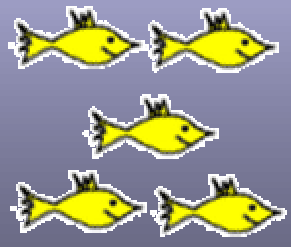
Introduction

- Hypothesis
- Topology, technical constrains
- Redundancy, budget constrains
- Grounding
- Reliability
- Conclusion

NIKHEF

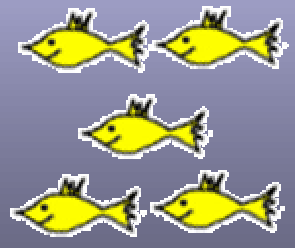
E. Heine, H.Z. Peek



Hypothesis

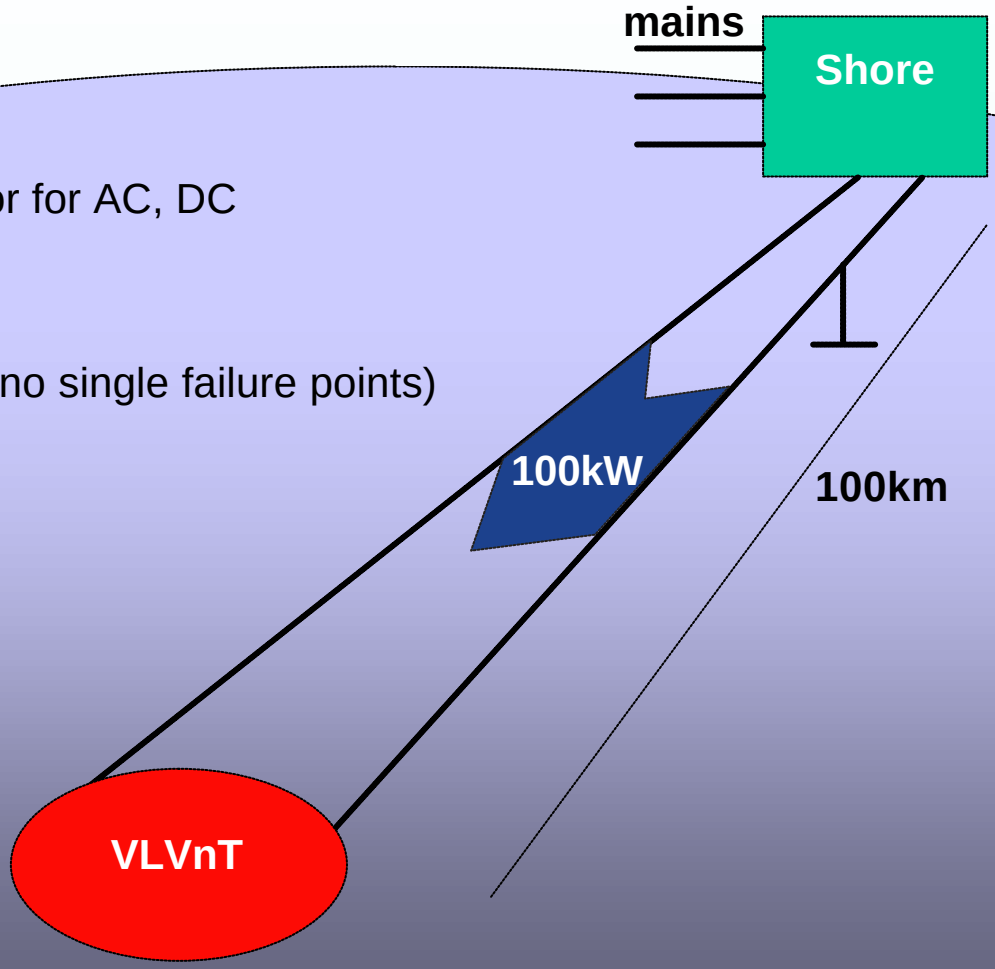
- **Power**
  VLVnT structure = 10 * Antares
  VLVnT power < 5 * Antares = **100 kW**
  Technology progress
  Structure upgrades
  Demands of other users?

- **Environmental**
  Distance shore-facility = **100 km**
  Power cables combined with fibers
  Single point failures has to avoid

