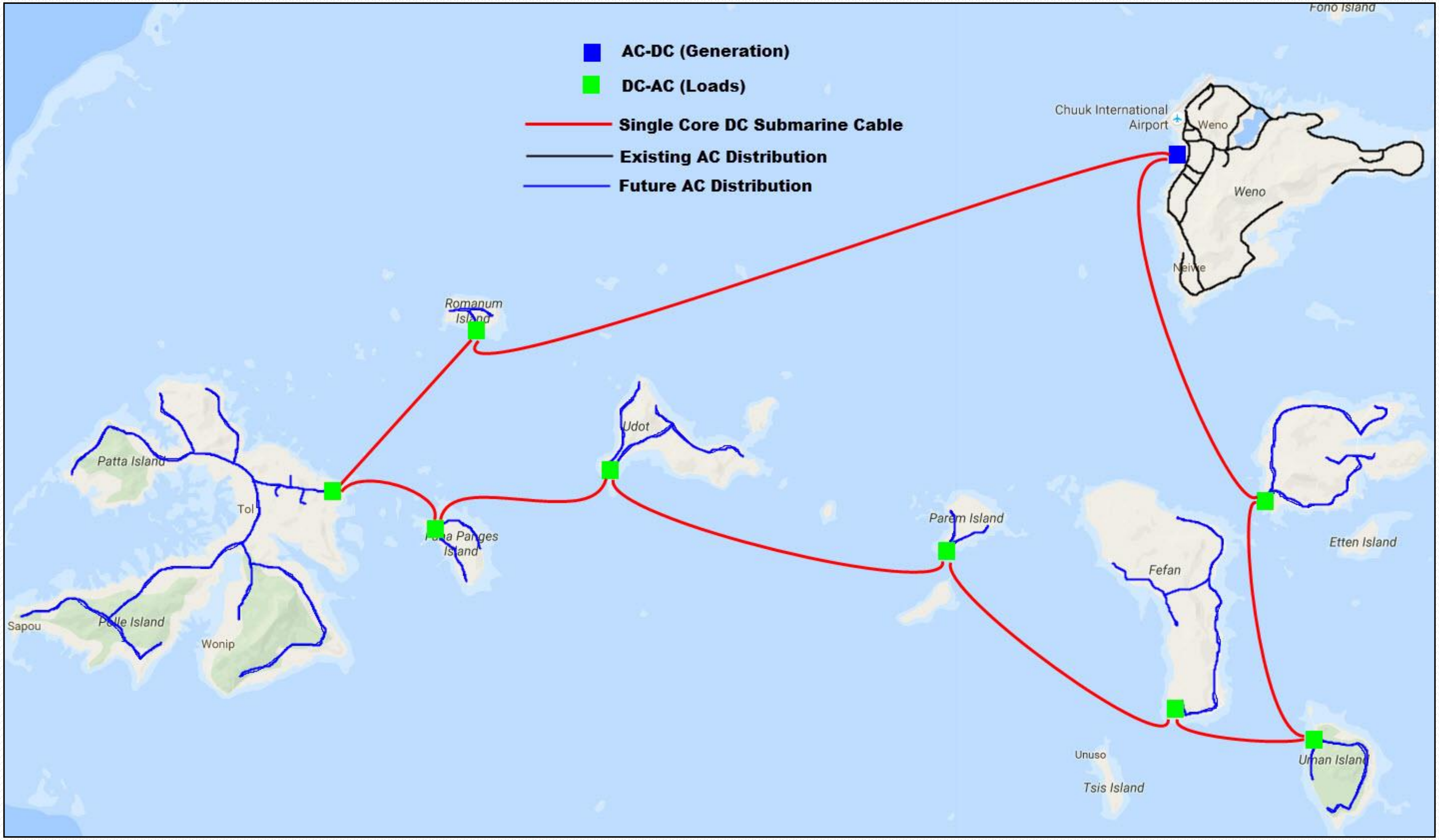


# AC-DC Interfaces

All load locations are converted to 3-phase AC.

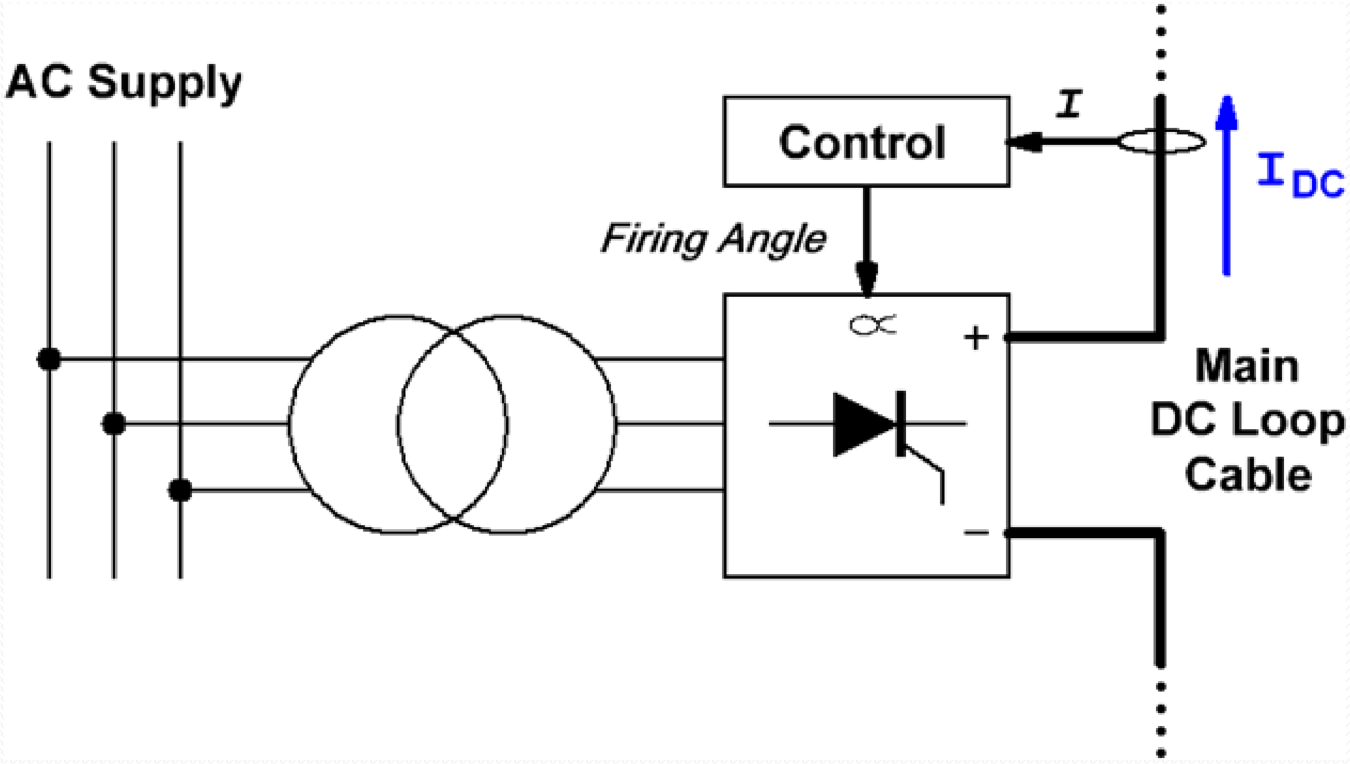


# DC Transmission / AC Distribution



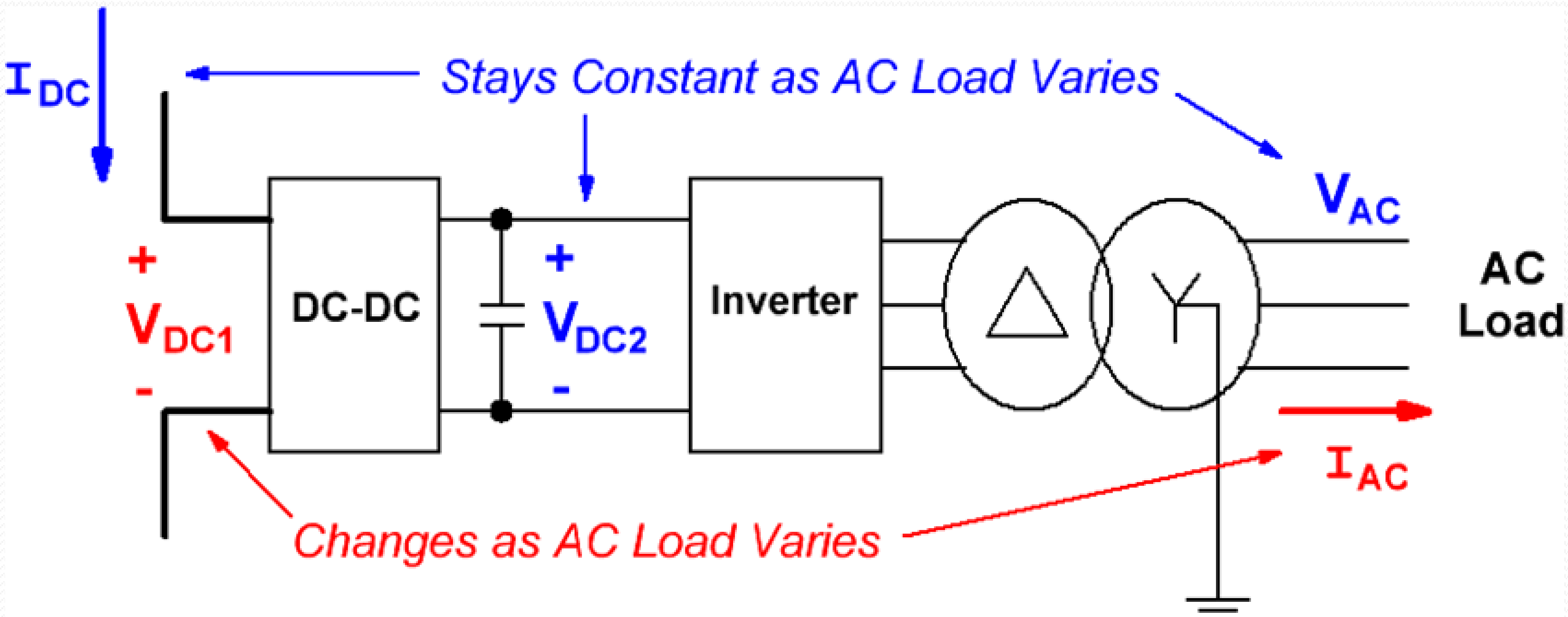
# DC Constant Current Source

- Requires a controllable DC voltage source. Easily achieved with a thyristor rectifier.



# Power Conversion for Loads

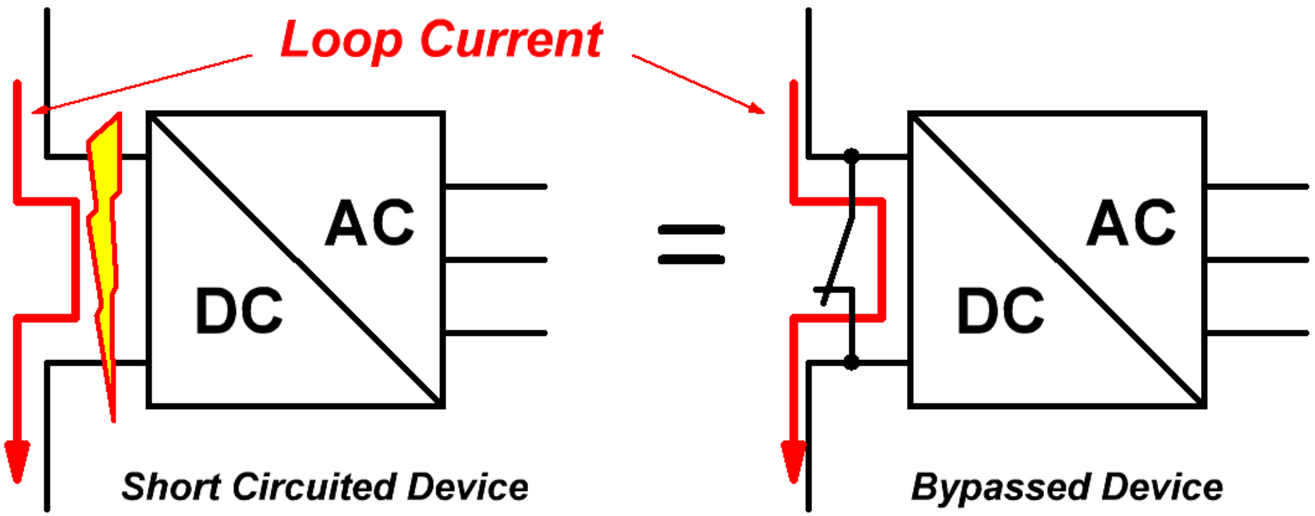
- DC-AC conversion for loads employs widely utilised industrial power conversion modules – DC-DC modules and inverters.



# Short Circuit Fault

- Constant current supply means no change in current for a short circuit.

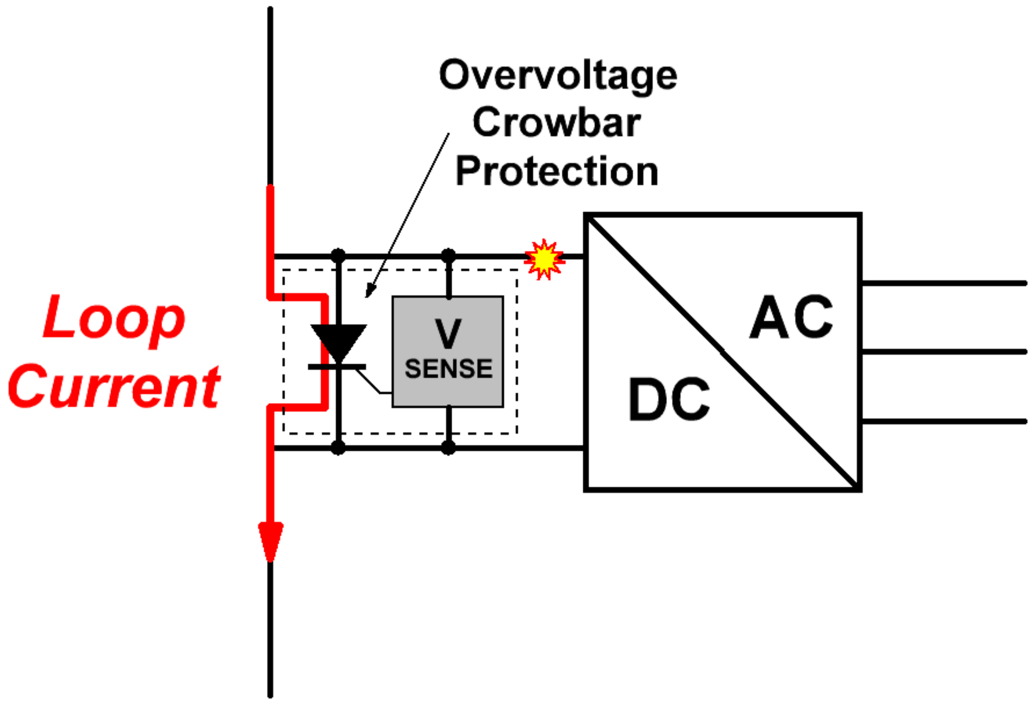
Therefore, no such thing as Fault Current Levels!