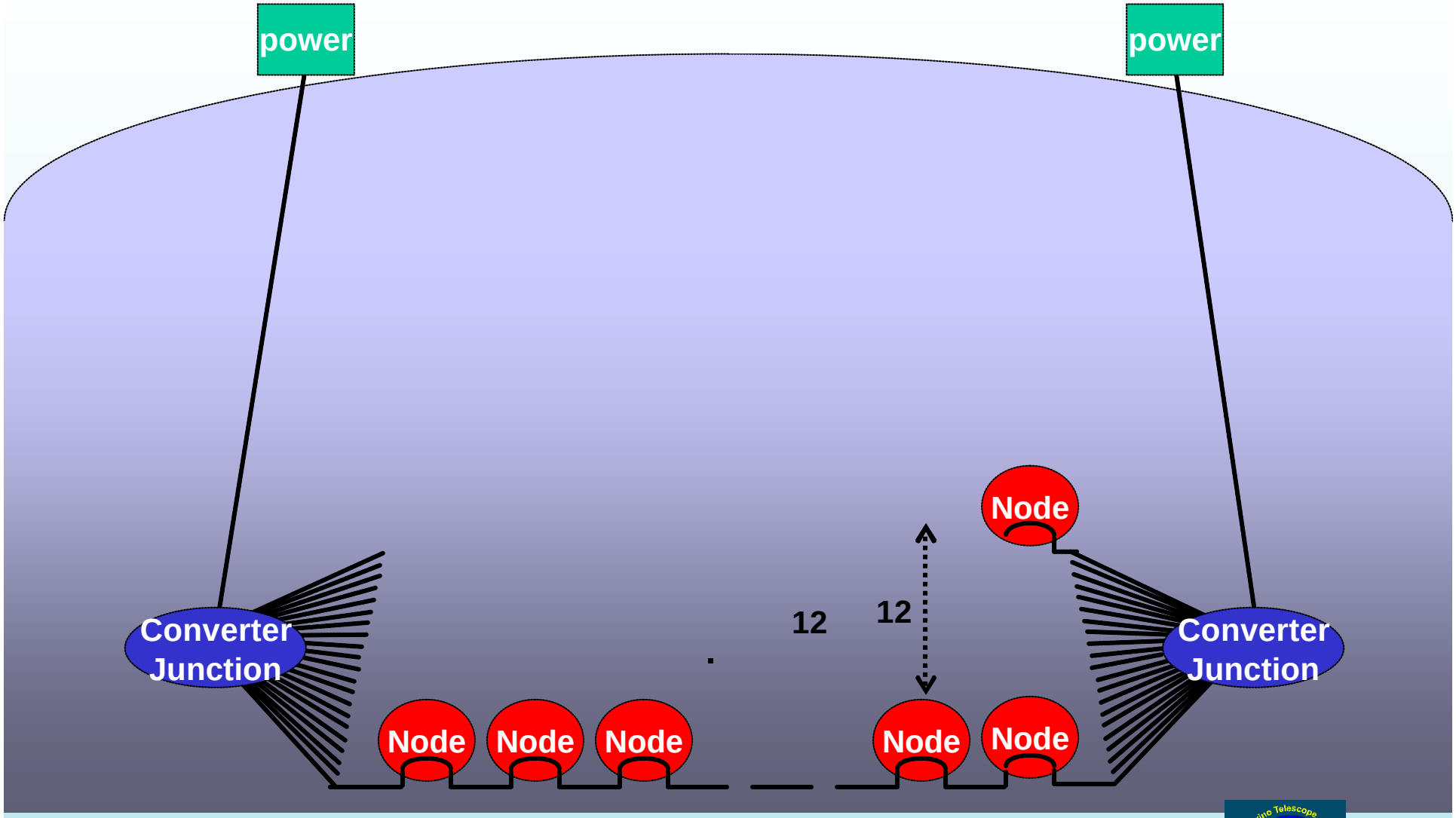


Power transmission

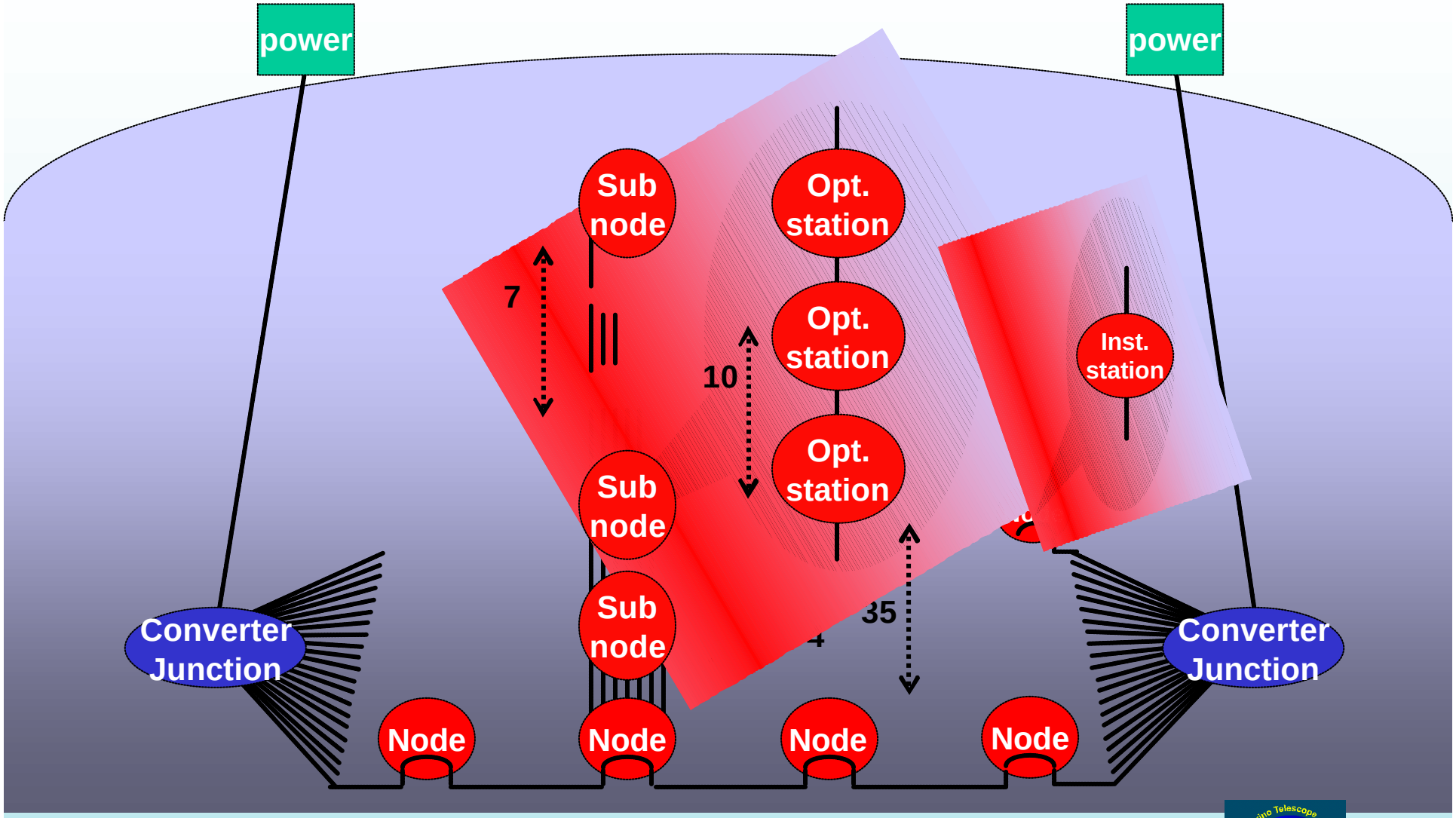
- Cable behavior for AC, DC
- AC systems
- DC systems
- Redundancy (no single failure points)



Node grid


power
power
Converter Junction
Converter Junction
Node
Node
Node
Node
Node
Node
12
12