# Open Circuit Fault

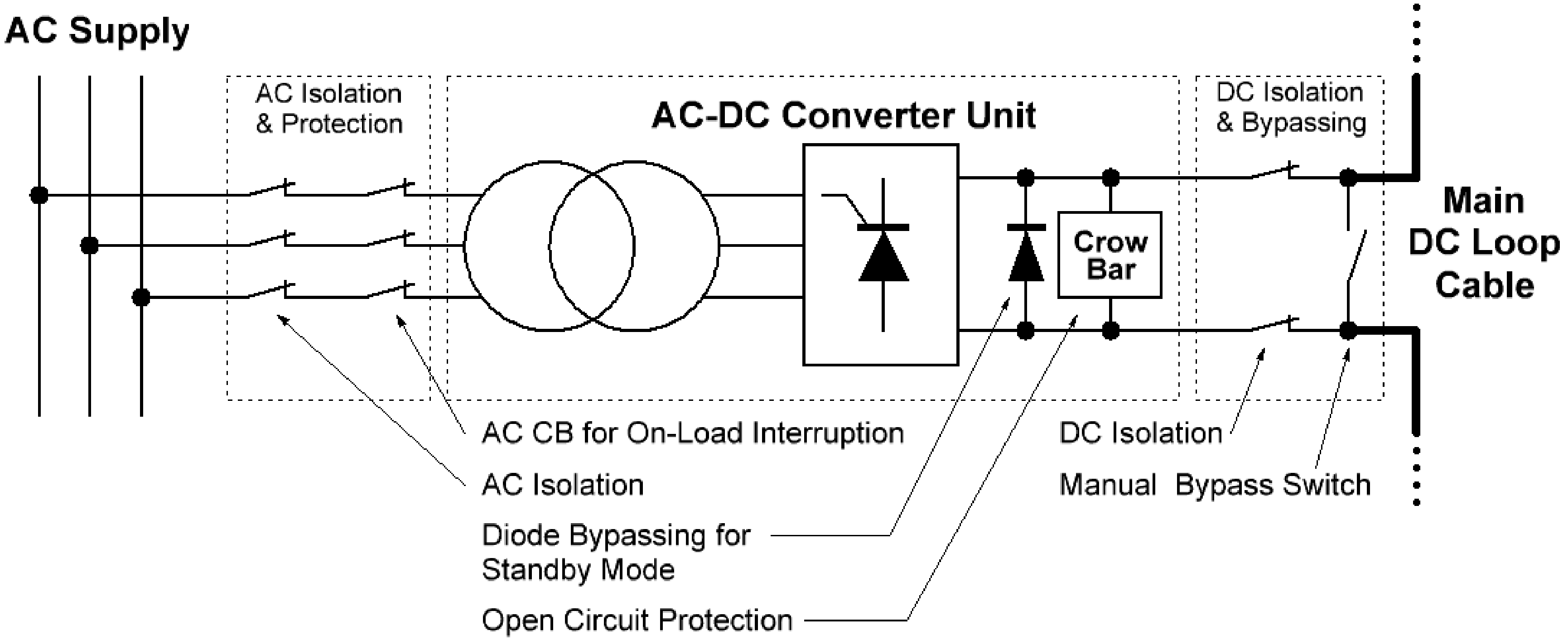
- Current will drop towards zero & voltage will rise.

Crowbar protection will trigger and bypass faulty unit.



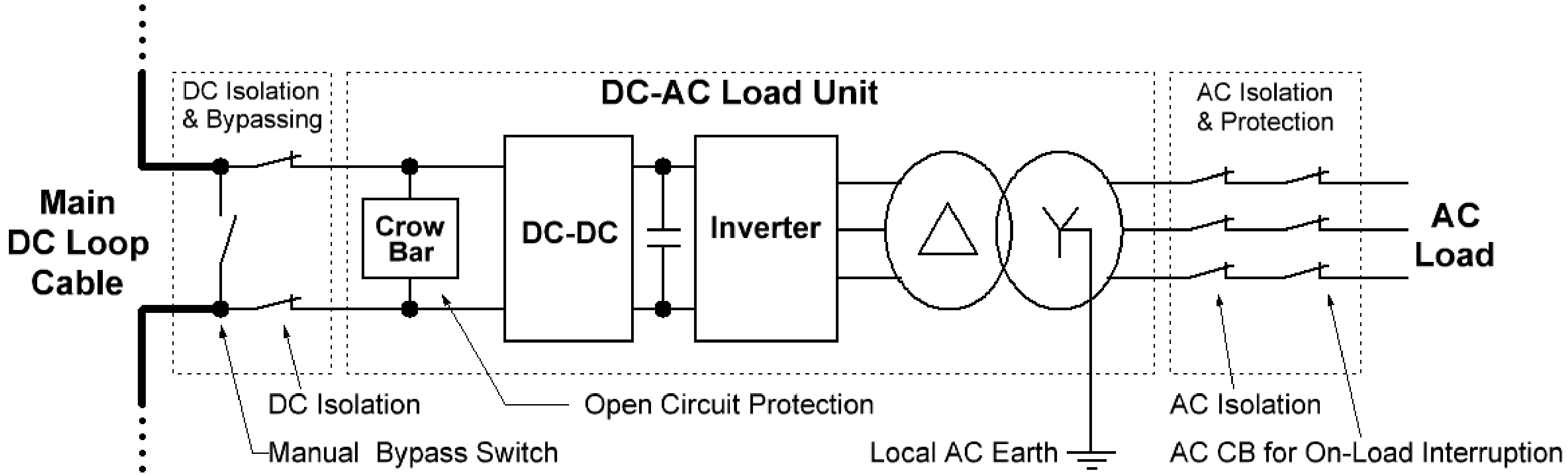
# Protection - Sources

No need for 'on load' DC breaking ability.



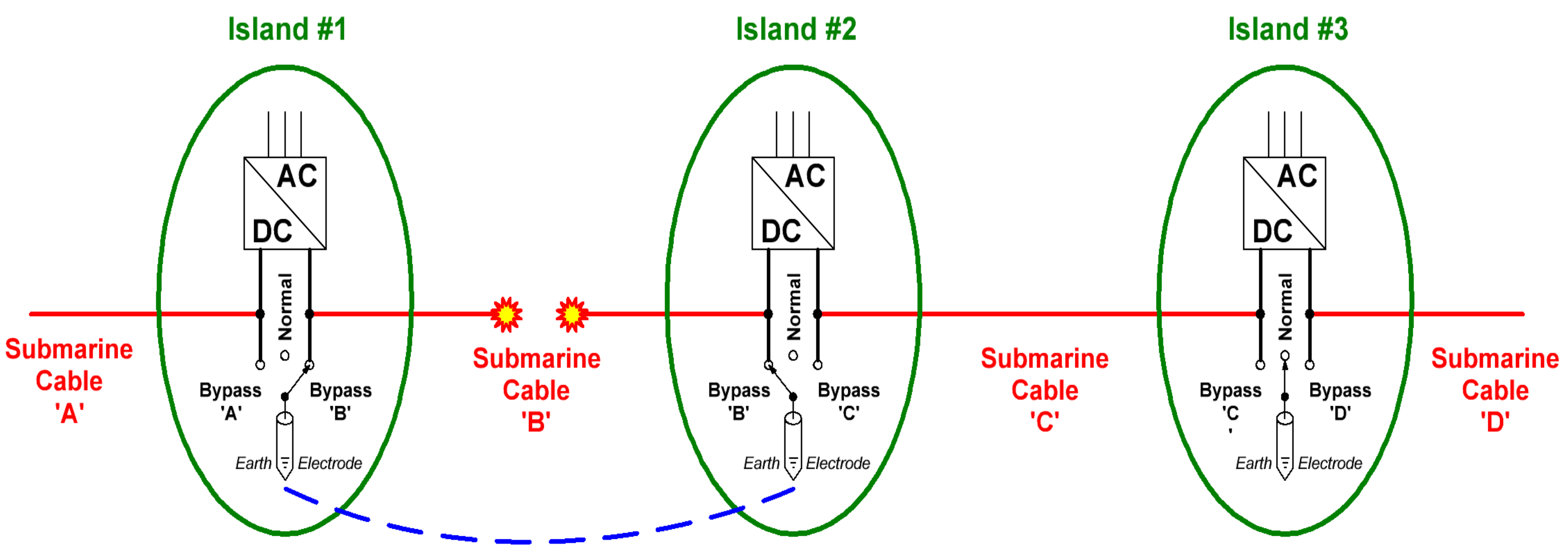
# Protection - Loads

Again, DC switchgear ‘makes’ , but does not ‘break’.



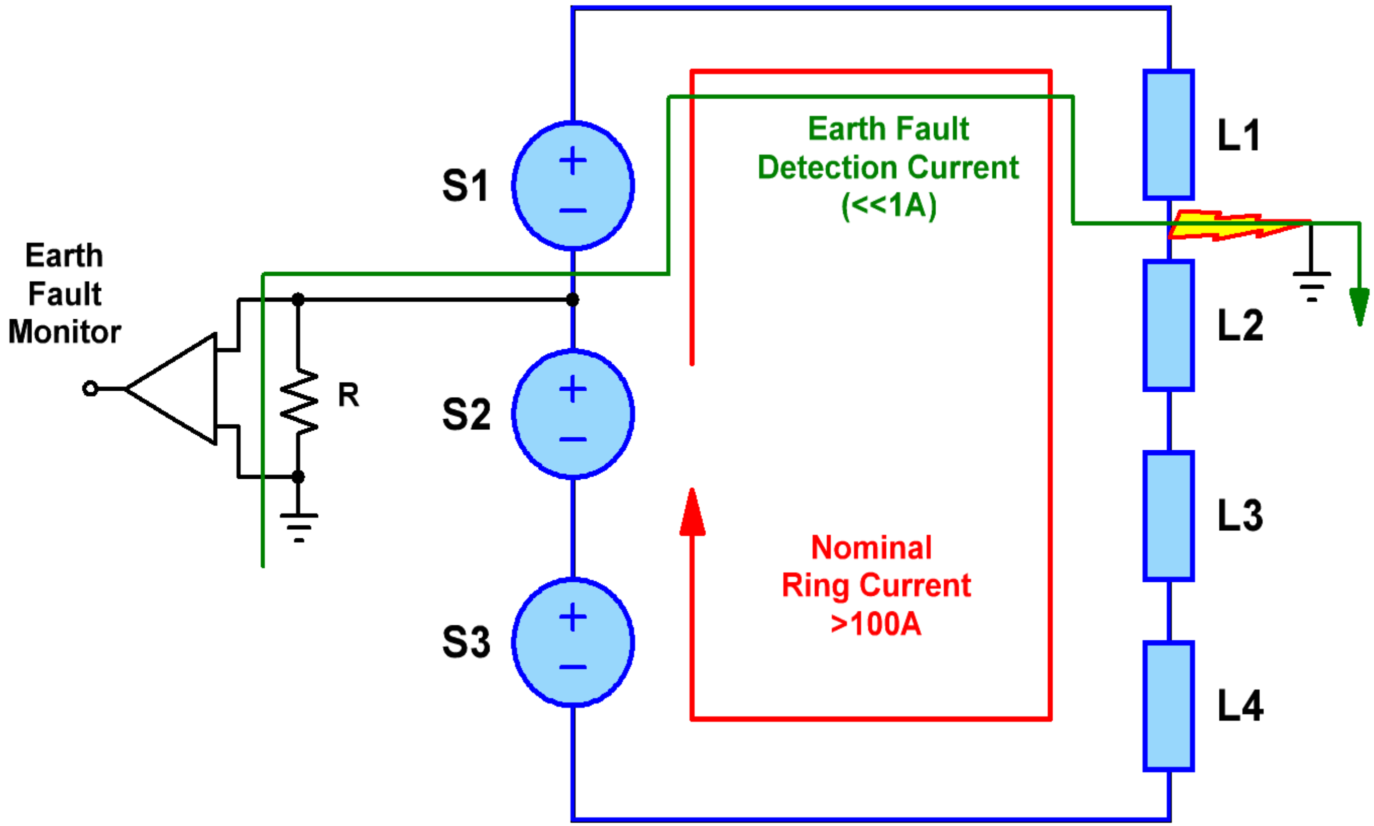
# Redundancy

- A submarine cable failure can be bypassed until the cable repair is completed.