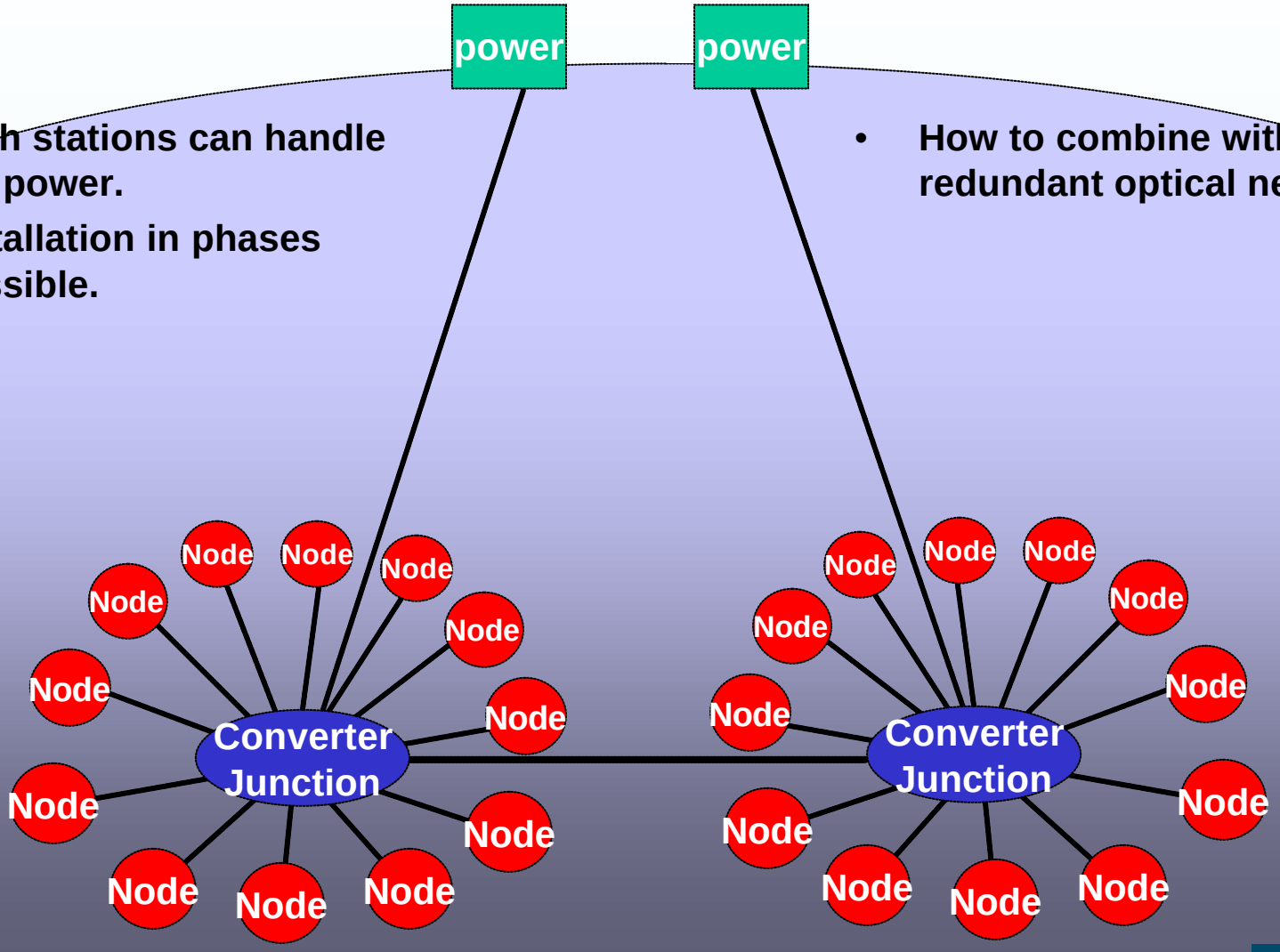
Node grid II


power
power
Sub node
Opt. station
Opt. station
Opt. station
Inst. station
Sub node
Sub node
7
10
35
Converter Junction
Converter Junction
Node
Node
Node
Node

Node grid III

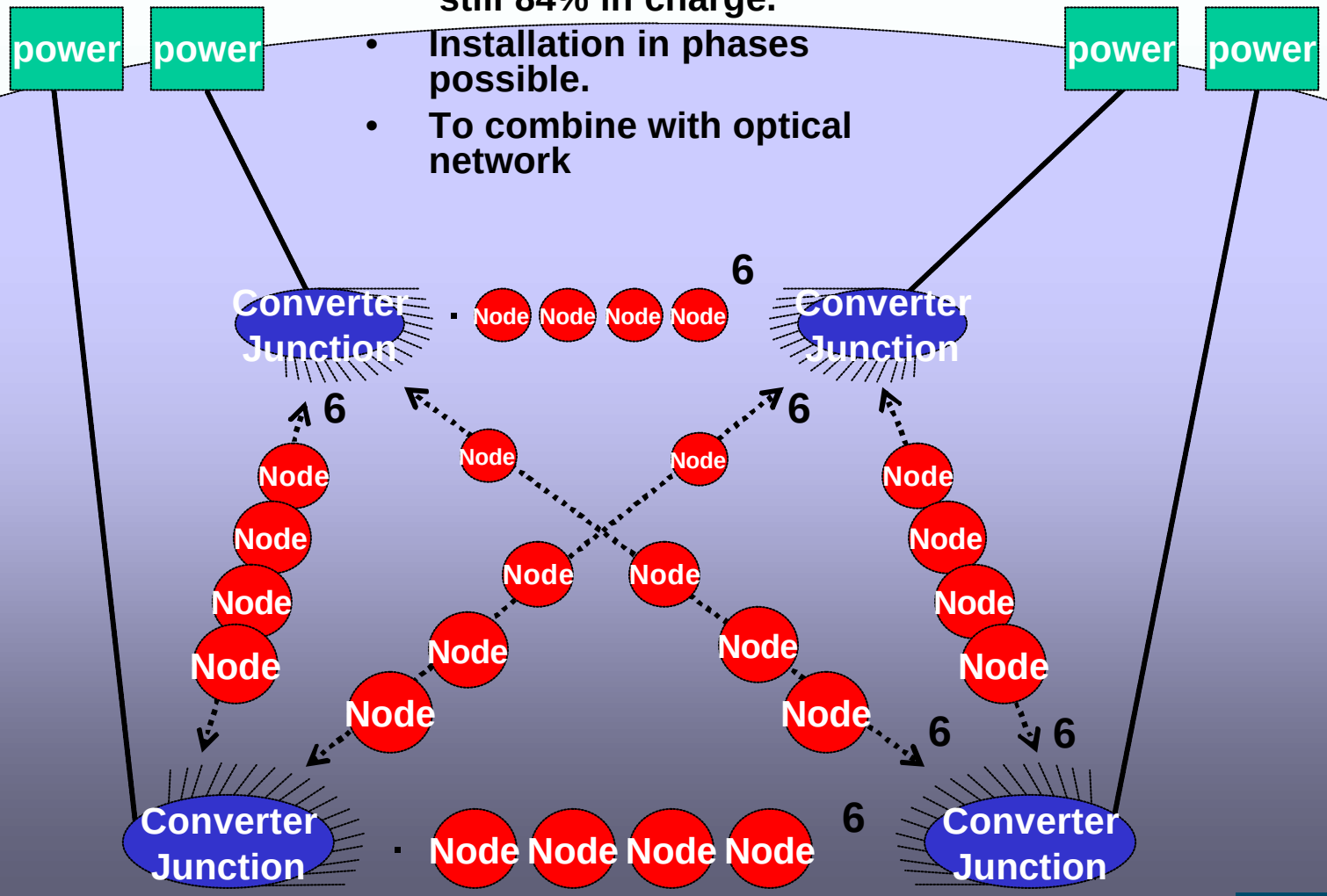
- **Both stations can handle full power.**
- **Installation in phases possible.**

- **How to combine with redundant optical network.**

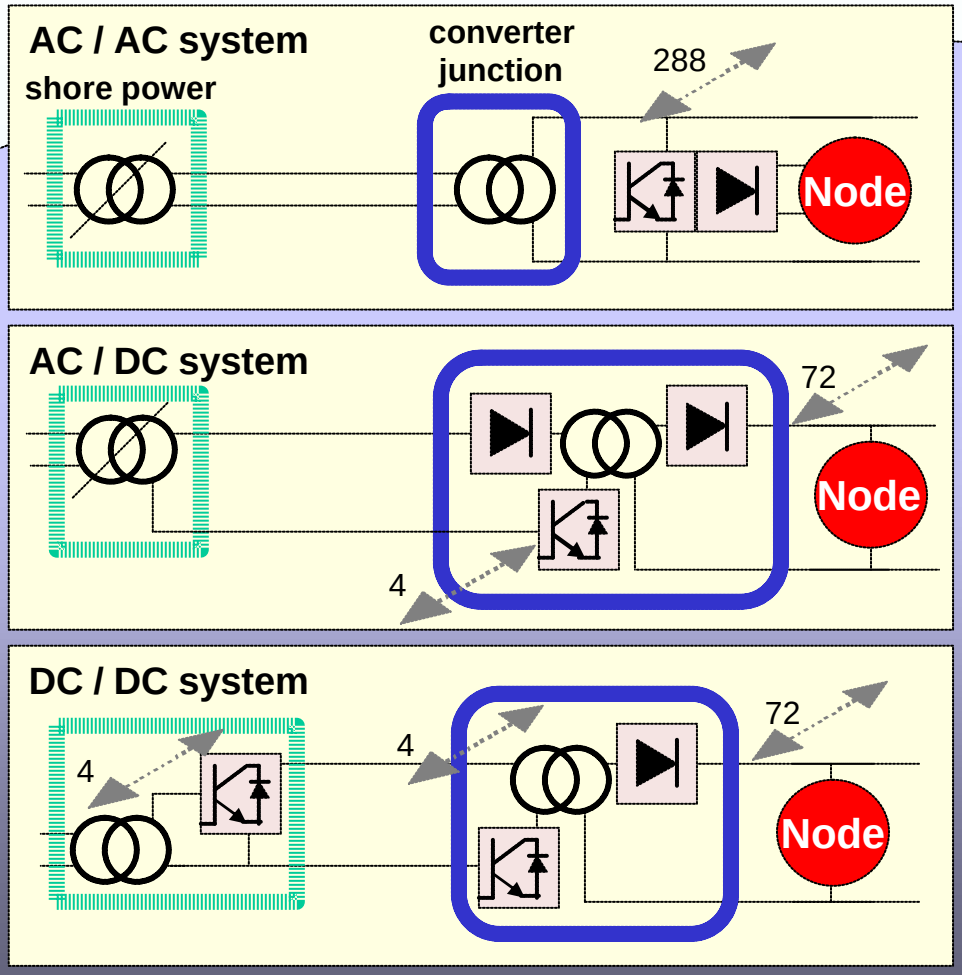


Redundant Power distribution

- Two long distance failures, still 84% in charge.
- Installation in phases possible.
- To combine with optical network



Long distance to local power



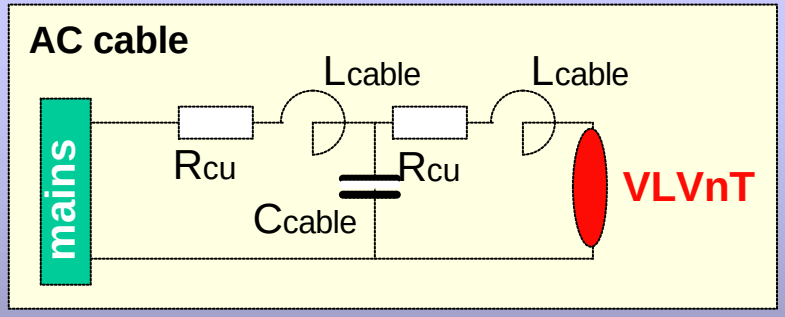
- 2x144 el.units submarine
- low power conversion

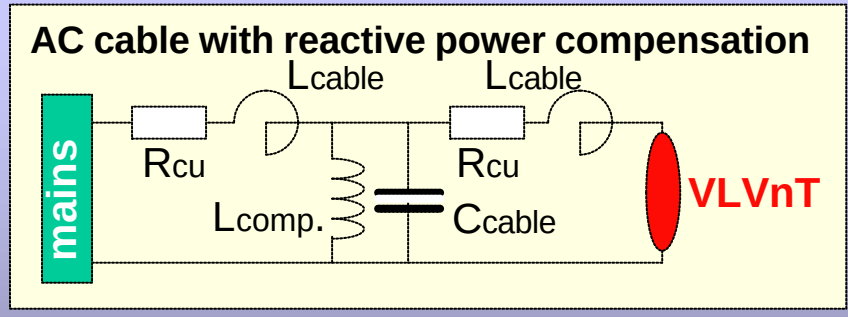
- 2x36 + 4 el.units submarine
- high power conversion

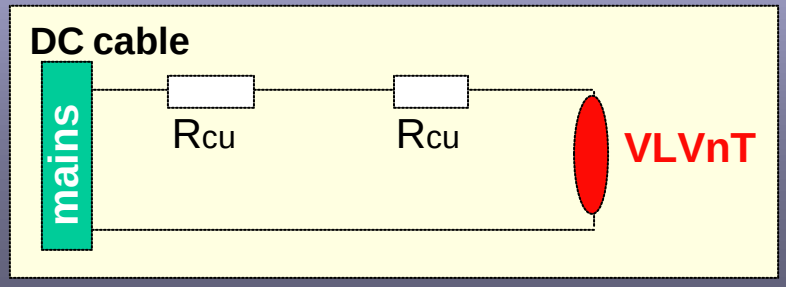
- 2x36 + 4 el.units submarine
- 4 el.units on shore
- high power conversion

Long distance cable behavior

- Higher voltage = lower current = less Cu losses = higher reactive losses
- AC losses $(I_{load}^2+(\mathbf{kU_W C_{cable}})^2)$ R_{cu} > DC losses $(I_{load}^2 R_{cu})$
- AC charging/discharging C, DC stored energy = ½CV^2
- DC conversions more complex then AC conversions
- AC cables have be partitionized to adapt reactive compensation sections.