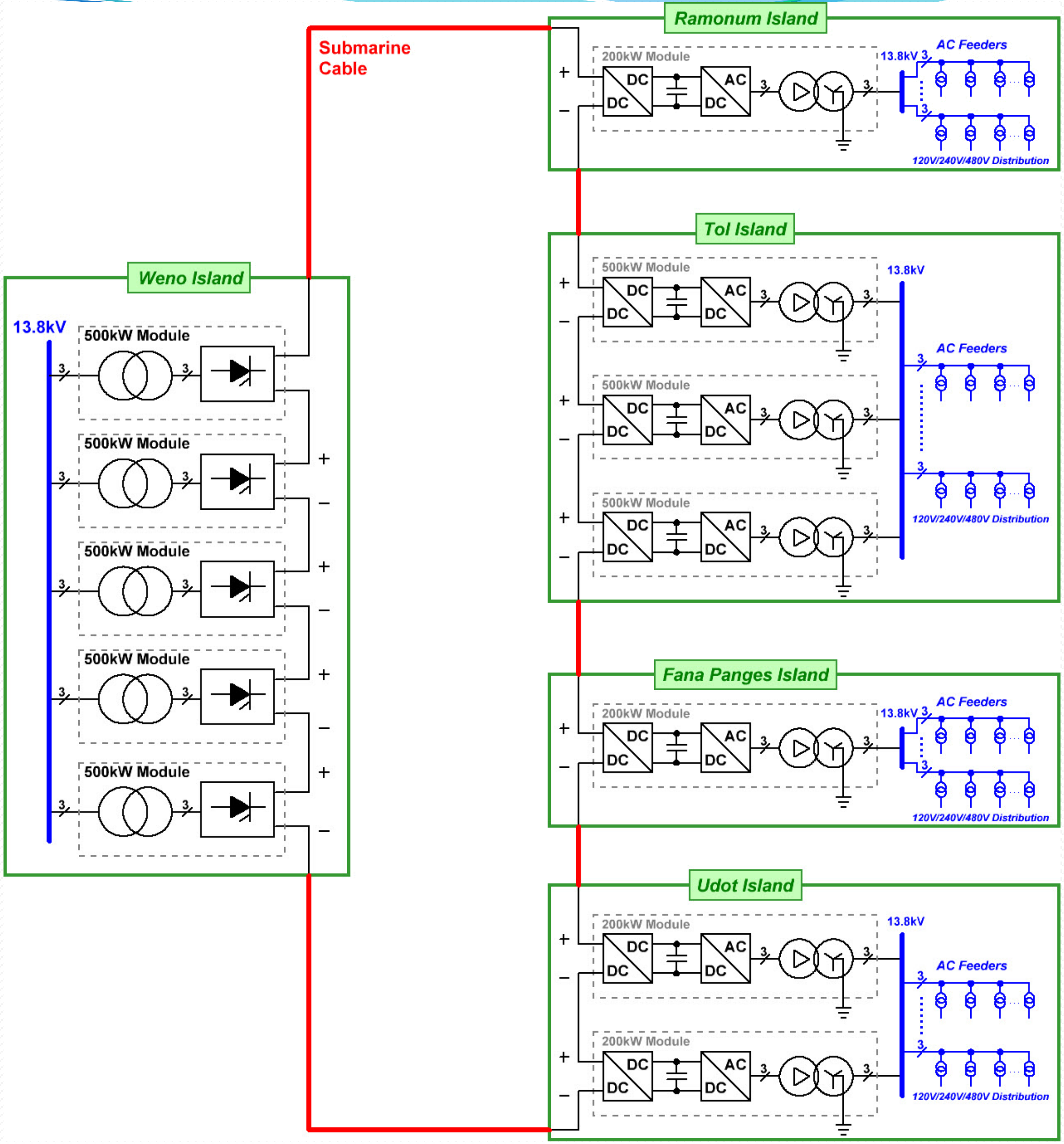


# Earth Fault Detection

- Normal operation is maintained for a single earth fault on the DC transmission network.