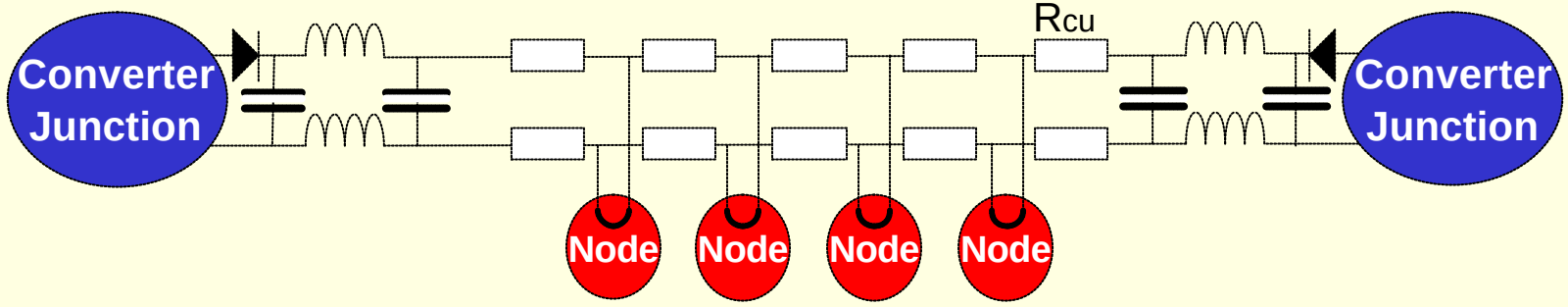




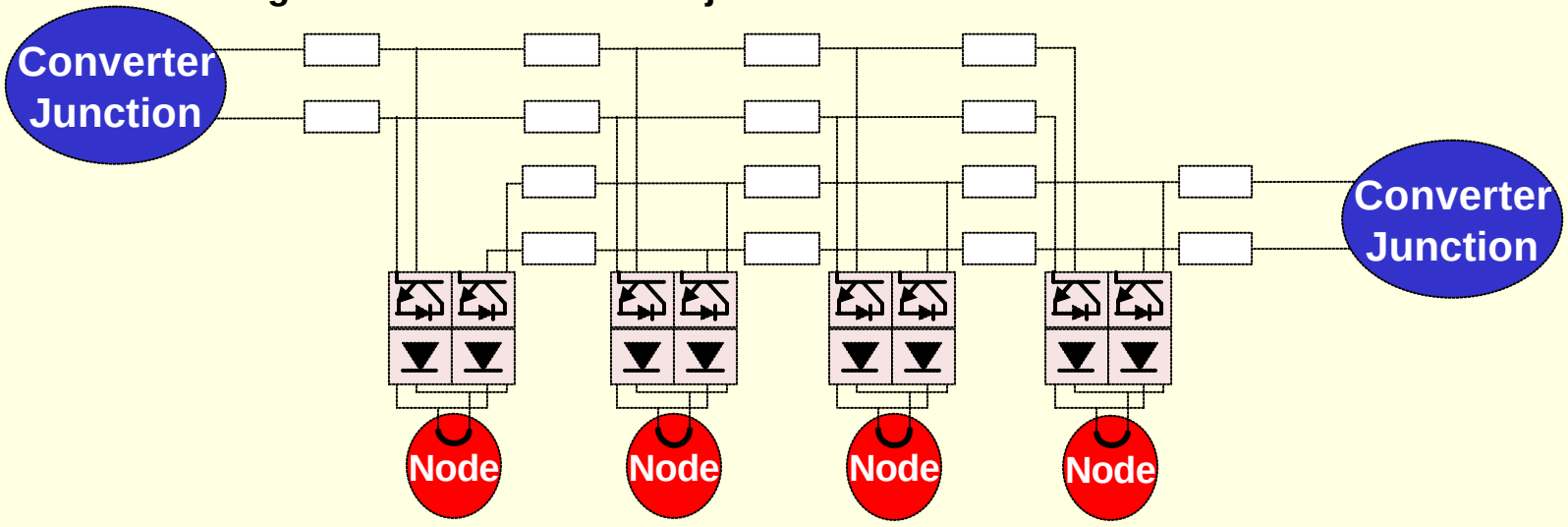


Redundant Node grid

DC load sharing between two converter junctions



AC load sharing between two converter junctions



Conclusions on topology

AC/AC

- \+ passive components
- \+ initial costs
- − losses
- − fixed ratio by transformers
- − extra DC conversion subm.
- − running costs
- − extra cabling

AC/DC

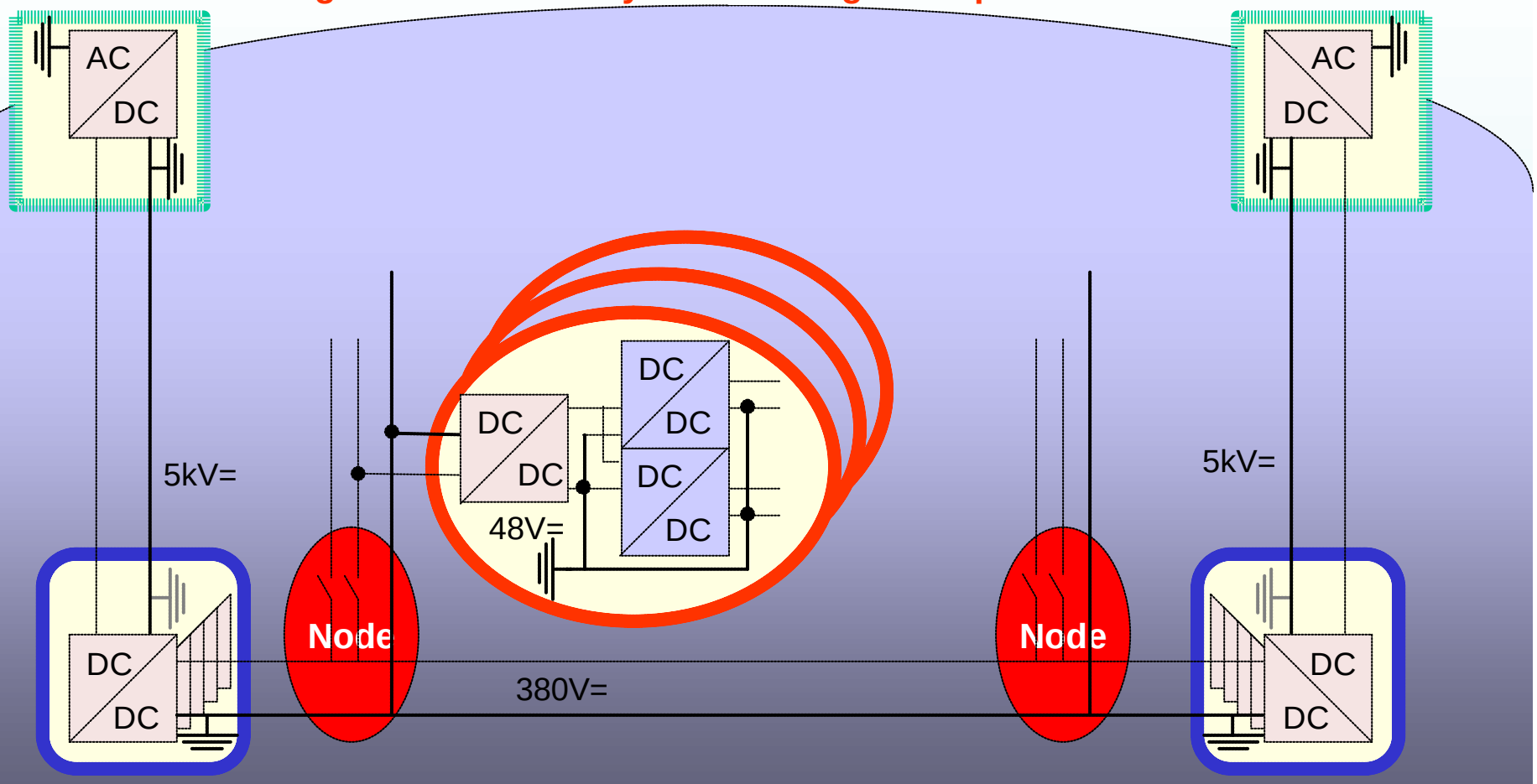
- \+ constant output level
- − initial costs
- − active components subm.
- − running costs

DC/DC

- \+ constant output level
- \+ cable losses
- \+ running costs
- \+ active components
- − initial costs

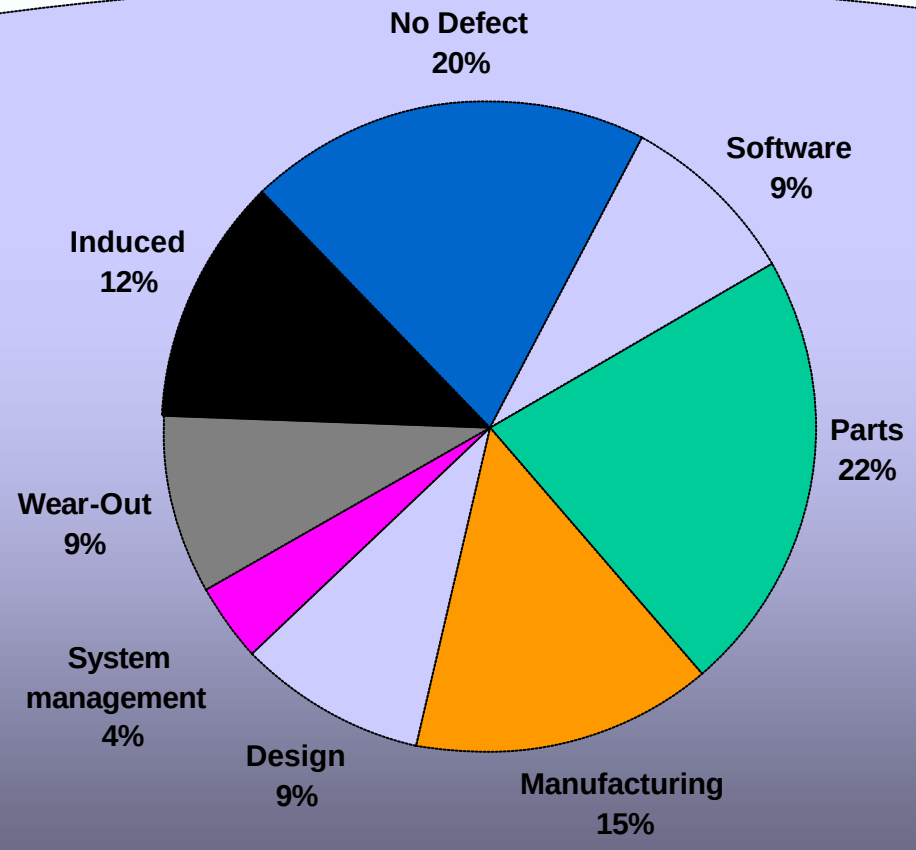
Grounding

- Grounding is essential to relate all potentials to the environment.
- Prevent ground currents by use of one ground point in a circuit.



Reliability

Not something we buy, but something we make!