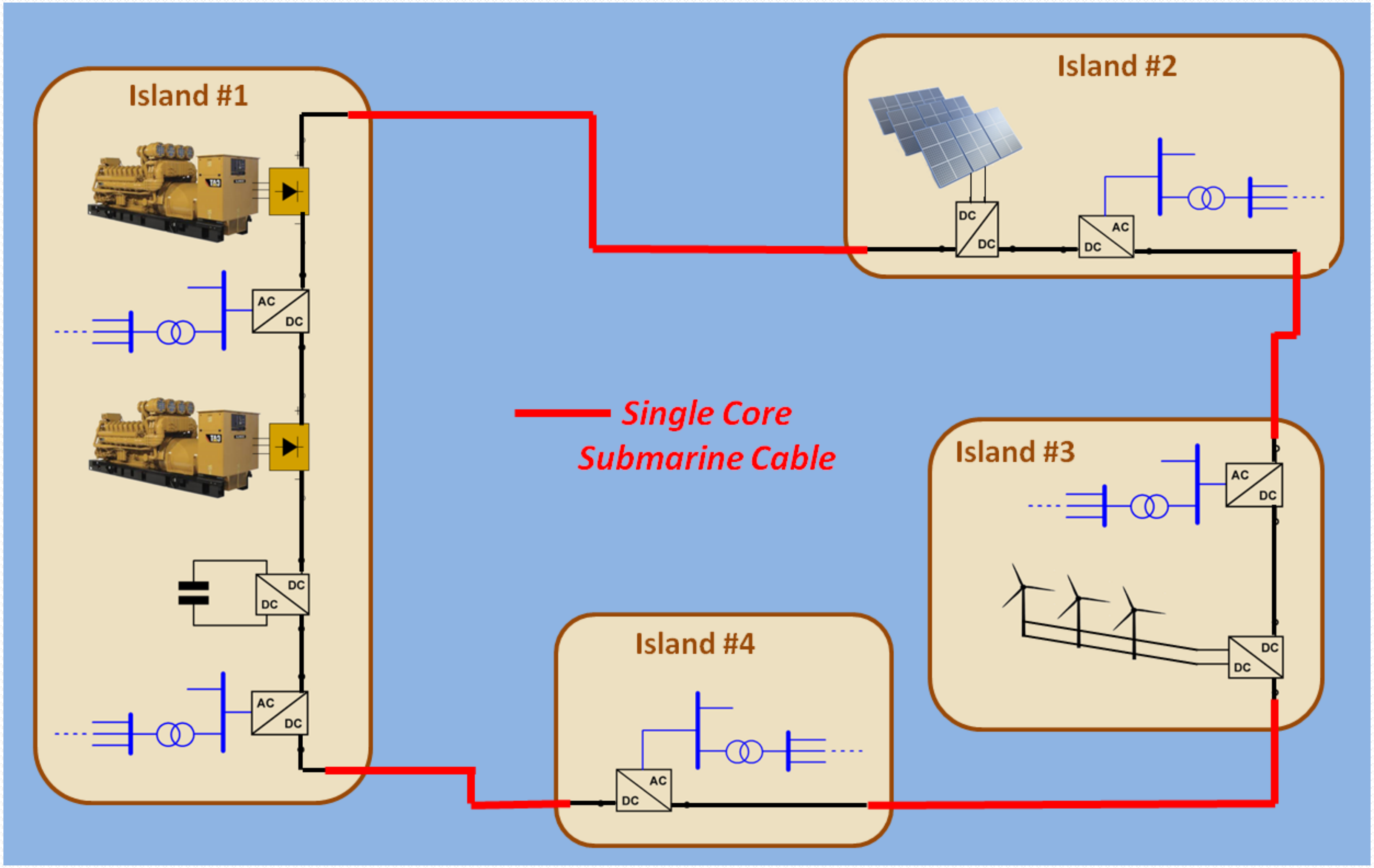


# Modular Design



# Future Expansion

- Other Diesel/RE generation easily added at any time



# Chuuk Lagoon Study

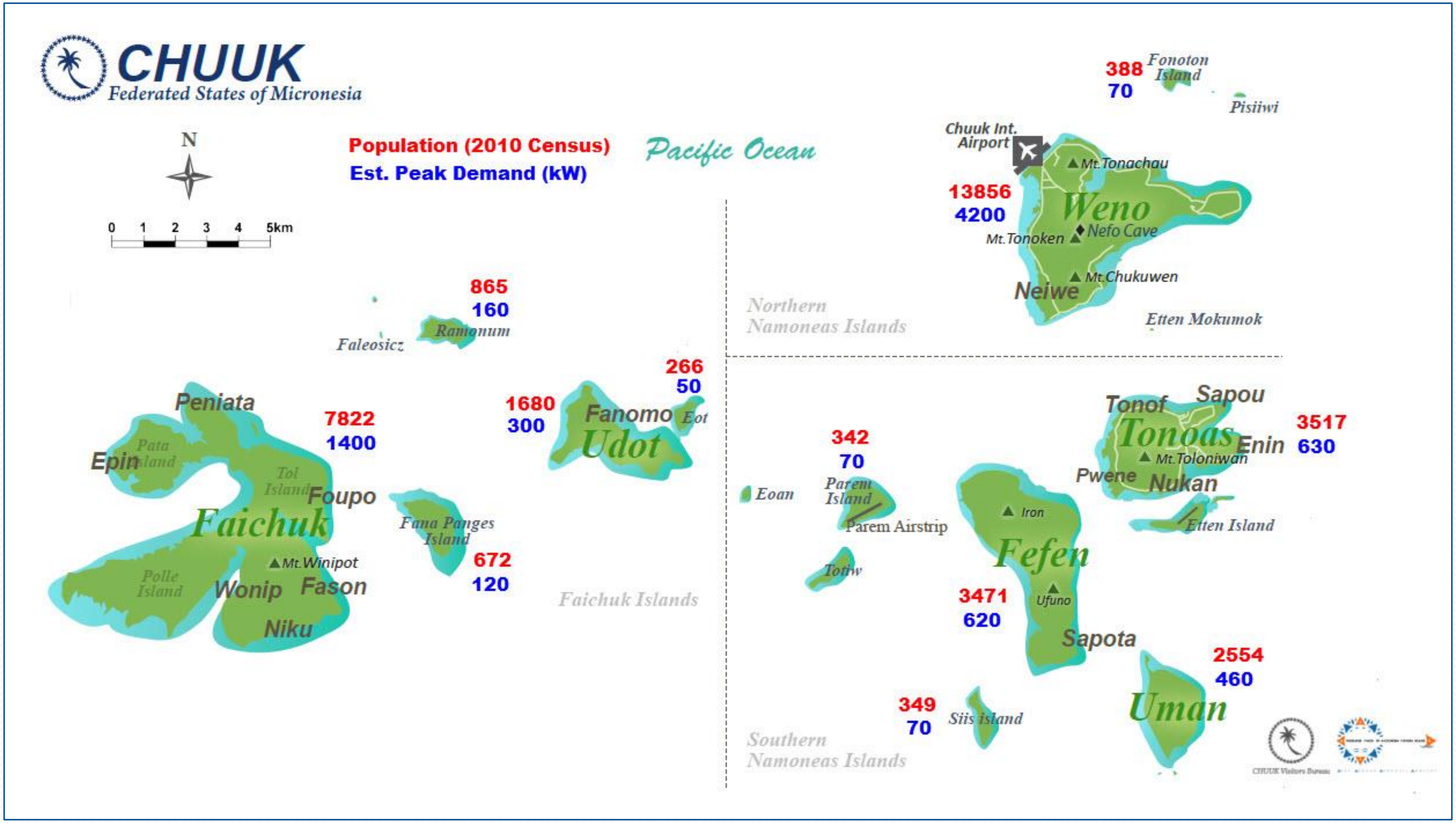
- A detailed design application and modelling of a potential DC Series Transmission network as could be applied to Chuuk Lagoon was performed as an exercise

# Peak Load Estimates

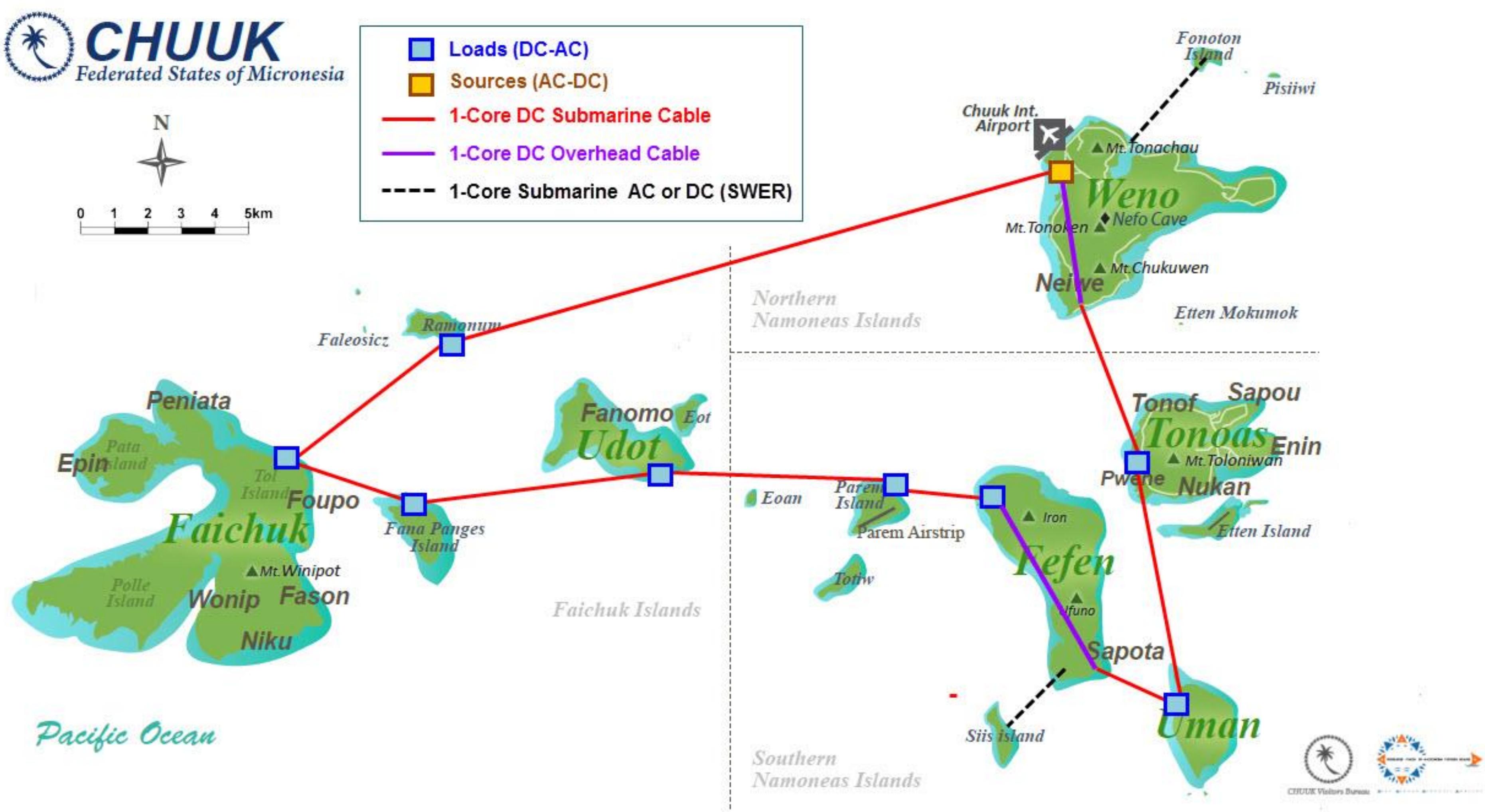
- Population data based on 2010 FSM Census.
- Load vs population data based on KEMA/NREL energy snapshots. Averaged across ~10 PPA countries.
- Resulting formula:

$$Peak\ Load\ (kW) = \frac{Population}{5.6}$$

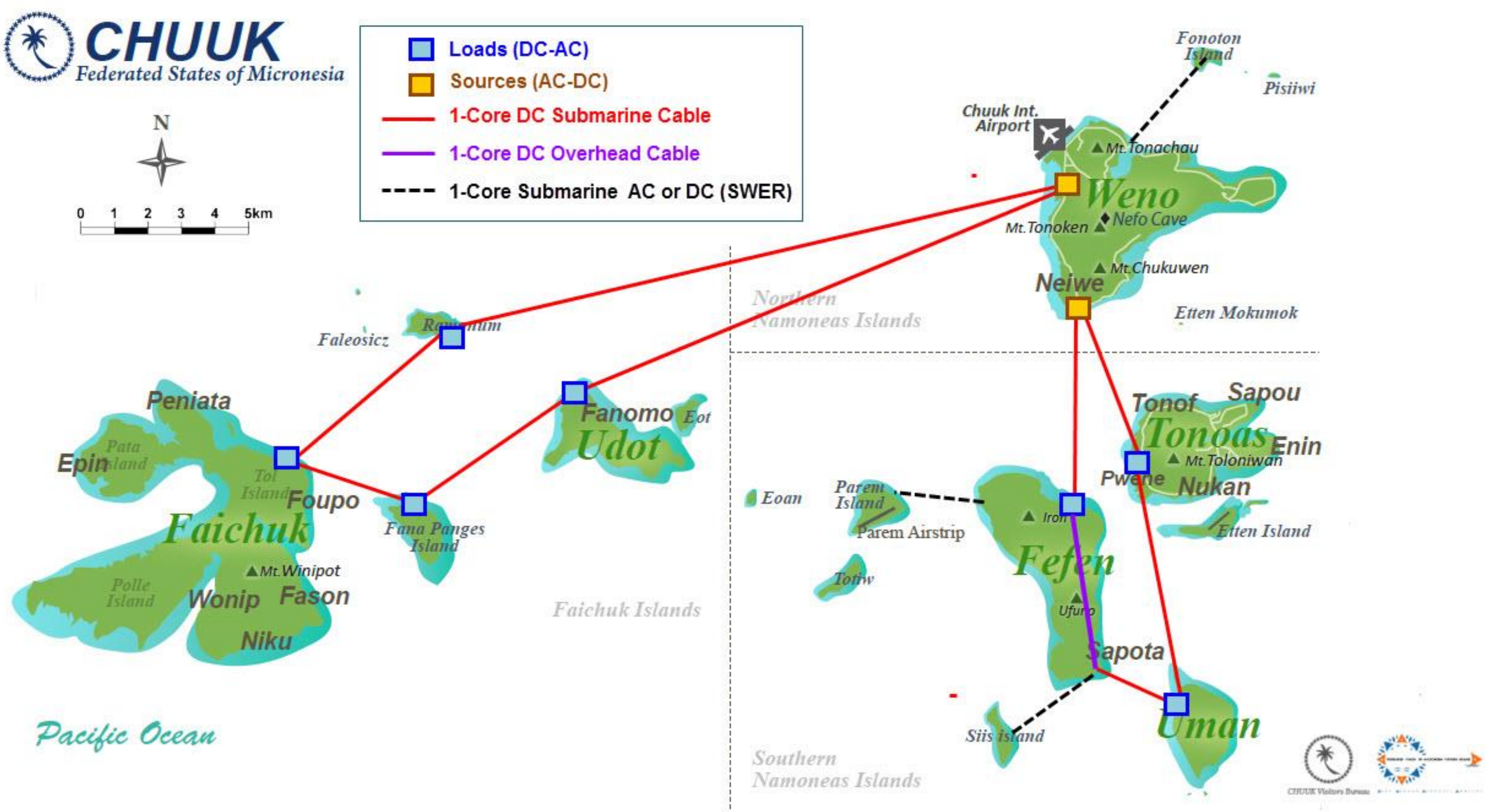
# Peak Load Estimates



# Loop Options - Single



# Loop Options – Double

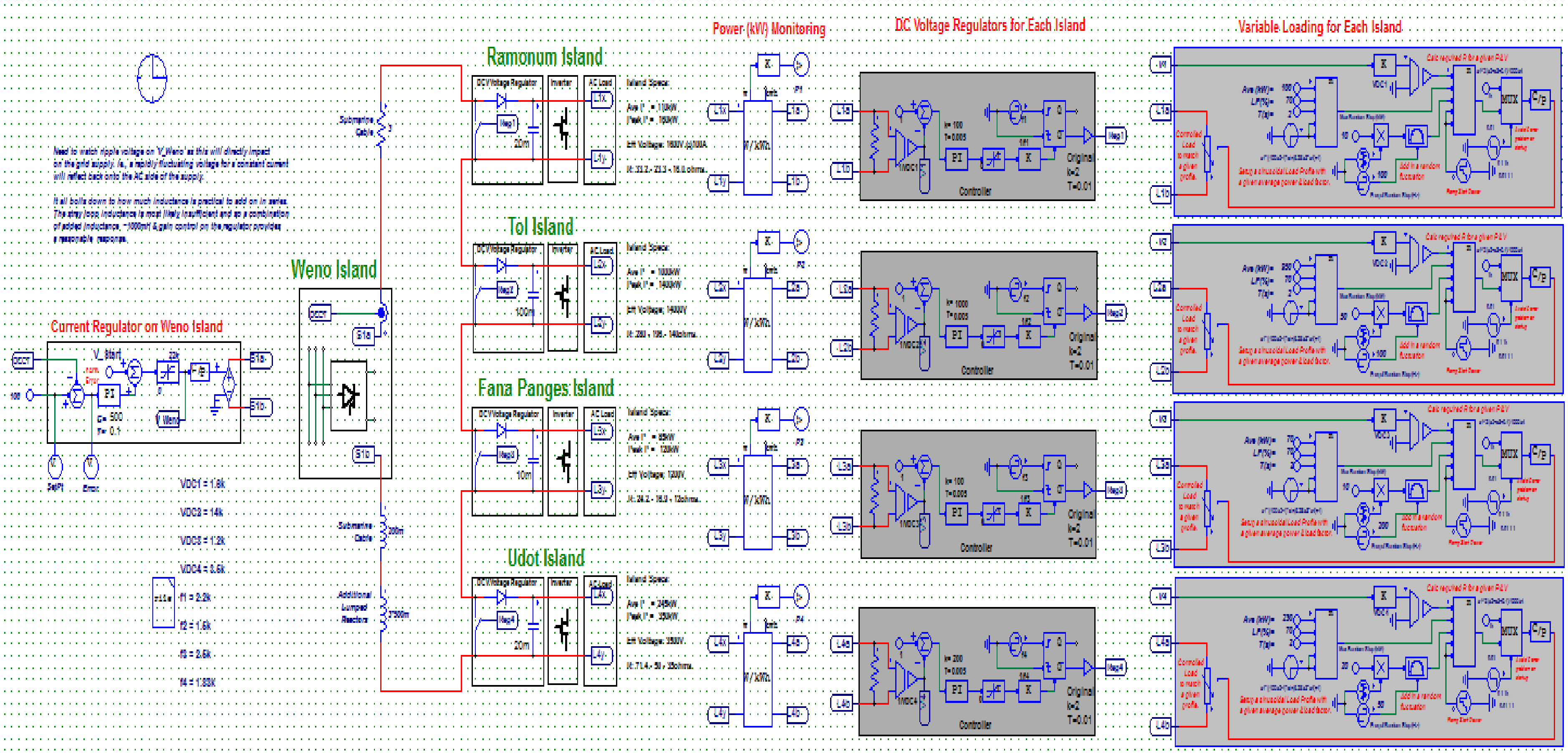


# Loop Calculations

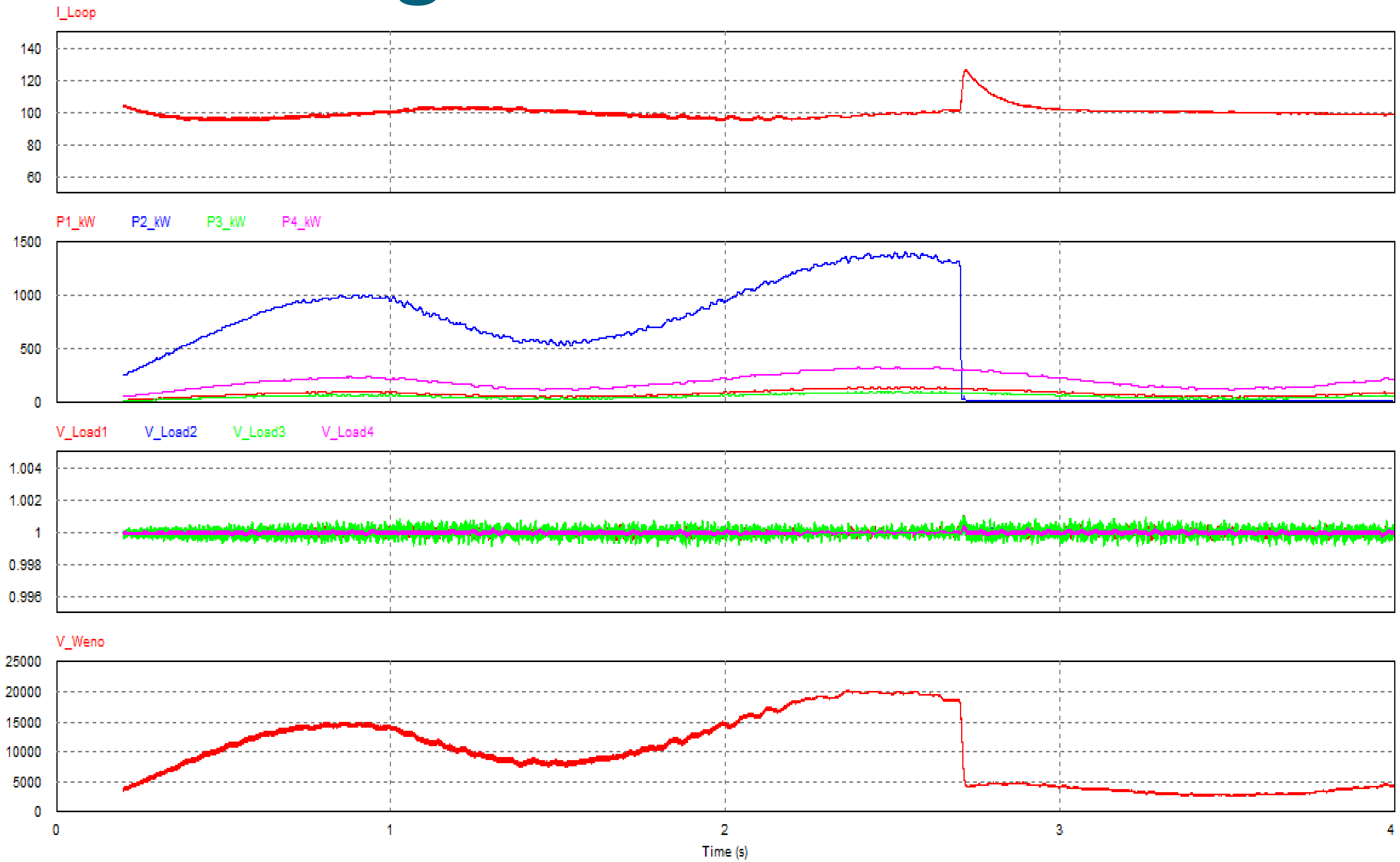
- Based on Max DC voltage of 20kV.

| Parameter | One Loop | Two Loops | |
|---|---|---|---|
| | | Faichuk Islands | Nomoneas Islands |
| Length (km) | 70 | 50 | 25 |
| Peak Demand (MW) | 3.9 | 2.0 | 1.9 |
| Average Demand (MW) | 2.7 | 1.4 | 1.3 |
| Cable Size ($mm^2$) | 240 | 95 | 50 |
| $I_{LOOP}$ for Peak Demand (A) | 200 | 105 | 100 |
| $I_{LOOP}$ for Average Demand (A) | 150 | 75 | 70 |
| Cable Losses @ Peak Demand (%) | 5.4 | 5.3 | 5.1 |
| Cable Losses @ Average Demand (%) | 4.4 | 3.9 | 3.6 |