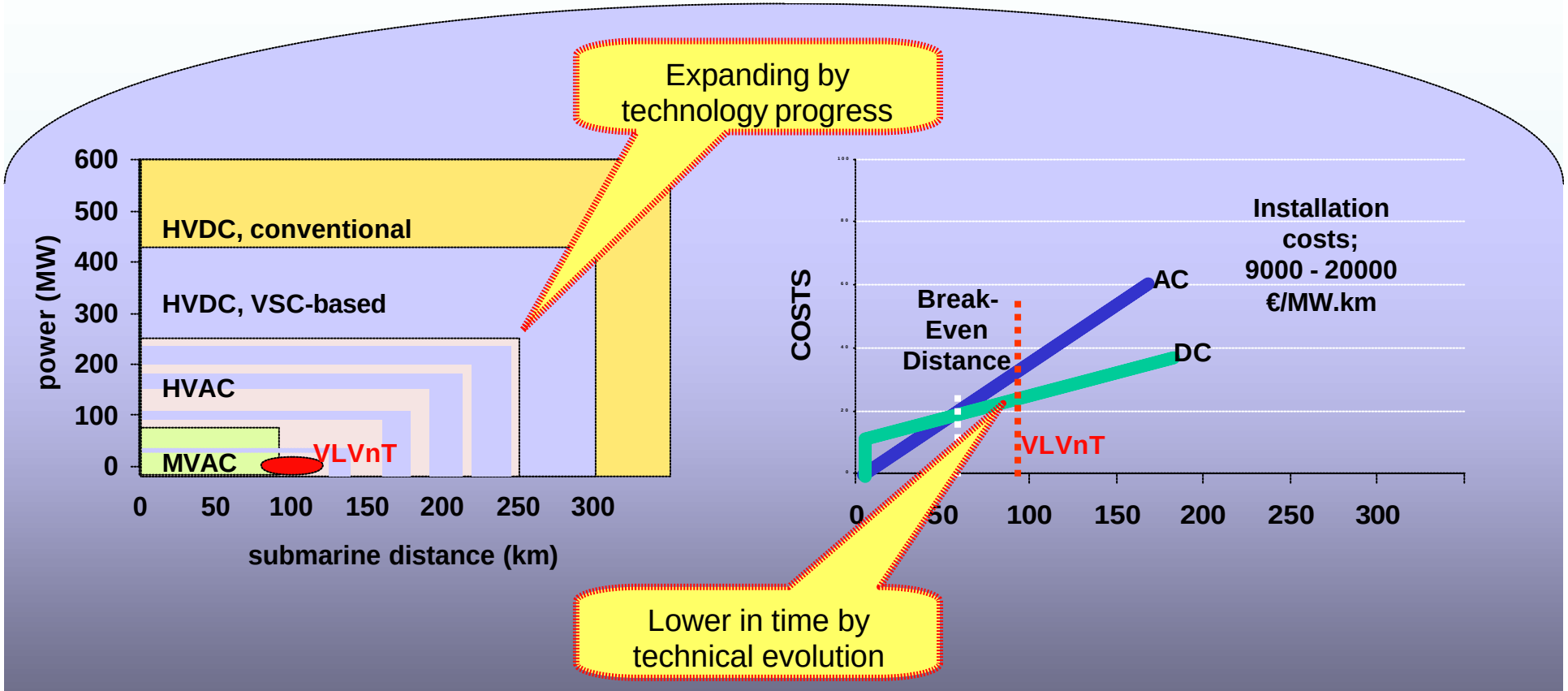
Denson, W., “A Tutorial: PRISM”,RAC, 3Q 1999, pp. 1-2

General conclusions

- **Technical issues to investigate**
  - DC for long distance is promising-> breakeven study for costs and redundancy
  - node grid gives redundancy
  - node grid can be made of components used in railway industry
  - inter module grid can be made of components used in automotive industry
  - each board / module makes its own low voltages

- **Organization**
  - power committee recommend
  - specify the power budget (low as possible, no changes)
  - coordination of the grounding system before realizing
  - watching test reports, redundancy and reliability
  - try to involve a technical university for the feasibility study
  - coordination between power and communication infrastructures

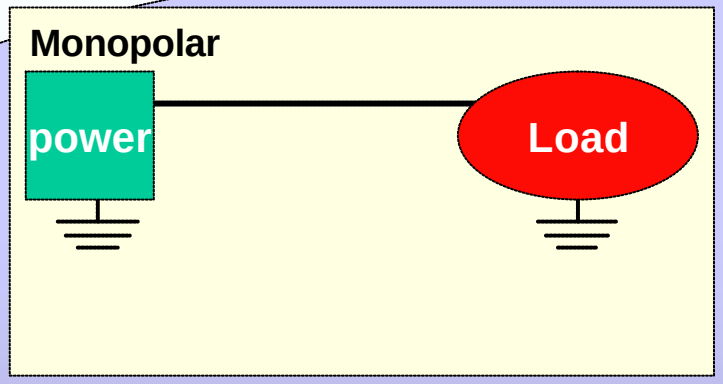
Industrial references

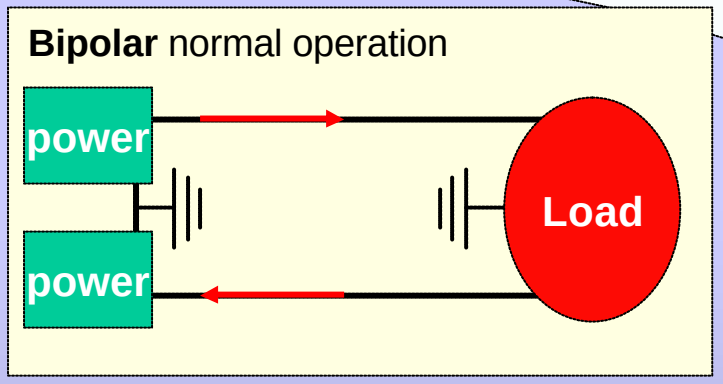


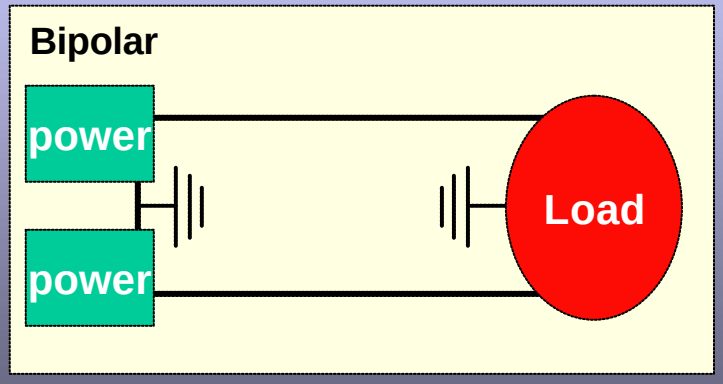
Sally D. Wright, Transmission options for offshore wind farms in the united states, University of Massachusetts
High Voltage Direct Current Transmission, Siemens
HVDC light, ABB
Gemmell, B; e.a. "HVDC offers the key to untapped hydro potential", IEEE Power Engineering Review, Volume:22 Issue: 5, May 2002 Page(s): 8-11