# Modelling - PSIM



# Modelling - PSIM



# Costing

| Equipment Required | DC Series Loop | 13.8kV 3-Phase AC |
|---|---|---|
| | | |
| Substations | | |
| Weno | $ 950,000 | $ 300,000 |
| Faichuk | $ 475,000 | $ 150,000 |
| Fefen | $ 385,000 | $ 150,000 |
| Tonoas | $ 385,000 | $ 150,000 |
| Uman | $ 325,000 | $ 125,000 |
| Udot | $ 325,000 | $ 125,000 |
| Ramonum | $ 290,000 | $ 100,000 |
| Fana Panges | $ 290,000 | $ 100,000 |
| Parem | $ 270,000 | $ 100,000 |
| Siis | $ 270,000 | $ 100,000 |
| | | |
| Subtotal | **$ 3,965,000** | **$ 1,400,000** |
| | | |
| Submarine Cable | | |
| 75km of Cable | $ 2,925,000 | $ 9,375,000 |
| Transport | $ 235,000 | $ 750,000 |
| Installation Cost | $ 3,085,000 | $ 9,900,000 |
| | | |
| Subtotal | **$ 6,245,000** | **$ 20,025,000** |
| | | |
| Total | **$ 10,210,000** | **$ 21,425,000** |

Thank you.

Any Questions?