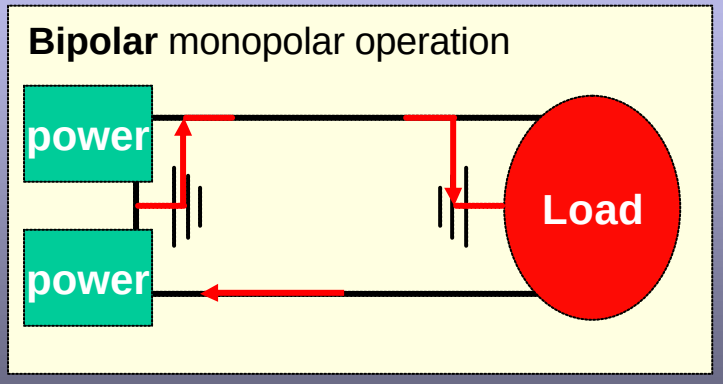
Cable configuration

- Combined with fibers for communication
- Redundancy



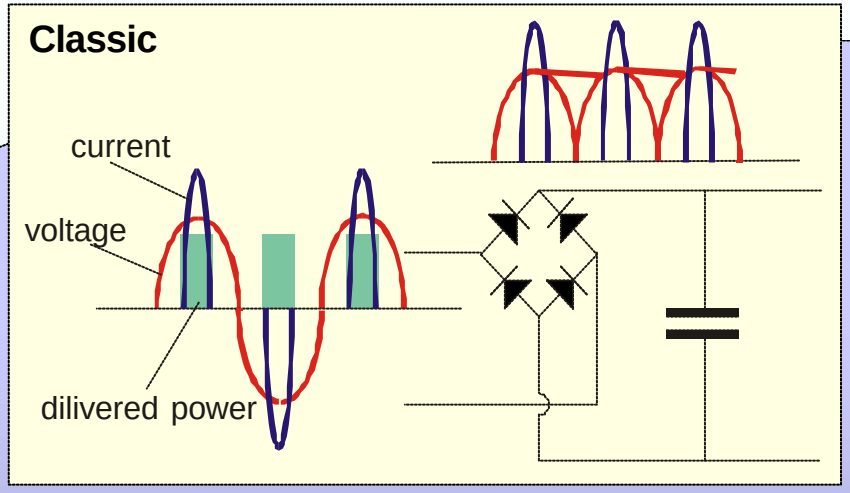


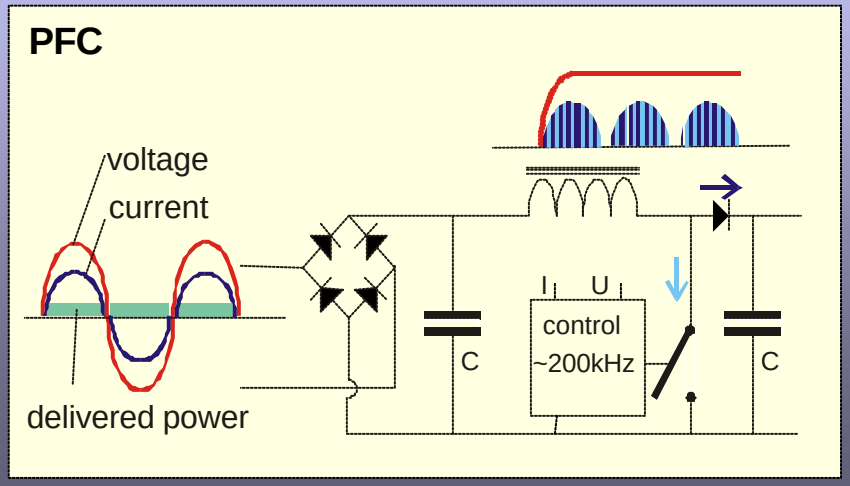




High Voltage Direct Current Transmission, Siemens

Power factor corrector





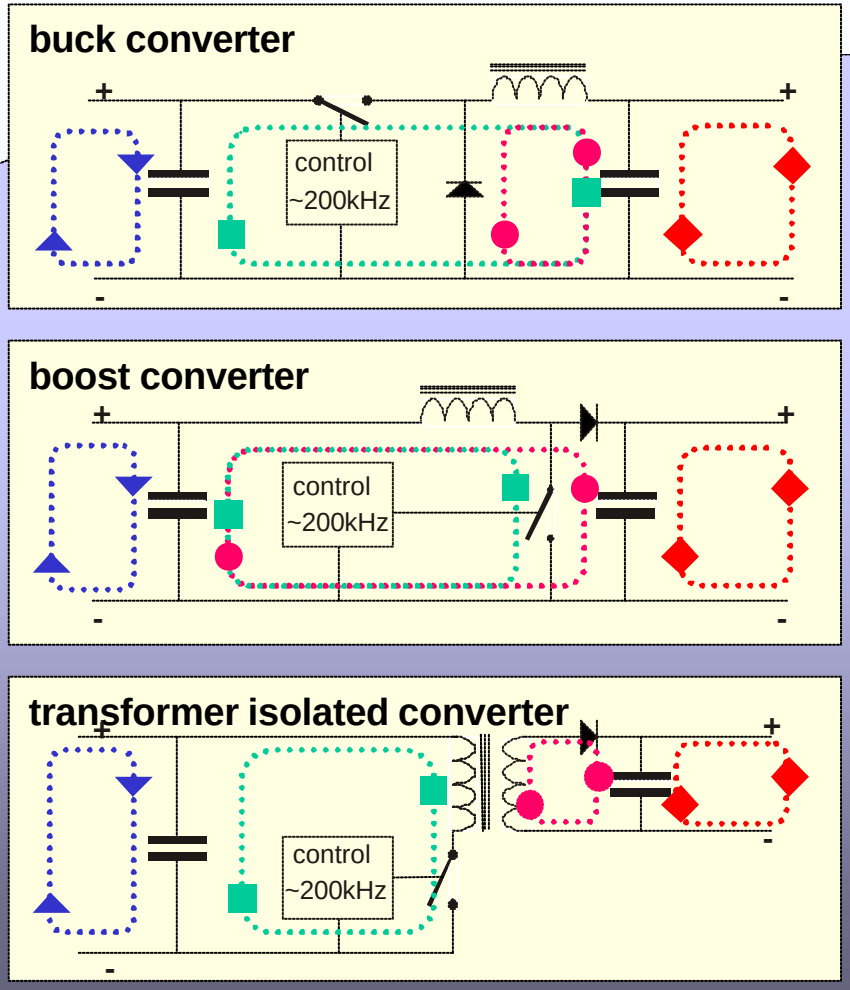
Classic:

- more harmonic noise
- higher I^2R losses

PFC

- constant power load
- voltage and current in phase

Converter types



input circuit
switching circuit
rectifying circuit
output circuit

- Efficiency up to 90%
- Power driven

Local power

Converters on each board or function

- Control of switch on/off sequences
- Control of Vh>Vl (by scotky diodes)
- Control of voltage limits;
  1V8 ± 4%, 5V ± 5%, 12V ± 10%

Power consistence

- PCB-layout (noise)
- efficiency